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FACTORS INFLUENCING DAIRY CATTLE CULLING
DECISIONS AND THEIR ECONOMIC IMPLICATIONS

presented by

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Major Professor's Signature

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Date

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FACTORS INFLUENCING DAIRY CATTLE CULLING DECISIONS AND THEIR ECONOMIC IMPLICATIONS

By

Gregg L. Hadley

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ABSTRACT

FACTORS INFLUENCING DAIRY CATTLE CULLING DECISIONS
AND THEIR ECONOMIC IMPLICATIONS

By

Gregg L. Hadley

Dairy cattle culling is the act of removing dairy cattle from a herd and replacing them with other cows. Dairy cows can be culled from a herd for production or health reasons. The average annual culling rate describes the percentage of cattle that are culled from a herd annually. Determining the optimal culling rate can be difficult for a producer. If the culling rate is too high, farmers fail to earn an adequate return on their cattle investment. If too low, the farmer forgoes production and genetic improvement.

This dissertation contains three studies on dairy cattle culling. The first study examines how individual cow and farm characteristics as well as market prices affected the likelihood of a cow being culled on DHIA participating farms in five Midwestern and five Northeastern states during 1993 through 1999. In general, cow attributes such as age, calving season, breed and production affected culling likelihood. Farm attributes such as size, expansion and whether the farm raised registered dairy cattle also affected culling likelihood. Both the milk to feed price and cull cow to replacement heifer price ratio affected culling likelihood.

Data from the NAHMS '96 Dairy Survey was used in the second study to determine what management factors affected the udder and mastitis, lameness and injury,

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disease, and reproduction culling rates. Overall, very few management programs showed a significant effect on culling rates. This may be due to the cross sectional design of the survey. Farms with employee handbooks culled less for udder and mastitis problems. On farms where cattle had access to soft walking surfaces, fewer cows were culled due to lameness and injury problems. Farms with herd bulls had lower reproduction culling rates as did farms that used a combination of an employee handbook and employee incentive programs.

In the third study, a decision support system (DSS) was developed to determine the amount producers could afford to pay to reduce health culling rates. This amount varied based upon the underlying culling probabilities, breed and herd size. For most situations, the health cull reduction type with the greatest potential returns was lameness and injury culls. It was more profitable for herds with more than 600 cows to reduce mortalities, however.

The (DSS) was used to evaluate the adoption of two health cull reduction technologies, a rubberized cattle alleyway floor and gonadotropin releasing hormone (GNRH). The DSS determined that a rubberized alleyway floor was not profitable to adopt on the basis of reducing lameness and injury culls alone. It was profitable to adopt, however, after including the savings from an overall reduction in lameness episodes and their respective treatments. Using GNRH to treat cows with cystic ovaries proved profitable in the DSS estimation.

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I thank my fellow graduate student colleagues – especially George Young, Lorie Srivastava, and James McQueen – for their support throughout graduate school and beyond. I will cherish their friendship forever. I especially thank George who took pity on an ABD professor and agreed to submit this dissertation for me.

I also thank my colleagues at UW- River Falls and UW- Extension for their support during the completion of my degree. Special acknowledgement needs to be given to Dr. Lewis May for teaching my spring semester course and to the members of the UW-River Falls Agricultural Resource Center Union: Laura Walsh, Paul Kivlin, Brenda Boetel, and Alycia Aiken. These friends supplied me with moral support, and, in one case, even a car while completing this dissertation.

I thank my heroes, Mom and Dad, for always encouraging me to further my education. I also thank my wife Shelly for her love and support throughout the years. Last but certainly not least, I also thank Beaufort Franklin Hadley for being my constant companion in completing my dissertation. We can now get back to fishing, hiking, long walks, and playing in the snow.

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CHAPTER 1.

INTRODUCTION

I. Background and Motivation

Culling is the act of identifying and removing a cow from a herd, and, assuming a constant or expanding herd size, replacing the cow with another cow, usually a first lactation heifer. The culling rate[1] describes the percentage of cows removed from a herd (Dairy Records Management Systems, 1999).

Many researchers have shown that estimated optimal average annual culling rates tend to be lower than those observed. Selected previous work concerning estimated herd level optimal dairy cattle culling rates can be seen in Table 1. The estimated optimal culling rates range from 19 to 29 percent. Actual average annual culling rates tend to be higher. The average annual culling rate for Midwest DHIA herds during 1996 – 2000 was reported to be 38 percent by Quaiffe (2002).

There are numerous trade articles offering suggestions for reducing culling rates. There are far fewer articles informing producers how to decide how to profitably reduce culling rates. Van Arendonk and Dykhuizen (1985) determined that it was more profitable to continue breeding average producing dairy cattle that do not settle until the end of a typical lactation before culling the animal. Ngatzke, Harsh, and Kaneene (1990) found that it was more profitable to treat cattle with cystic ovaries twice rather than culling them outright. Houben, Huirne, and Dykhuizen (1994) found that it was more profitable to treat mastitic cattle than to cull them.

[1] The culling rate for this research was calculated by taking the number of cattle culled in a year divided by the average number of lactating and dry cows for that year.

Table 1.

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Rogers, Van Arendonk, and McDaniel (1
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Table 1. Estimated "Optimal" Culling Rates of Select Studies

Study	Research Question	Optimal Culling Rate (%)
Renkema and Stelwagen (1979)	What is the economic significance of longer herd life?	19
Van Arendonk and Dykhuizen (1985)	Should an animal be bred, kept but left open, or replaced?	27
Rogers, Van Arendonk, and McDaniel (1988)	What is the influence of production and price on optimum culling rates in the United States?	25
Ngatzke, Harsh, and Kaneene (1990)	Should an infertile cow be treated, kept but not bred, or replaced?	22
Bauer, Mumey, and Lohr (1993)	What is the optimal range of culling rates given a planned lactation removal policy?	25
Houben, Huirne, and Dykhuizen (1994)	Should a currently mastitic cow be bred, kept but not bred, or replaced?	29
Stott (1994)	When should the typical U.K. cow under typical financial conditions be replaced?	21 - 24
Jones (2001)	What is the optimal culling rate given various price and cost conditions?	22-25%

The ultimate goal of this research is to develop a Decision Support System (DSS) to enable farmers to determine the financial feasibility of reducing the number of culls caused by health problems. Prior to developing a culling reduction DSS, it is important to understand how culling affects production, how many cattle are culled, why cattle are culled and how management programs affect culling rates. In Chapter 2, DHIA records for five Midwestern states and five Northeastern states are examined to determine how culling affects milk production, the percentage of cattle culled each year, why cattle are culled, and when cattle are culled within a lactation. In Chapter 3, the DHIA dataset and a probit model are used to determine how individual cow and herd characteristics affect the likelihood of an individual cow being culled. Four OLS models are applied to the USDA-

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APHIS NAHMS Dairy '96 Survey dataset in Chapter 4 to determine how management programs affect culling rates. In Chapter 5, a DSS system is described and explained using a hypothetical farm situation. In Chapter 6, the DSS is used to determine what a producer would be willing to pay to reduce his or her culling rates.

II. Culling Rate Terminology

Culling due to health reasons is commonly referred to as involuntary culling. Culling due to low production, cow aggression, or when a cow is sold to another farm for dairy purposes is referred to as voluntary culling. Involuntary culling typically refers to culls caused by health problems, but the name infers something else. "Involuntary" actually refers to something that cannot be controlled by the principal agent. In the short run, there are some health problems that are beyond the control of the producer, others are not.

Two examples illustrate this. Assume that cattle must be culled due to a particular disease. These culls would be referred to as involuntary culls under the usual nomenclature. If the producer could have prevented the disease through an available vaccine but chose not to vaccinate, the underlying culling cause is not involuntary but voluntary. Alternatively, cattle that are culled for relatively low production are referred to as voluntary culls, but how much control does an owner have over the ability of an individual cow to produce relative to the rest of the herd? Assuming that the manager chose a sire that offered enhanced genetics, the fact that a cow is a production anomaly is actually beyond the producer's control and the cull should be deemed an involuntary cull.

Because this research is concerned with the financial feasibility of management strategies and programs designed to reduce the level of culling due to health problems,

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which infers that at least a portion of the health culls are within the control of the producer, the usual classification of "voluntary" and "involuntary" culls were ignored. Culls due to low production, aggression, and being sold for dairy purposes were classified as production culls. Culls caused by health problems – udder and mastitis, lameness and injury, disease, and reproduction – were classified as health culls.

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CHAPTER 2.

CULLING AND LONGEVITY DESCRIPTIVE STATISTICS

I. Introduction

To determine the financial feasibility of health cull reduction, information is needed concerning how profitability is affected by cow longevity, health culls, state of origin, cow age, breed, herd size, and production level. If culling is not affected by such factors, there is no need to develop a DSS that is flexible enough to accommodate a dairy farm's individual culling statistics and culling related information and a "one size fits all" approach can be used when designing the DSS.

The purpose of this chapter is to examine descriptive culling statistics from 1993 through 1999 for Dairy Herd Improvement participating dairy farms in ten Midwestern and Northeastern states: Illinois, Indiana, Iowa, Maine, Michigan, New Hampshire, New York, Pennsylvania, Vermont, and Wisconsin. The information in this chapter is used to help develop hypothesis tests as well as to provide culling and longevity information for the culling rate reduction decision model.

II. Data Description

Information for this chapter was taken from data supplied by Dairy Records Management Systems (DRMS). The data contained production records of Dairy Herd Improvement (DHI) participating dairy farms in Illinois, Indiana, Iowa, Maine, Michigan, New Hampshire, New York, Pennsylvania, Vermont, and Wisconsin from 1993 through 1999 for individual cow records and 1995 through 1999 for herd level records. There were 7,087,699 individual cow lactation observations in the data. Depending on the type of statistical

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of statistical analysis, many of the observations were dropped in the various analyses used in this research due to incomplete information.

III. The Effect of Cow Longevity and Culling on Production

Not only does culling affect farm cash flow through the buying and selling of animals, culling can also affect farm cash flow through its effect on production. Bauer, Mumey and Lohr (1993) showed that milk production per lactation for Alberta dairy cattle increased from the first lactation before declining after the sixth lactation. Stott (1994) showed a similar relationship for United Kingdom cattle. Jones (2001), however, showed a negative correlation between age and milk production per lactation.

Table 2 shows how cow age affected production on the farms of the ten Midwestern and Northeastern states. These values were determined by comparing the Actual 305 day milk, milk fat and milk protein production of cattle that completed a given lactation with those that completed their first lactation. Milk, milk protein, and milk fat production increased with cow age through the fifth lactation. Milk, milk fat and milk protein production did not slip below first lactation levels until the tenth lactation. Thus, there is a production-based incentive to keep cows through the fifth lactation.

Nevertheless, there are also disadvantages to increasing cow longevity. Somatic cell count values, which measure the number of white blood cells per milliliter of milk and serves as a measure of milk quality (Dairy Records Management Systems, 1999), increased with each completed lactation. Higher somatic cell count values can lead to price deductions for dairy farmers. Another problem with increasing cow longevity is that the overall genetic improvement rate for the herd decreases as less heifers enter the herd.

Table 2.

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Table 2. The Effects of Cow Age on Actual 305 Day Milk Production, Milk Fat Production, Milk Protein Production, and Somatic Cell Count

Lactation Number	Actual 305 Day Milk Production (% of First Lactation Values)	Actual 305 Day Milk Fat Production (% of First Lactation Values)	Actual 305 Day Milk Protein Production (% of First Lactation Values)	Somatic Cell Count (% of First Lactation Values)
1	100	100	100	100
2	112	112	112	127
3	115	115	115	143
4	116	117	117	154
5	115	116	116	163
6	112	113	113	173
7	109	109	109	170
8	106	106	106	178
9	102	102	102	182
10	99	99	99	181

It is logical to assume that culled cattle produce less milk than cattle retained in the herd. To determine the extent to which milk production declines when cattle are culled for health and production problems, the projected 305 day milk for the DHI cattle that were culled for mortality, health problems, production and sold for dairy purposes were compared to the actual 305 day milk yield for the DHI cattle that successfully completed their lactations (Table 3). Cattle that were culled for health reasons produced from 2 percent more to 6 percent less than their healthy counterparts. Cattle that died produced from five to sixteen percent than their non-culled herd mates. Cattle culled for low production produced from six to twenty nine percent less than cattle that weren't culled. Cattle sold for dairy purposes produced between two to 7 percent less than those who were not culled.

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Somatic cell counts also differed between culled and retained DHI cattle. Except for cattle that died, culled cattle typically have higher somatic cell counts as well (Table 3).

Table 3. The Percentage Difference in Milk Production and Somatic Cell Counts Between Retained and Culled Cattle

Lactation	Health		Mortalities		Production		Sold for Dairy Purposes	
	Milk	SCC	Milk	SCC	Milk	SCC	Milk	SCC
1	6	19	16	5	26	29	11	4
2	1	15	7	-1	7	19	4	2
3	0	13	6	-1	11	15	3	3
4	1	13	6	-4	11	11	3	6
5	2	12	11	-5	10	13	1	7
6	0	9	7	-10	9	10	1	6
7	-2	9	5	-5	3	6	1	7
8	0	11	9	-6	8	9	5	7
9	0	11	11	-6	7	11	5	3
10	6	8	14	-8	11	11	6	5

There are both incentives and disincentives to increasing cow longevity through the reduction of health culls. A production incentive for decreasing health culls is that milk, milk fat, and milk protein production increase with each completed lactation through the fifth lactation. Another incentive to reduce health culls is that cattle who become a health cull are less productive than their healthy herd mates. Disincentives exist in that somatic cell counts increase with cow age and increased cow longevity means that the herd genetic improvement rate declines as less heifers enter the herd.

IV. Average Culling Rates for 1993 – 1999 by State, Breed, Production Level, and Herd Size

Across all ten states over the seven year period, the average culling rate for the 1993 – 1999 period was 35.1 percent (Table 4). These culling rates are higher than the estimated optimal culling rates determined by Rogers, Van Arendonk, and McDaniel

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(1988), Bauer, Mumey, and Lohr (1993) , Stott (1994), and Jones (2001). The estimated optimal herd-level culling rates determined by these researchers ranged from 19 percent to 29 percent. These researchers, however, did not include cattle that were sold for dairy purposes in their estimated optimal culling rates. If such culls are removed from the DHIA records, the average culling rate for the ten states during the 1993 – 2000 period, 31.6 percent, is much closer to the estimated optimal culling rate values. This shows the importance of understanding how culling rates are calculated when making comparisons. For the remainder of this chapter, the culling rate will not include cattle sold to other farms for dairy purposes unless noted otherwise.

Northeastern (Maine, New Hampshire, New York , Pennsylvania and Vermont) herds had annual average lower culling rates, ranging from 29.1 to 31.4 percent, than Midwestern (Illinois, Indiana, Iowa, Michigan, and Wisconsin) herds, whose annual average culling rates ranged from 33.2 to 35.1 percent. Vermont and New Hampshire herds had the lowest state level average annual culling rate for the 1995 – 1999 period at 29.1 percent. Michigan had the highest average annual culling rate, 35.1 percent, for the period.

Holstein herds exhibited the second-highest average annual culling rate among dairy cattle breeds during the 1993 through 2000 period with 31.9 percent. Jersey herds experienced a lower average annual culling rate of 27.2 percent for the period. Farms with Brown Swiss cattle had an average annual culling rate of 30.9 percent, but this was not significantly different than the Holstein culling rate (p-value

Table 4.

All ten states
New Hampsh
Vermont
Maine
New York
Pennsylvania
Indiana
Illinois
Michigan
Wisconsin
Iowa
Holstein
Jersey
Brown Swiss
Guernsey
Ayreshire
Milking Shorthorn
RHA < 18,000 lbs
18,001 – 21,00 lbs RHA
21,001 – 24,00 lbs RHA
24,001 – 27,00 lbs RHA
RHA > 27,001 lbs
Cows < 150
150 to 300 Cows
301 to 450 Cows
451 to 600 Cows
Cows > 601

Table 4. Average Culling Rates for 1993 – 1999.

	Average Culling Rate with Sold for Dairy Culls			Average Culling Rate without Sold for Dairy Culls		
	Farm Observations	Rate (%)	Standard Deviation	Farm Observations	Rate (%)	Standard Deviation
All ten states	58,498	35.1	19.4	58,181	31.6	15.7
New Hampshire	799	33.9	19.5	779	29.1	12.6
Vermont	7,700	32.6	16.6	7,630	29.1	11.4
Maine	994	36.3	22.8	975	31.4	15.8
New York	15,363	33.5	16.2	15,289	30.3	12.0
Pennsylvania	12,068	32.9	13.3	12,034	30.5	11.4
Indiana	7,827	38.9	21.3	7,785	33.2	13.9
Illinois	2,978	33.6	12.7	2,963	33.6	12.7
Michigan	3,302	37.7	15.4	3,287	35.1	12.7
Wisconsin	2,201	38.2	40.4	2,192	34.8	38.6
Iowa	5,266	37.9	26.3	5,247	34.9	24.8
Holstein	50,244	34.8	17.2	50,164	31.9	14.2
Jersey	3,334	33.0	22.1	3,237	27.2	15.3
Brown Swiss	723	38.0	57.0	699	30.9	53.9
Guernsey	621	45.3	30.1	604	42.0	23.2
Ayreshire	816	37.0	24.3	778	29.6	17.9
Milking Shorthorn	104	36.5	26.7	100	26.7	13.1
RHA < 18,000 lbs.	22,777	34.6	23.1	22,522	30.8	19.0
18,001 – 21,000 lbs RHA	19,954	34.8	16.4	19,919	31.9	13.6
21,001 – 24,000 lbs RHA	11,852	35.5	15.9	11,832	32.2	9.8
24,001 – 27,000 lbs RHA	3,292	37.2	19.2	3,287	32.3	11.7
RHA > 27,001 lbs	623	40.9	22.7	621	32.2	13.6
Cows < 150	53,003	35.0	20.1	52,686	31.4	16.2
150 to 300 Cows	3,936	35.1	10.9	3,936	33.4	9.2
301 to 450 Cows	849	35.6	11.3	849	34.0	8.5
451 to 600 Cows	335	35.5	8.6	335	34.2	8.4
Cows > 601	375	38.3	15.8	375	36.8	14.3

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= 0.6242). Guernsey herds had the highest average annual culling rate of 42 percent. Ayreshire herds exhibited lower culling rates as compared to Holstein farms with 29.6 percent. Farms with milking shorthorn cattle exhibited the lowest average annual culling rate for the period at 26.7 percent, but this was not significantly different than the culling rate of Holstein cattle.

Herds with a Rolling Herd Average (RHA) of less than 18,000 pounds of milk per cow per lactation exhibited an average annual culling rate of 30.8 percent for the 1993-2000 period. This culling rate was lower than the all sample (all ten state) average of 31.6 percent. Herds with higher production levels had higher culling rates as compared to those with a RHA of less than 18,000 pounds. Herds with a RHA of between 18,000 and 21,000 pounds of milk experienced an average annual culling rate of 31.9 percent. The average annual culling rate seemed to plateau for herds producing more than 21,000 pounds of milk. Herds producing between 21,000 and 24,000 and herds producing more than 27,000 pounds had an average annual culling rate of 32.2 percent. Farms with a RHA of between 24,001 and 27,000 pounds per cow experienced an average annual culling rate of 32.3 percent for the period.

Farms with a herd size of less than 150 cows exhibited an average annual culling rate of 31.4 percent for the 1993 – 2000 period. Farms with more than 150 cows exhibited higher culling rates. Farms with 150 to 300 cows exhibited a 33.4 percent average annual culling rate for the period Farms with 301 to 450 cows exhibited an average annual culling rate of 34 percent, while herds with 451 to 600 cows experienced a 34.2 percent average annual culling rate for the period. The largest size group, herds with more than 600 cows, exhibited the highest average culling rate, 36.8 percent.

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V. Culling Reasons for 1993 – 1999 by State, Lactation, Breed, Herd Size and Production Level

Understanding why cattle are culled on a farm is just as important as knowing what its culling rate is (Natzke, 2002). Understanding culling reasons assists the farm manager or advisor in deciding whether to reduce culling rates and how to do so. The phrase *"whether to reduce culling rates"* is not typical in discussions about culling rates, but it is appropriate. When an above average culling rate is encountered, a culling rate reduction is generally prescribed. Nevertheless, a farm that has a high culling rate due to having a high number of sold for dairy culls may be at its optimal culling rate. Conversely, a farm with a low average culling rate may need to further reduce its culling rate if it has a larger-than-normal proportion of health culls and mortalities.

Table 5 displays the percentage of culled cattle removed for particular reasons by state. The most common reason for culling cattle for all ten states combined was *"Injury or Other"* with twenty-seven percent of all culls in the ten states being attributed to this reason. Reproduction problems was the second-most prevalent

Table 5. Culling Reasons by State

Culling Reason	All 10 States (% of	NH (% of Culled	VT (% of Culled	ME (% of Culled	NY (% of Culled	PA (% of Culled	IN (% of Culled	IL (% of Culled	MI (% of Culled	WI (% of	IA (% of

Table 5. Culling Reasons by State

Culling Reason	All 10 States (% of Culled Cows)	NH (% of Culled Cows)	VT (% of Culled Cows)	ME (% of Culled Cows)	NY (% of Culled Cows)	PA (% of Culled Cows)	IN (% of Culled Cows)	IL (% of Culled Cows)	MI (% of Culled Cows)	WI (% of Culled Cows)	IA (% of Culled Cows)
Feet and Legs	4	5	7	4	4	5	5	4	4	3	3
Sold for Dairy	8	9	9	8	6	7	10	9	7	13	8
Low Production	13	8	14	9	6	19	17	10	20	9	12
Reproduction	19	21	19	19	16	22	22	22	18	15	18
Injury or Other	27	26	24	31	43	20	18	18	16	28	20
Died	10	10	8	11	10	8	10	11	14	10	13
Mastitis	12	16	14	12	10	14	14	12	10	9	14
Disease	3	3	2	3	3	3	2	4	4	3	4
Udder	4	2	3	3	2	2	2	8	7	10	8
Total Health Culls	79	83	77	83	88	74	73	81	73	78	80

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culling reason accounting for nineteen percent of all culls. Thirteen percent of the culled cattle were culled due to low production. Mastitis was the fourth most common reason accounting for twelve percent of all culls. Cattle mortalities was the fifth ranked reason in the ten state sample accounting for ten percent of the culled cattle.

New Hampshire farms had the second lowest proportion of culls due to production reason. The majority of New Hampshire cull cattle were culled due to injuries. New Hampshire had the highest proportion of culls caused by mastitis problems.

Eight percent of the cattle culled in Vermont were removed from their herds due to mortalities. This value tied with Pennsylvania for the lowest mortality removals among the ten states. Injuries caused the majority (twenty four percent) of culls in Vermont. Vermont had the highest proportion of culled cattle removed for feet and leg problems at seven percent. Overall, Vermont culled less cattle for health reasons than the ten state average.

Eighty three percent of all cattle culled in Maine were culled due to health problems. Maine exhibited the second and third highest proportion of culled cattle that left the herd due to injuries and mortalities respectively. Thirty one percent of the culled cattle in Maine were culled for injuries. Eleven percent of the culled cattle died.

New York exhibited the highest percentage of cull cattle removed for health reasons at eighty eight percent and the highest percentage of cull cattle being removed for injuries at forty three percent. New York herds exhibited the lowest percentage of culled cattle removed for reproduction (sixteen percent), low production (six percent) and sold for dairy purposes (six percent) reasons.

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Pennsylvania had the second lowest percentage of cull cattle removed for health reasons at seventy four percent. Pennsylvania tied with Vermont for having the lowest percentage of culled cattle being removed for mortality reasons at eight percent. Unlike the other eastern states in this study, the primary reason for cattle removal in Pennsylvania was reproduction problems instead of injuries. In fact, Pennsylvania tied with Indiana and Illinois for having the highest proportion of cull cattle being removed for reproduction problems at twenty two percent. Pennsylvania also had the second highest percentage of cull cattle removed for production reasons at nineteen percent.

Indiana tied with Michigan for the lowest percentage of cull cattle removed for health problems at seventy three percent. Indiana had the largest percentage (ten percent) of culled cattle removed for sold for dairy purposes. Indiana also had the third largest percentage (seventeen percent) of culled cattle removed for production purposes. The majority (twenty two percent) of Indiana cull cattle were removed for reproduction reasons.

Eighty one percent of Illinois cull cattle were removed for health reasons. Reproduction problems were the primary reason why culled cattle were removed from Illinois herds. Illinois tied with Maine for having the second highest percentage of culled cattle removed for mortalities at eleven percent.

Michigan tied with Indiana for the lowest percentage, seventy three percent, of cattle culled due to health problems. The most common culling reason in Michigan was low production, which accounted for twenty percent of all culls. Reproduction reasons accounted for eighteen percent of all culls and was the most common health cull reason in Michigan. Michigan had the highest percentage of cattle removed due to mortalities (fourteen pe

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(fourteen percent). Michigan also experienced the lowest percentage of cattle culled due to injury with sixteen percent.

Seventy eight percent of Wisconsin culled cattle were culled due to health problems. Injuries accounted for most of the Wisconsin cattle culls (twenty eight percent). Wisconsin had the lowest percentage of cattle culled for reproduction reasons (fifteen percent), mastitis (nine percent), and tied for the lowest percentage of culled cattle removed for feet and leg problems. Wisconsin had the highest percentage of culled cattle removed for udder (ten percent) and sold for dairy purposes (thirteen percent).

Eighty percent of culled cattle were culled due to health problems in Iowa. Accounting for twenty percent of all cattle culls, injuries was the most common culling reason in Iowa. Iowa had the second highest mortality rate among the ten states with thirteen percent.

Holstein cattle were most often culled for injury or other health related problems (Table 6). Seventy-six percent of Holstein cattle were culled for health reasons. Jersey cattle were culled less often for health problems. Besides Jersey cattle having the lowest overall culling rate of the six breeds analyzed, most of the culled Jersey cattle were sold for dairy purposes. Culled Brown Swiss cattle were primarily plagued by reproduction problems, but 20 percent were also sold to other farms for dairy purposes. Twenty four percent of the Guernsey cattle were culled for injury reasons, and 21 percent were sold due to low production. The majority of Ayreshire cattle were culled for reproduction problems. Milking Shorthorn cattle had the lowest percentage of cattle culled for health purposes at 54.9 percent and the highest percentage of cattle sold for dairy purposes at 31.7 percent. Most of the culled Milking Shorthorn cattle were sold to other farms for dairy purpo

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Table 6.

Culling Reason
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dairy purposes. The most common cause of health culls among Milking Shorthorn was injury or other health problems.

Table 6. Culling Reasons by Breeds

Culling Reason	Holstein (% of Culled Cows)	Jersey (% of Culled Cows)	Brown Swiss (% of Culled Cows)	Guernsey (% of Culled Cows)	Ayreshire (% of Culled Cows)	Milking Shorthorn (% of Culled Cows)
Feet and Legs	4	2	4	4	3	2
Sold for Dairy	7	19	17	7	15	28
Low Production	13	14	13	18	13	13
Reproduction	19	16	20	19	22	15
Injury or Other	27	20	19	27	25	20
Died	11	11	10	11	9	8
Mastitis	12	12	9	9	9	7
Disease	3	2	3	2	2	2
Udder	4	4	5	3	2	5
Total Health Culls	80	67	70	77	72	59

The primary reason for cattle being culled on farms with less than 300 cows was injury (Table 7). Injury problems decreased as herd size increased. Larger herds, however, experienced proportionately more feet and leg problems as well as mortalities. The results for the larger herd category are higher than those reported by Quaiffe (2002) for all DHI herds participating in the DRMS DHI recordkeeping system.

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Table 7. Culling Reasons By Herd Size

Culling Reason	0 – 150 Cows (% of Culled Cows)	151 – 300 Cows (% of Culled Cows)	301 – 450 Cows (% of Culled Cows)	451 – 600 Cows (% of Culled Cows)	More than 601 Cows (% of Culled Cows)
Feet and Legs	4	7	7	9	8
Sold for Dairy	8	5	4	3	7
Low Production	13	13	13	13	13
Reproduction	19	18	17	16	14
Injury or Other	27	26	25	23	23
Died	10	13	14	14	16
Mastitis	12	13	14	15	13
Disease	3	3	4	5	4
Udder	4	2	2	2	2
Total Health Culls	79	82	83	84	80

The most common reason an animal was culled on herds producing less than 18,000 pounds of milk per cow per lactation was injury, but these farms also had the highest proportion of low production culls, possibly indicating that these herds aretrying to increase production through culling (Table 8). As production levels increased, proportionately more cattle were culled due to reproduction problems. Higher producing herds also experienced less injuries per cow. The proportion of cattle culled for mastitis problems peaked for farms averaging between 18,000 and 21,000 pounds of milk per cow before declining with higher production levels.

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Table 8. Culling Reasons By Rolling Herd Average

	0 – 18,000 Pounds Per Cow (% of Culled Cows)	18,001 – 21,000 Pounds Per Cow (% of Culled Cows)	21,001 – 24,000 Pounds Per Cow (% of Culled Cows)	24,001 – 27,000 Pounds Per Cow (% of Culled Cows)	More than 27,000 Pounds Per Cow (% of Culled Cows)
Feet and Legs	2	6	7	7	6
Sold for Dairy	8	7	8	9	10
Low Production	14	12	11	11	9
Reproduction	19	20	18	17	17
Injury or Other	28	26	24	23	24
Died	10	11	12	12	12
Mastitis	11	13	14	15	15
Disease	3	3	4	4	4
Udder	5	2	2	2	3
Total Health Culls	78	81	81	80	81

VI. Lactation Specific Culling Rates for 1993 – 1999

In general, the lactation specific total culling rate (Table 8), health culling rate (Table 9), and the mortality rate increased through the tenth lactation (Table 10). This pattern was similar when the data was sorted by breed (Table 11), herd size (Table 12) , and production (Table 13). First lactation culling rates ranged from 18.7 percent in Vermont to 25.8 percent in Indiana. Vermont also had the lowest second lactation culling rates. Over forty percent of the second lactation cattle were culled. Although Indiana had the highest first lactation culling rate, it had the second to lowest second lactation culling rate. Overall, Vermont had the lowest lactation specific culling rate.

Table 9. Lactation Specific Total Culling Rate[1] by State for 1993 – 1999

Lactation	All Ten States Culling	NH	VT	ME	NY	PA	IN	IL	MI	WI	IA
		(% of	(% of	(% of	(% of	(% of	(% of	(% of			

Table 9. Lactation Specific Total Culling Rate[1] by State for 1993 – 1999

Lactation	All Ten States Culling Rate (% of Cows)	NH (% of Cows)	VT (% of Cows)	ME (% of Cows)	NY (% of Cows)	PA (% of Cows)	IN (% of Cows)	IL (% of Cows)	MI (% of Cows)	WI (% of Cows)	IA (% of Cows)
1	18	16	16	16	16	18	21	20	20	16	19
2	31	31	23	30	32	32	28	36	39	27	34
3	37	39	28	36	40	38	33	41	46	34	40
4	43	44	33	42	46	45	38	47	52	38	45
5	47	50	38	47	51	51	42	51	55	42	50
6	51	54	42	54	55	56	47	47	58	45	54
7	54	58	46	56	58	60	50	58	62	50	56
8	57	61	49	58	61	63	53	61	64	52	58
9	60	65	52	62	64	67	58	62	66	55	60
10 lactations or more	62	74	56	48	68	69	60	70	66	55	65

[1] Includes all culls except those associated with cattle being sold to other farms for dairy purposes.

Table 10. Lactation Specific Health Culling Rate[1] by State for 1993 – 1999

Lactation	All Ten States	NH	VT	ME	NY	PA	IN	IL	MI	WI	IA

Table 10. **Lactation Specific Health Culling Rate[1] by State for 1993 – 1999**

Lactation	All Ten States Culling Rate (% of Cows)	NH (% of Culled Cows)	VT (% of Culled Cows)	ME (% of Culled Cows)	NY (% of Culled Cows)	PA (% of Culled Cows)	IN (% of Culled Cows)	IL (% of Culled Cows)	MI (% of Culled Cows)	WI (% of Culled Cows)	IA (% of Culled Cows)
1	13	12	12	12	13	12	14	15	12	12	14
2	23	23	17	24	26	23	19	28	24	21	25
3	27	31	21	28	32	27	23	32	29	27	29
4	33	34	25	33	26	32	27	36	33	30	33
5	36	40	29	37	41	37	30	39	35	33	37
6	39	44	33	43	46	41	34	34	36	35	40
7	41	47	36	45	48	43	37	45	39	37	41
8	43	50	37	45	51	44	39	48	41	39	42
9	46	54	41	53	54	44	42	48	42	43	43
10 lactations or more	46	61	44	37	57	45	42	53	37	40	44

[1] Includes culls due to udder and mastitis problems, lameness and injury, disease, reproduction problems but not death.

Table 11. ***Lactation Specific Mortality Rate by State for 1993 – 1999***

Lactation	All Ten	NH	VT	ME	NY	PA	IN	IL	MI	WI	IA

Table 11. Lactation Specific Mortality Rate by State for 1993 – 1999

Lactation	All Ten States Culling Rate (% of Culled Cows)	NH (% of Culled Cows)	VT (% of Culled Cows)	ME (% of Culled Cows)	NY (% of Culled Cows)	PA (% of Culled Cows)	IN (% of Culled Cows)	IL (% of Culled Cows)	MI (% of Culled Cows)	WI (% of Culled Cows)	IA (% of Culled Cows)
1	2	2	1	2	2	2	2	2	3	2	2
2	3	4	2	3	4	3	3	4	6	3	4
3	5	5	3	5	5	4	4	6	8	4	6
4	5	6	3	5	6	5	5	7	9	4	7
5	6	7	4	6	6	5	6	8	10	5	8
6	6	7	4	7	6	5	7	7	10	6	8
7	7	7	4	6	7	5	7	8	11	7	9
8	7	8	5	7	7	6	7	8	11	6	9
9	7	7	5	6	7	7	9	9	11	6	9
10 lactations or more	8	9	5	6	8	5	10	9	12	8	11

Table 12. **Lactation Specific Total Cull (CR)[1], Health Cull (HR)[2] and Mortality (MR) Rate by Breed for 1993 – 1999 (Percent of Cattle of Lactation n)**

Lactation	Holstein	Guernsey	Jersey	Ayreshire	Brown Swiss	Milking

Table 12. Lactation Specific Total Cull (CR)[1], Health Cull (HR)[2] and Mortality (MR) Rate by Breed for 1993 – 1999 (Percent of Cattle of Lactation n)

Lactation	Holstein (% of Cows)			Guernsey (% of Cows)			Jersey (% of Cows)			Ayreshire (% of Cows)			Brown Swiss (% of Cows)			Milking Shorthorn (% of Cows)		
	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR
1	19	13	2	28	8	3	14	10	1	17	13	1	17	13	1	13	9	1
2	31	22	4	35	11	4	20	13	2	26	18	3	26	18	3	24	17	2
3	36	26	5	40	14	5	23	16	3	29	21	3	29	20	4	24	17	2
4	41	31	5	43	17	6	27	19	4	33	24	4	33	24	4	30	21	5
5	46	34	6	46	20	6	31	22	5	38	29	4	37	28	5	35	23	6
6	49	36	6	50	23	7	34	25	5	41	32	5	40	30	6	38	28	6
7	53	40	7	54	24	8	37	28	5	47	38	5	46	35	7	37	30	5
8	56	42	7	53	24	6	44	33	5	49	40	4	51	39	8	45	31	11
9	59	44	7	57	36	7	48	37	5	54	45	6	56	42	8	59	43	16
10 lactations or more	61	44	8	62	32	8	48	36	5	55	44	6	56	43	10	25	17	0

[1] Includes all culls except those associated with cattle being sold to other farms for dairy purposes.
[2] Includes culls due to udder and mastitis problems, lameness and injury, disease, reproduction problems but not death.

Table 13. ***Lactation Specific Total Cull (CR)[1], Health Cull (HR)[2] and Mortality (MR) Rate by Herd Size for 1993 – 1999***

Lactation	0 – 150 Cows (% of Culled	151 – 300 Cows (% of Culled	301 – 450 Cows (% of Culled	451 – 600 Cows	More than 601

Table 13. **Lactation Specific Total Cull (CR)[1], Health Cull (HR)[2] and Mortality (MR) Rate by Herd Size for 1993 – 1999**

Lactation	0 – 150 Cows (% of Culled Cows)			151 – 300 Cows (% of Culled Cows)			301 – 450 Cows (% of Culled Cows)			451 – 600 Cows (% of Culled Cows)			More than 601 Cows (% of Culled Cows)		
	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR
1	18	13	2	20	14	3	21	15	3	21	15	3	24	13	5
2	30	21	3	29	21	4	30	20	4	32	23	4	36	22	7
3	35	24	4	37	27	5	38	26	6	41	30	6	39	23	9
4	39	29	5	43	32	6	45	31	7	48	35	7	44	22	11
5	43	32	6	48	36	7	50	34	9	53	38	9	49	25	12
6	48	35	6	52	38	8	54	38	8	57	40	9	49	27	11
7	51	38	7	55	41	8	58	40	9	57	40	10	45	27	10
8	54	40	7	57	42	8	62	40	10	62	42	9	58	28	15
9	57	43	7	60	46	7	64	44	10	62	40	12	59	43	8
10 lactations or more	57	42	7	63	45	10	74	53	10	70	43	10	56	36	20

[1] Includes all culls except those associated with cattle being sold to other farms for dairy purposes.
[2] Includes culls due to udder and mastitis problems, lameness and injury, disease, reproduction problems but not death.

Table 14. ***Lactation Specific Total Cull (CR)[1], Health Cull (HR)[2] and Mortality (MR) Rate by Rolling Herd Average for 1993 – 1999***

Lactation	Less Than 18,000 lbs	18,001 – 21,000 lbs	21,001 – 24,000 lbs	24,001 – 27,000 lbs	More Than 27,001

Table 14. Lactation Specific Total Cull (CR)[1], Health Cull (HR)[2] and Mortality (MR) Rate by Rolling Herd Average for 1993 – 1999

Lactation	Less Than18,000 lbs (% of Cows)			18,001 – 21,000 lbs (% of Cows)			21,001 – 24,000 lbs (% of Cows)			24,001 – 27,000 lbs (% of Cows)			More Than 27,001 lbs (% of Cows)		
	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR	CR	HR	MR
1	17	12	2	20	15	2	20	15	2	19	13	3	20	14	3
2	34	26	3	28	21	3	29	21	4	29	21	4	30	23	4
3	39	29	4	34	26	4	37	28	5	38	29	5	39	30	5
4	44	33	5	40	30	5	43	33	6	45	34	6	44	35	6
5	48	36	6	45	34	6	48	38	6	49	38	7	50	39	8
6	51	39	6	49	38	6	52	40	7	53	41	7	54	42	8
7	54	41	6	53	41	7	56	44	7	57	44	8	53	40	8
8	57	42	8	56	43	7	58	45	7	58	44	8	55	43	8
9	61	46	7	59	46	7	60	46	8	61	44	10	60	46	6
10 lactations or more	62	45	8	62	49	7	64	48	8	56	49	9	48	38	10

[1] Includes all culls except those associated with cattle being sold to other farms for dairy purposes.

[2] Includes culls due to udder and mastitis problems, lameness and injury, disease, reproduction problems but not death.

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Guernsey cattle had the highest lactation specific culling rates of the breed records analyzed for each lactation (Table 12). Jersey cattle had the lowest lactation specific culling rate for each lactation. Although Brown Swiss and Ayreshire cattle had higher first lactation cattle rates than Holstein cattle, the culling rates for lactations two through ten were lower than Holsteins. Milking Shorthorns had higher lactation specific culling rates than Holsteins in all but the sixth lactation; however, the majority of Milking Shorthorn culls are due to sales to other farms for dairy purposes. An implication of the information in Table 12 is that culling reduction programs using the lactation specific culling rates of Holstein cattle may not produce accurate results for other breeds.

Although there were exceptions, lactation specific culling rates increased with herd size (Table 13). Farms with larger than 600 cows had the highest lactation specific culling rates. Farms with less than 150 cows, except for lactations two and three, had the lowest lactation specific culling rates.

There was no apparent correlation between milk production and lactation specific culling rate (Table 14). Herds producing less than 18,000 pounds of milk per cow per lactation had the lowest lactation specific culling rate. These herds had the highest culling rate of lactation 2 cattle. Third lactation animals were more heavily culled in herds producing more than 27,000 pounds of milk. Cattle of ten lactations or more had better survivability on herds producing less than 18,000 pounds of milk and more than 27,000 pounds of milk.

The differences in lactation specific culling rates among states, breeds, herd size and production level indicates that a DSS needs to accommodate different lactation specific cu

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specific culling rates. Without this feature, a DSS will not provide reliable information regarding the feasibility of reducing health culling rates.

VII. Within Lactation Culling Pattern for Health Culls for 1993 – 1999

The net returns of a cow culled at the end of a lactation are generally higher than those associated with a cull in early lactation. As such, a DSS designed to estimate the feasibility of reducing health culls needs to consider when those cull occur. Natzge (2002) reported that most cattle are culled during the first 20 day period following the first 21 days after calving. In this research, the within lactation culling pattern was determined for non-death health culls and mortalities. The majority of cattle culled due to non-death health reasons are culled at the end of a lactation (Table 15). Over a third of the cattle culled for health reasons are removed in lactation month 11 or beyond. The cow disappearance pattern for cattle that die appears to be bimodal. The majority of cattle that die during a lactation die in the early part of the lactation. Forty-two percent of the cattle die within the first sixty days of lactation. Over twenty-three percent of the cattle that die do so in the eleventh lactation or later.

Table 15. **Within Lactation Cow Removal Pattern for Health Culls (H) and Mortalities (M) by Lactation for All Ten Midwestern and Northeastern States 1993 – 1998**

Table 15. Within Lactation Cow Removal Pattern for Health Culls (H) and Mortalities (M) by Lactation for All Ten Midwestern and Northeastern States 1993 – 1998

Lactation Month	Lactation 1 (% of Culled Cattle)		Lactation 2 (% of Culled Cattle)		Lactation 3 (% of Culled Cattle)		Lactation 4 (% of Culled Cattle)		Lactation 5 (% of Culled Cattle)		Lactation 6 (% of Culled Cattle)		Lactation 7 (% of Culled Cattle)		Lactation 8 (% of Culled Cattle)		Lactation 9 (% of Culled Cattle)		Lactation 10 (% of Culled Cattle)	
	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M
1	8	23	8	28	10	37	12	41	12	44	13	46	12	46	12	45	12	44	11	43
2	8	9	5	8	6	8	6	8	6	8	6	7	6	7	6	7	6	7	6	7
3	6	6	5	5	5	5	5	5	6	5	6	5	6	6	6	5	6	6	6	7
4	5	5	5	4	5	4	6	4	6	4	6	4	6	4	6	4	7	5	7	5
5	5	4	5	4	6	4	6	3	6	3	6	3	6	4	6	4	7	3	8	4
6	5	4	6	4	6	3	6	3	6	3	6	3	6	3	7	3	6	3	7	2
7	5	4	6	4	6	3	6	3	7	3	7	3	7	2	7	3	8	2	6	4
8	5	4	7	4	7	3	6	3	7	3	7	3	7	2	7	3	7	3	8	3
9	6	5	7	5	8	4	7	4	7	3	7	3	7	4	7	4	7	4	7	4
10	8	7	9	7	9	6	8	5	8	5	8	5	8	5	7	5	7	4	9	4
11	40	29	37	26	33	22	31	21	30	19	29	19	29	18	29	19	29	19	27	19

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VIII. Conclusions

The financial feasibility of reducing health culls is complicated by two competing factors. First, reducing culls saves producers in making replacement heifer expenditures. Second, cattle increase in milk production through the first five lactations. Thus, milk, milk fat, and milk protein per cow should increase with increased longevity until the fifth lactation. Third, as health culls are reduced, the milk losses associated with health culls are reduced as well. Disincentives exist in the form of increasing somatic cell counts and genetic improvement rates. Somatic cell counts, which can possibly result in milk price discounts, increase with cow age. As fewer cattle are replaced each year, the overall genetic improvement rate for the herd decreases.

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CHAPTER 3.

EXPLAINING WHY INDIVIDUAL DAIRY COWS ARE CULLED IN NORTHEASTERN AND MIDWESTERN DAIRY HERDS

I. Introduction

In this chapter a model is developed and estimated to determine which individual cow and herd characteristics significantly contributed to the likelihood that an individual dairy cow was culled due to low production, health (including reproductive health) or mortality reasons. The independent variables of this model included individual cow productive characteristics, farm characteristics, output and input prices, as well as cattle salvage values and acquisition prices. The model was estimated using Dairy Herd Improvement data from Dairy Management Records Systems for participating herds in five Midwestern states (Illinois, Indiana, Iowa, Michigan and Wisconsin) and five Northeastern states (Maine, New Hampshire, New York, Pennsylvania, and Vermont) for the 1993 – 1999 period.

II. Methods and Model Development

A variety of individual and herd level characteristics can contribute to a cow being culled. It is the cumulative effect of these reasons that causes a manager to cull a cow. A model was needed that would predict the probability that the cumulative effect of the explanatory variables had exceeded the needed threshold value for a cow to be culled.

Both the logit and probit models predict the probability of an event occurring. These estimated probabilities for the dependent variable remain within the upper and lower limits. The marginal effects are nonlinear (Gujarati, 1995). Both methods also accomm

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accommodate non-normally distributed explanatory variables (Maddala, 1992). As such, both are suitable for this analysis.

The logit and probit model differ in that the normal cumulative distribution function underlying the probit model approaches the upper and lower limits of the dichotomous variable more quickly than the logistic cumulative distribution function of the logistic model (Gujarati, 1995). Thus, the tails of the probit model's normal cumulative distribution function are flatter than the logit model's logistic cumulative distribution function. This means that the probit model becomes more favorable as sample size increases and there are more observations in the tail (Maddala, 1992). As the sample size for this model was large, the probit model method was selected for this research. A generic probit model can be described as follows:

$$P(\text{ Event} = 1) = \beta_0 + (\beta_1 X_1 + \ldots + \beta_n X_n)$$

where:

$P(\text{ Event} = 1)$ refers to the predicted probability (range = 0 to 1) that an event will occur;

β_0 refers to the intercept for the probit model;

$(\beta_1 X_1 + \ldots + \beta_n X_n)$ refer to a set of independent variables that may influence whether a cull will occur.

To calculate the marginal effect of a parameter in a probit model, one must use the following formula:

Marginal effect of the *n*th parameter = $\beta_n \, \Phi \, (Y_i)$

where:

β_n refers to the coefficient of the *n*th parameter;

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Φ (.) is the density function of the standard normal variable; and,

Y_i refers to the regression model used in the analysis (Gujarati, 1995).

SAS statistical software was chosen for this research and calculated the marginal effects. A drawback of this model is that the marginal effect must be explained in terms of the baseline situation as opposed to a general situation.

Model Description

The probit model used to estimate the likelihood of a cull is summarized as follows:

$$P(\text{Cull} = 1) = \beta_0 + (\beta_1 X_1 + \ldots + \beta_n X_n)$$

where *"P(Cull = 1)"* refers to the predicted probability (range = 0 to 1) that a culling event will occur, *"β_0"* refers to the intercept for the probit model, and *"$(\beta_1 X_1 + \ldots + \beta_n X_n)$"* refer to a set of independent variables that may influence whether a cull will occur. These variables are described in Table 16.

Calving Season

The climate differences characterizing each season (Spring, Summer, Winter, and Fall) affects the profitability of cattle producing in those conditions. Delorenzo, Spreen, Bryan, Beede and Van Arendonk (1992) showed that seasonal variations in milk production, conception, and milk price affected the profit maximizing replacement decisions for Florida herds. For example, a cow calving during the extremes of Summer or Winter may undergo a more stressful calving than in Spring or Fall. Alternatively, a cow that freshens in late Spring and enters peak milk production and is bred during the hottest part of the year may not peak as high or

Table 16.

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Herd Size

Table 16. Independent Variable Descriptions for the Probit Model Estimation Used to Predict the Probability of a Cow Being Culled

Parameter	Description
Winter Calving	1 = yes, 0 = no
Summer Calving	1 = yes, 0 = no
Fall Calving	1 = yes, 0 = no
Lactation *n*	1 = yes, 0 = no where *n* = 2 through 10 or more
Milk Difference	The 305 Day ME Milk hundredweight difference between the cow and its herd mates
Fat Difference	The 305 Day ME Fat difference in pounds between the cow and its herd mates
Protein Difference	The 305 Day ME Fat difference in pounds between the cow and its herd mates
Persistency Percent	A DHI measurement indicating how well the observation cow maintained its production throughout its lactation as compared to its herd mates
SCC Difference	The difference between the cow's somatic cell count score and the average somatic cell count score for its herd
Previous Services Per Conception	The difference between the observation cow's previous lactation services per conception and the previous lactation services per conception of cattle in its herd and age group (Lactations 1, 2, or 3 or more)
PTA Milk	A DHI measure indicating the cow's ability to transmit milk production traits to its offspring
PTA Fat	A DHI measure indicating the cow's ability to transmit fat production traits to its offspring
PTA Protein	A DHI measure indicating the cow's ability to transmit protein production traits to its offspring
Guernsey	1 = yes, 0 = no
Jersey	1 = yes, 0 = no
Other	1 = yes, 0 = no
Registered Herd	1 = yes, 0 = no
Illinois	1 = yes, 0 = no
Iowa	1 = yes, 0 = no
Michigan	1 = yes, 0 = no
Wisconsin	1 = yes, 0 = no
Maine	1 = yes, 0 = no
New Hampshire	1 = yes, 0 = no
New York	1 = yes, 0 = no
Pennsylvania	1 = yes, 0 = no
Herd Size	Indicates the average number of milking and dry cows that were in the cow's herd

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Table 16 (cont'd).

Small Expansion Year *n*	Cow observation was from a farm that was in the ***nth*** year of an expansion of more than 20 percent but less than 300 percent; 1 = yes, 0 = no where ***n*** = 1 through 5
Large Expansion Year *n*	Cow observation was from a farm that was in the ***nth*** year of an expansion of more than 20 percent but less than 300 percent; 1 = yes, 0 = no where ***n*** = 1 through 5
Heifer Ratio Year *n*	One current and four lagged parameters measuring the proportion of the number of dairy replacement heifers herd greater than thirteen months of age relative to the number of the milking and dry cow herd size on the observation cow's farm
Milk Feed Price Ratio *n*	The milk feed price ratio during the ***nth*** lactation month where ***n*** = 1 through 12 or more
Cull Cow to Replacement Heifer Price Ratio *n*	The cull cow to replacement heifer price ratio during the ***nth*** lactation month where ***n*** = 1 through 12 or more
Year *n*	Cow observation was in year ***n***; 1 = yes, 0 = no where ***n*** equals 1996, 1997, 1998, 1999
Farm *n*	Cow observation was from farm ***n***; 1 = yes, 0 = no

breed back as soon as its herd mates. As such, it is important to address how seasonality affects the probability of a cow being culled. It was hypothesized that the effects of Winter, Summer and Fall calving season variables would be significantly different from the Spring calving season effect, which was set as the default calving season in the estimation.

Cow Age Variables

The profitability of that cow changes as it ages. She may become unable to produce as much milk as she once did. In Chapter 2, it was shown that cattle are more likely to be culled as they age. The cow may become more susceptible to injury, infertility, and disease. All of these factors affect the cow's profitability, which, in turn, affect the likelihood of a cull.

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Past researchers have also shown that the incidence of culling due to health, reproduction, somatic cell count (a measurement of udder health and milk quality), and production efficiency increases with age. Dutch data used by Van Arendonk and Dykhuizen (1985) showed that the probability of an animal being culled due to health reasons (injury, disease, somatic cell count, and reproduction) increased with age. Jones (2001) found that the somatic cell count of Wisconsin cattle increased with age. Bauer, Mumey and Lohr (1993) determined that the costs of producing milk for Alberta cattle increased with age until the eighth lactation.

One important decision in developing this model was how to value the age of a cow. There are two alternatives, by normal time (age in months or years) or by lactation. Hansen (2002) reported that some studies show that the average age of cattle at removal has not varied significantly over time even though culling rates have risen and the number of lactations completed by removal have decreased. As the number of lactations should be positively correlated with the number of peak milk production periods encountered during a cow's lifetime, lactation number was chosen to represent cow age.

The default cow age variable for the estimation was the first lactation. It was hypothesized that later the effect of later lactations would be significantly different than the first lactation.

Milk Production Variables

Van Arendonk (1985) showed that the herd production level of Dutch dairy farms should not affect the optimal cow longevity and culling rate. Stott (1994) found similar results for United Kingdom dairy herds. Rogers, Van Arendonk, and McDaniel (1988) found that larger milk yields supported only slightly higher culling rates for dairy farms in the Uni

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in the United States. Work conducted later by Jones (2001) on Wisconsin dairies also supported the premise that average milk yield had little effect on optimal culling rates. Weigel and Palmer (2003), however, reported a positive correlation between involuntary culling of high producing cows, defined as cattle within the top 20 percent of their herd in terms of milk production and the herd level Rolling Herd Average.

It is the relative productivity of an individual cow as compared to its herd mates, however, that should affect the probability of whether that cow will be culled. For instance, a cow that produces 25,000 pounds of milk may be a poor cow to a producer whose cattle average 27,000 pounds of milk per lactation. Alternatively, a 25,000 pound cow in a herd averaging 18,000 pounds of milk per lactation would be deemed a good cow. Because U.S. milk producers are paid on the basis of fluid, butterfat, and milk protein yield – the effect of the differences in fluid milk production, butterfat production, and milk protein production on the likelihood of an animal being culled were determined. For milk production, the difference in the 305 ME Milk between the individual cow and its herd mates were analyzed. The 305 ME Milk, Fat and Protein are production measurements that standardize production per cow so that the values represent the production as if all of the cattle were the same age, from the same location, milked twice a day and had calved during the same season (Dairy Records Management Systems, 1999). Unless there is a economic disadvantage to produce either milk fluid, fat, or protein, it is expected that a cow producing more than her herd mates will stay in the herd longer.

Lactation persistency was also considered in the model. The lactation persistency percentage is a DHI measure that compares the persistency of a cow's lactation with those

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those of her herdmates. When trying to judge whether an animal should be culled, a producer should take into account the expected future profitability of the cow currently in the herd and its potential replacement. In periods of poor milk price cost margins, however, producers may be tempted to cull lower producing cattle that are not covering short run variable costs even if a replacement is unavailable. If two cows have identical milk production per lactation, but one is more persistent that the other, the one that is more persistent will have an increased probability of remaining in the herd as the less persistent cow will be less likely to cover variable costs in late lactation. Dijkhuizen, Renkema and Stelwagen (1985) determined that it became more advantageous to retain a long-open cow and continue breeding the animal as persistency increased. It is expected that lactation persistency is negatively correlated with culling rate.

Herd Health Parameters

Two DHIA herd health measures were used as explanatory variables, somatic cell count score – which is a measure of milk quality – and services per conception. The somatic cell count score is based on the somatic cell count, which measures the number of white blood cells per milliliter of milk. As this number rises, it indicates the presence of infectious agents that the cow's immune system is fighting (DRMS, 1999). Mastitis, an udder infection, is strongly correlated with somatic cell counts and somatic cell count scores. In the U.S., milk processors pay producers a premium for low somatic cell counts and assess a discount for high somatic cell counts. High somatic cell count scores hinder milk production. For somatic cell scores greater than or equal to three, corresponding to a somatic cell count of between 72,000 and 141,000 – there is an expected milk loss of 1.5 pounds per cow per day (DRMS, 1999). This decrease in milk production increases through th

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Houben, Huirne and Dijkhuizen (1994) examined the effect of mastitis on optimal culling strategies for Dutch herds. They found it more profitable to treat animals than to cull them for mastitis. When the incidence of mastitis was increased by fifty percent and mastitic cattle were voluntarily removed, the mastitis incidence still increased by fifty percent. This was due largely to the fact that many of the replacement animals contracted mastitis.

While the overall incidence of mastitis and high somatic cell count scores should not effect the average culling rate and optimal cow longevity, the difference between a cow's somatic cell count and that of her herd mates should contribute to the likelihood that the cow will be culled. As an individual cow's somatic cell count score increases relative to the rest of the herd, the cow becomes less profitable due to treatment costs, lost production and somatic cell count discounts. The somatic cell count score difference parameter was calculated by subtracting the herd average somatic cell count score from the individual cows somatic cell count score. As such, the somatic cell count score difference parameter is expected to be positively correlated with the probability of a cow being culled.

Cassell (2002) noted that cows that become pregnant easier than their herd mates remain in the herd longer. Thus, a measure was needed to represent fertility. Two common reproductive capability measures monitored by DHI that proxy reproductive capability are calving interval and services per conception. Calving interval refers to the length of time b

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length of time between successive calvings. The calving interval is heavily influenced by the decision of when to start breeding a cow. A producer may elect to have a longer voluntary waiting period prior to breeding at one point during the year than at another time. This makes calving interval a potentially poor parameter of reproductive efficiency across farms.

The services per conception measure, however, measures how many artificial insemination services were required before a cow becomes pregnant. Assuming that two cows producing the same amount of milk are bred at the same time by technicians with comparable skill, the difference in the services per conception measurement between the cows should also proxy the fertility difference between the cows. This makes services per conception an appropriate measure of reproductive efficiency for this study.

The difference in services per conception from the prior lactation between the cow and her herd mate of the same maturity classification (Lactation 1, Lactation 2, or Lactation 3 or more) was used to represent an individual cow's reproductive efficiency. The previous lactation service per conception difference was used because cows that are kept for numerous services in the current lactation are generally being kept in the herd for reasons other than reproductive efficiency, and this would adversely affect the analysis. Nevertheless, as eluded to in earlier work by Van Arendonk and Dijkhuizen (1985), a cow that was a difficult breeder last lactation but finally became pregnant may be viewed more critically during the present lactation.

As a larger, more positive number indicates that a cow has less reproductive efficiency, it is expected that the effect of the previous lactation service per conception parameter is positively correlated with the probability of a cull in the current lactation.

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Genetic Capability

As dairy farmers typically get paid based on fluid milk production, butterfat production and milk protein production - the measures of cow PTA milk, cow PTA fat and cow PTA protein were chosen to represent the cow's genetic ability to produce those products. PTA stands for the predicted transmitting ability and estimates the ability to transmit a given trait (DRMS, 1999). As higher genetic capability should reduce the likelihood of an animal being culled, it was hypothesized that the effects of the cow PTA milk, fat and protein parameters are negatively correlated with culling probability.

Herd Breed Characteristics

For this model, four breed categories were used: Holstein, Guernsey, Jersey, and "Other" dairy breeds. Chapter 2 showed that mean culling rates differed across breeds. Jersey cattle had significantly lower culling rates than Holstein cattle. Guernsey cattle had significantly higher culling rates than Holsteins. Nevertheless, farm level effects may have influenced those averages. Having long lived breeds gives the manager a greater opportunity to cull for production or sold for dairy purposes. This is especially true for cattle from registered herds. However, even with registered herds, predicting culling probability is difficult. Less desirable cattle may be culled quicker on these herds, and cattle with very desirable traits may be kept in the herd for longer than their milk production merits. The Holstein breed was chosen to be the default breed in the estimation. Although the correlation of the effect of breed on the likelihood that a cow would be culled could not be hypothesized, it is expected that the effect of the Guernsey, Jersey, and Other breed variables is significantly different from Holstein cattle, which served as the default breed in the estimation.

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Registered Herd

Registered herds, as opposed to commercial herds, emphasize producing both milk and high genetic capability cattle. In the previous section, it was discussed how culling strategies may differ on registered herds. Although the correlation of the effect of registration status on the likelihood of a cull could not be hypothesized, it was hypothesized that registered herds cull differently than commercial herds.

State of Origin

The data contained dairy cattle records from five Midwestern states (Illinois, Indiana, Iowa, Michigan and Wisconsin) and five Northeastern states (Maine, New Hampshire, New York, Pennsylvania, and Vermont). Chapter 2 indicated that the Northeastern states had lower culling rates than Midwestern herds. In Corn Belt states like Indiana, the hot, humid summers may increase the likelihood of a cow being culled. Alternatively, there is less dairy infrastructure in this state, which may make it more expensive to replace cattle as opposed to Wisconsin, Michigan or Vermont. Thus, where a farm resides can affect the likelihood of an animal being culled.

Two estimates were run, one for the Midwestern states and one for the Northeastern states. This was done for a variety of reasons. First, there were computational constraints to running the entire dataset at once. As the Midwestern and Northeastern states were separated geographically from each other, it made sense to divide the large dataset by geographical region. Second, the Northeastern states generally had lower culling rates than the Midwestern states (Chapter 2). It was deemed important to see how each parameter differed between the two regions rather than having the regional differences absorbed by each state independent variables. Third, the two regions differ in reso

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For the Midwestern estimation, it was expected that the Illinois, Iowa, Michigan and Wisconsin culling probability effects differed from the Indiana effect, which served as the default state for the estimation. It was hypothesized that the Maine, New Hampshire, New York, and Pennsylvania effects differed from the effect of the Northeastern default state, Vermont.

Herd Size and Expansion

There are two basic arguments concerning the effects of herd size on culling rates. First, as herds get larger, the managers cannot devote the time needed to provide the individual care that each animal needs to achieve a long herd life. The second argument is that larger herds can afford more specialized labor and technologies that enable these large farms to provide better overall healthcare for their cattle. Quaiffe (2002), quoting DHIA data, noted that culling rates for herds with 600 or more cows were larger than the culling rates for herds with fewer than 100 cows, but that the difference was only 2 percent. Kluth found that herd size was positively correlated with Idaho culling rates due in part to a reluctance by the dairy owners to hire enough employees to provide adequate cow care (Dairy Profit Weekly, 2002). Weigel and Palmer (2003) found that high producing cattle were more likely to be culled in larger herds due to herd health problems than in smaller herds. Chapter 2 showed that average culling rates increased after herds exceeded 300 cows. Because of the potential mixed effects of herd size on the probability of a cull, the correlation of the herd size effect on culling probability could not be hypothesized.

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Dairy farm expansion has been cited as a contributing factor to increased culling rates and high replacement heifer prices (Hoard's Dairyman, 2003). The issue of importance for this study is not whether expansion increases the likelihood of an dairy cow being culled. Instead, the true issue is determining when the increase in culling probability will occur following an expansion. Hadley (2001) found that dairy farms in Wisconsin and Michigan actually experienced a decrease in culling rates the first two years of an expansion. However, this does not necessarily mean that the likelihood of a cull decreases during the first two years of an expansion. Kluth noted that expanded Idaho herds experienced an initial decrease in culling rates but also found that the underlying culling probability for a given lactation increased following expansion. Kluth further noted that as the initial replacement heifers that fueled the expansion reached their terminal lactation, the expansion dairy farm experienced a sharp increase in culling rates (Dairy Profit Weekly, 2002). Weigel and Palmer (2003) reported that expansion dairies were more likely to involuntarily cull high producing cattle due to health problems, but expansion dairies were less likely to cull low producing cattle.

Two groups of five expansion dummy variables were designed to test the hypothesis that expansion is positively correlated with the likelihood of a cow being culled. The first expansion group, "*Small Expansion n,*" included those herds that increased herd size by between twenty and three hundred percent. Dummy variables for this expansion group represented the first through fifth years of an expansion. The second group of expansions, "*Large Expansion n,*" consisted of those farms that expanded by more than three hundred percent. A dummy variable was also assigned to represent the first through fifth

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Replacement Heifer Availability

As the ratio of the number of heifers beyond 13 months of age to the average number of milking and dry cow herd grows, a manager may choose to allow all of the surplus heifers to enter the herd through increased culling, sell the surplus heifers, or do a combination of both. Radke and Lloyd (2000) asserted that many producers adjust culling rates to accommodate the number of springing heifers they have available. If managers do cull heavier to accommodate surplus heifers, they are indicating that they believe it is more profitable to have the heifer enter their herd than to sell them as replacement dairy cattle to other farms. Miranda and Schnitkey (1995) found evidence to suggest that Ohio producers who cull heavier than predicted do so because of unobserved replacement premiums. The authors suggested two possible reasons for these premiums. First, it is too costly to find and negotiate with heifer buyers in underdeveloped replacement heifer markets. Second, the producers may place a larger rate-of-return for genetic improvement than what is typically used in dairy cattle culling research.

If managers do not allow every heifer to enter the herd, they are indicating that it is less profitable to do and more profitable to sell them. Managers may engage in this activity for various reasons. First, managers who engage in this replacement strategy may do so because they believe that the genetic improvement rate is not high enough to allow every heifer to enter their herd. Second, these managers may perceive that increased cow longevity increases their returns on their heifer development investment. A third justification for this behavior may be that the marketing costs involved in selling replacement dairy

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replacement dairy cattle are low with regard to the price they receive. A fourth reason is that the replacements have to be culled due to health reasons prior to entering the milking herd, which means that these animals never enter the milking herd or the milking herd culling statistics.

An explanatory variable, *"Heifer Ratio n"* representing the ratio of the number of heifers over 13 months of age (corresponding to cattle that will calve within 10 to 13 months) to the average annual milking and dry cow herd size (heifer ratio) was developed to determine the effect that the number of available replacements has on the likelihood of a cow being replaced. If the marginal effect of this heifer ratio is positively correlated with the likelihood of a cull and relatively large, it may indicate that producers tend to make their culling decisions on the basis of the number of available heifers, that search costs to find buyers for their replacement heifers are too high, and/or that the perceived genetic improvement rate is high enough to justify letting all replacement heifers to enter the herd. If the parameter's effect is insignificant or significantly correlated but relatively small, it either indicates that producers find it more profitable to sell surplus heifers or that the heifers are culled prior to entering the milking herd. As a culling event for a mature cow today may be triggered by the fact that the cow was part of a relatively large heifer group in years past, four lagged heifer proportion variables were also used in the analysis. It is expected that the culling rate is positively correlated with the heifer ratios.

The Relative Price of Output and Variable Inputs

Renkema and Stelwagen (1979) concluded that the effects of milk price on optimal replacement decisions were small for Dutch dairy farms. Later work by Rogers, Van Arendonk and McDaniel (1988) concluded that the same was true for U.S. dairy farms. Bauer, N

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farms. Bauer, Mumey and Lohr (1993) found that the optimal terminal lactation for Alberta herds was not affected by changes in milk price. Jones (2001) did find that the optimal longevity for Wisconsin dairy cows changed with milk price but only when in conjunction with opposite changes in replacement heifer prices.

If one views the culling decision as a cow replacement decision, then the effects of a change in milk price should be small. During periods of low milk price-cost margins, however, a producer may cull an animal without a replacement if the cow's financial return does not exceed or equal the variable costs associated with that production. In this instance, the milk feed price ratio can serve as an important indicator as to whether a cow will be able to cover its variable costs. By having milk price ratio variables for each lactation month from calving through twelve months-and-beyond, one can judge which months of lactation act as trigger months for a culling decision by looking at the magnitude of the marginal effect of the significant parameters. As an increasing milk to feed price ratio represents an easier ability to cover variable costs, the marginal effect of each lactation month's milk price ratio is expected to be negatively correlated with the likelihood of a cow being culled.

The Relative Price of Replacement Heifers

While milk and variable input prices have been shown by previous researchers to have little effect on culling rates, the prices of replacement heifers and cull cattle have been shown to affect culling rates and optimal cow longevity. Renkema and Stelwagen found that cull cow prices had a small effect on optimal culling policies for Dutch herds. (1979). Rogers, Van Arendonk and Stelwagen (1988) showed that replacement heifer prices should have a large effect on culling decisions for U.S. dairy farm managers.

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Bauer, Mumey and Lohr (1993) estimated that changes in replacement heifer prices and/or a large decrease in cull cow prices should have large effects on the optimal terminal lactation for Alberta producers. Stott (1994) found that the optimal herd life for U.K. herds was also sensitive to changes in replacement heifer prices.

As the price farmers receive for selling cull cattle increases relative to replacement heifer price, it becomes less expensive from a capital expenditure perspective to cull and replace a given animal. It is expected that the marginal effect of the cull cow price to replacement heifer price ratio to be positively correlated with the likelihood of a cow being culled. As with the milk feed price ratio, by using monthly cull cow price to replacement heifer price ratios, one can determine which lactation months are important in the culling decision process by looking at the magnitude of the marginal effect and the significance of the parameter. It was hypothesized that the cull cow to replacement heifer price ratio is positively correlated with the likelihood of a cull.

Trend Variable

As the data consists of individual, herd and price information from 1995 – 1999, dummy variables were established for each year. These annual variables will indicate whether there was a particular trend in culling rates or whether any particular year was associated with an increase (decrease) in culling rates. 1995 was chosen to be the default year for the estimation when the 1996 thorough 1999 dummy variables were set to zero. It is expected that the effect of 1996, 1997, 1998, and 1999 differs from 1995.

Fixed Effects Variables

The data included multiple observations from individual farms. In order to keep the previous independent variables from capturing effects caused from farm characteristic

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characteristics not included in the model, a fixed effect dummy variable was included for each farm observation. The correlation of the fixed effects variable could not be hypothesized.

III. Estimation Results

The Midwestern Estimation

The previously described probit dairy cattle culling model was estimated for dairy cattle from Midwestern DHIA dairy farms in Illinois, Indiana, Iowa Michigan, and Wisconsin. The overall model results are summarized in Table 2. There were 432,444 observations in which 160,135 culling events and 272,309 nonevents occurred. The estimation had to drop 2,797,017 observations due to missing information regarding the independent or dependent variables.

Table 17. Overall Results for the Probit Model Estimation of the Likelihood that a Cow Will Be Culled on Midwestern Dairy Farms

Observations	432,444
R-Square	0.3196
Likelihood Ratio Test Chi-Square	166,508 (p-value <0.0001)
Wald Test Chi-Square	107,853 (p-value <0.0001)
Degrees of Freedom	3,583
Number of Correct Culling Events Predicted	78,430
Number of Correct Culling Non-events Predicted	257,468
Percentage Correct	80.40

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The estimation had a R-square of 0.5462. When testing the global null hypothesis that all $\beta_n = 0$, the likelihood ratio chi-square score was 166,508 (p-value < 0.0001) with 3,583 degrees of freedom. Using a probability level of 0.60 as a threshold value to distinguish a culling event from a nonevent, the model was able to successfully classify 80.4 percent of the Midwestern culling events and nonevents.

Table 18 displays the coefficient estimate results for the culling probability model. In order to calculate the marginal effects of the independent variables on the probability of a cull, the model was designed to provide a culling probability for a baseline situation. The baseline situation for the Midwestern estimation consisted of a first lactation Holstein cow calving on a particular farm in Indiana in the Spring of 1995 with the sample average milk production capability, milk quality, reproductive efficiency and genetics. The farm this representative cow came from was equal in size to the sample average herd size of 193 cows and had not undergone an expansion prior to or during the 1995 – 1999 time period. The representative farm had a current year heifer ratio that was equal to the sample average of 0.4974. For the baseline situation, there was a 2.58 percent chance that a first lactation, average producing Holstein cow would be culled during or at the termination of the first lactation on a particular farm in Indiana.

Calving season variables did play a significant role in contributing to the likelihood of a cow being culled. As compared to the Spring calving season (March, April, and May), calving in Winter (December, January, and February) increased the probability of a cull by 0.23 percent (p-value = 0.0008). Calving in Summer decreased

Table 18. C
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Parameter	I
Intercept	
Winter Calving	
Summer Calving	
Fall Calving	
Lactation 2	
Lactation 3	
Lactation 4	
Lactation 5	
Lactation 6	
Lactation 7	
Lactation 8	
Lactation 9	
Lactation 10	
305 ME Milk Difference	-(
305 ME Fat Difference	0
305 ME Protein Difference	-(
Persistency Percent	-(
Somatic Cell Count Score Difference	0
Previous Services Per Conception Differences	0
PTA Milk	0
PTA Fat	0
PTA Protein	1
Guernsey	0
Jersey	-0

Table 18. **Coefficient Estimate Results for the Probit Model Estimation of the Likelihood that a Cow Will Be Culled on Midwestern Dairy Farms**

Parameter	Estimate	Standard Error	Wald Chi-Square	Test [1]	p-value[2]	Marginal Effect (%)
Intercept	7.5011	0.2805	714.9159	2	<0.0001	
Winter Calving	0.0374	0.0112	11.1331	2	0.0008	0.2330
Summer Calving	-0.1903	0.0103	338.8005	2	<0.0001	-0.9500
Fall Calving	-0.2666	0.0124	461.6945	2	<0.0001	-1.2360
Lactation 2	0.4513	0.0063	5115.0913	2	<0.0001	4.1660
Lactation 3	0.5983	0.0070	7281.9900	2	<0.0001	6.3040
Lactation 4	0.7222	0.0082	7721.3005	2	<0.0001	8.4670
Lactation 5	0.8362	0.0102	6658.8324	2	<0.0001	10.7680
Lactation 6	0.9337	0.0137	4669.8139	2	<0.0001	12.9840
Lactation 7	1.0837	0.0195	3092.2544	2	<0.0001	16.8390
Lactation 8	1.1594	0.0294	1553.7702	2	<0.0001	18.9890
Lactation 9	1.3292	0.0459	838.6036	2	<0.0001	24.2820
Lactation 10	1.5560	0.0632	606.3097	2	<0.0001	32.2400
305 ME Milk Difference	-0.0054	0.0002	754.5362	1	<0.0001	-0.0330
305 ME Fat Difference	0.0003	0.00003	123.7454	1	NS	0.0020
305 ME Protein Difference	-0.0023	0.00007	101.5806	1	<0.0001	-0.0140
Persistency Percent	-0.0147	0.00007	39346.7812	1	<0.0001	-0.0870
Somatic Cell Count Score Difference	0.0662	0.0015	2036.7475	1	<0.0001	0.4230
Previous Services Per Conception Differences	0.0341	0.0016	430.0578	1	<0.0001	0.2110
PTA Milk	0.0015	0.0001	235.7387	1	NS	0.0090
PTA Fat	0.0281	0.0182	2.3685	1	NS	0.1730
PTA Protein	1.2520	0.0381	1080.7722	1	NS	21.7960
Guernsey	0.1122	0.0641	3.0606	2	0.0802	0.7510
Jersey	-0.1743	0.0382	20.8626	2	<0.0001	-0.8840

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Small Expansion Year 5	
Large Expansion Year 1	
Large Expansion Year 2	
Large Expansion Year 3	
Large Expansion Year 4	
Large Expansion Year 5	0
Heifer Ratio Year 0	-0
Heifer Ratio Year -1	0

Table 18 (cont'd).

Other Breed	-0.1601	0.0281	32.4168	2	<0.0001	-0.8230
Registered Herd	-0.0406	0.0180	5.0690	2	0.0244	-0.2350
Illinois	-1.3458	0.2301	34.1965	2	<0.0001	-2.5320
Iowa	-0.5514	0.2211	6.2214	2	0.0126	-1.9570
Michigan	-0.0945	0.1854	0.2595	2	0.6105	-0.5180
Wisconsin	-1.4951	0.4134	13.0811	2	0.0003	-2.5530
Herd Size	-0.0002	0.00005	16.3583	2	<0.0001	-0.0010
Small Expansion Year 1	0.0770	0.1006	0.5862	1	NS	0.4980
Small Expansion Year 2	0.1737	0.1020	2.9008	1	0.0443	1.2340
Small Expansion Year 3	0.0668	0.1005	0.4423	1	NS	0.4280
Small Expansion Year 4	0.1011	0.0968	1.0918	1	NS	0.6695
Small Expansion Year 5	-0.0353	0.1012	0.1218	1	NS	-0.2052
Large Expansion Year 1	0.1389	0.1586	0.7671	1	NS	0.9538
Large Expansion Year 2	-0.4044	0.1587	6.4969	1	NS	-1.6448
Large Expansion Year 3	0.3276	0.1526	4.6067	1	0.0159	2.6948
Large Expansion Year 4	-0.0955	0.1667	0.3278	1	NS	-0.5226
Large Expansion Year 5	0.4467	0.1550	8.3032	1	0.0040	4.1054
Heifer Ratio Year 0	-0.0049	0 0202	0.0575	1	NS	-0.0040
Heifer Ratio Year -1	0.0383	0.0138	7.6660	1	0.0028	0.0228

Table 18 (cont'd)

Heifer Ratio Year -2	0.0018	0.0095	0.0365	1	NS	0.0008
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Heifer Ratio Year -3	-0.0158	0.0104	2.3196	1	NS	-0.0097
Heifer Ratio Year -4	-0.0087	0.0109	0.6400	1	NS	-0.0055
MFR 1[3]	-0.0802	0.0125	41.4293	1	<0.0001	-0.4455
MFR 2	-0.1003	0.0130	59.1788	1	<0.0001	-0.5465
MFR 3	-0.0967	0.0125	60.1961	1	<0.0001	-0.5288
MFR 4	-0.0671	0.0124	29.0745	1	<0.0001	-0.3774
MFR 5	-0.0550	0.0123	19.9110	1	<0.0001	-0.3134
MFR 6	-0.2015	0.0112	324.3316	1	<0.0001	-0.9950
MFR 7	0.0271	0.0056	23.2047	1	NS	0.1668
MFR 8	-0.0144	0.0058	6.1236	1	0.0067	-0.0854
MFR 9	0.0132	0.0056	5.4891	1	NS	0.0801
MFR 10	0.0156	0.0061	6.4884	1	NS	0.0947
MFR 11	-0.0170	0.0061	7.8177	1	0.0026	-0.1006
MFR 12	0.0611	0.0059	107.2325	1	NS	0.3892
CRR 1[4]	-0.4706	0.2100	5.0213	1	NS	-0.2702
CRR 2	-1.2174	0.2641	21.2459	1	NS	-0.6496
CRR 3	-3.8868	0.2676	210.9043	1	NS	-1.6044
CRR 4	-2.8063	0.2762	103.2451	1	NS	-1.2840
CRR 5	-1.0736	0.2684	16.0069	1	NS	-0.5810
CRR 6	-3.8928	0.2657	214.6348	1	NS	-1.6060
CRR 7	-1.3217	0.2707	23.8453	1	NS	-0.6981
CRR 8	-0.0006	0.2862	0.0000	1	NS	-0.0007
CRR 9	-1.9446	0.3174	37.5413	1	NS	-0.9668
CRR 10	-1.0584	0.3293	10.3291	1	NS	-0.5735
CRR 11	-0.0243	0.3376	0.0052	1	NS	-0.0148
CRR 12	3.3629	0.2567	171.6191	1	<0.0001	2.7892
Year 1996	-0.2019	0.1180	2.9306	2	0.0869	-1.0007
Year 1997	0.2527	0.0133	361.1484	2	<0.0001	1.9359
Year 1998	-0.0551	0.0114	23.2176	2	<0.0001	-0.3136
Year 1999	-0.0926	0.0110	70.9526	2	<0.0001	-0.5086

[1] A "1" indicates the test was a one-tailed test. A "2" indicates the test was a two-tailed test.

[2] A "NS" indicates that the parameters effect was not significant (p-value $\leq$ 0.1000).

[3] "MFR n" refers to the milk feed price ratio for lactation month n.

[4] "CRR n" refers to the cull cow replacement heifer price ratio for month n.

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the likelihood of a cull by 0.95 percent (p-value < 0.0001). Calving in the fall (September, October, November) decreased the likelihood of a cow being culled by 1.24 percent (p-value = 0.0001). Given these results, if a manager were only interested in culling rate reduction, he or she could prioritize his or her breeding program to have proportionally more cattle calve in Fall followed respectively by Summer, Spring and Winter. Other factors, such as milk and input price seasonal movements should be considered prior to engaging in such calving scheduling. Because proportionally more cattle are culled in Winter and Spring, producers may want to consider synchronizing first lactation cow calvings in order to counterbalance the increased culling likelihood for Winter and Spring calving cattle.

A cow surviving to lactation 2 was 4.17 percent more likely to be culled than in lactation 1 (p-value < 0.0001). Cattle in lactation 3 were 6.30 percent more likely to be culled than first lactation cattle (p-value < 0.0001). Fourth lactation cattle were 8.47 percent more likely to be culled than first lactation cattle (p-value < 0.0001). Cattle in lactations 5 through 10 also exhibited a significant increased likelihood of being culled. Cattle in lactation 5 exhibited a 10.77 percent higher likelihood of being culled than their first lactation counterparts. Cattle in their tenth lactation experienced a 32.24 percent higher likelihood of being culled that first lactation cattle. Thus, as expected, cattle age significantly increased the likelihood of a cow being culled.

The difference in milk production between a cow and its herd mates significantly affected the probability of a cow being culled (p-value < 0.0001). A cow that produces one additional hundredweight more than the average 305 ME Milk yield was 0.033 percent less likely to be culled than the average producing cow. Higher fat production actually increased the likelihood of a cow being culled, but the effect was very small (0.002 percent). Cattle whose average difference in 305 ME Protein were one pound higher than the average producing cow were 0.014 percent less likely to be culled (p-value <0.0001). Cattle that were one persistency unit higher than the average producing cow were 0.087 percent less likely to be culled (p-value < 0.0001).

It is logical that cattle producing more milk and more protein than their herd mates are more profitable, ceteris paribus, and should remain in the herd longer than the less profitable cattle. Butterfat production, even though a principal component in milk price determination, seemed of little importance in culling decisions. In fact, cattle that produced relatively higher butterfat yields were more likely to be culled. This may result from managers trying to emphasize milk and protein production when making their genetic decisions. In the past, dairy farmers primarily got paid on fluid milk, butterfat, and somatic cell count. Managers currently get paid for fluid, butterfat, milk protein, solids-non-fat, and somatic cell count. Thus, managers may now place more emphasis on components other than fat. Nevertheless, butterfat production should be a factor in culling decisions as it is a principal component in the milk price formula.

Milk production persistency within a lactation seemed to be a much more important factor affecting Midwestern dairy culling probabilities than actual milk, butterfat or milk protein production. If managers are keeping more persistent cattle in the herd longer because they are more profitable in late lactation, this might be an erroneous strategy. Choosing the more persistent animal negates the profitability of the earlier part of the lactation curve, which may show that a less persistent cow is more profitable.

Dairy farm managers should consider the expected future profitability of the potential cull candidates instead of basing culling decisions on persistency. On the other hand, if producers are keeping more persistent open cattle around for longer periods of time for breeding purposes, the strategy of retaining more persistent cattle may be warranted. Dijkhuizen, Renkema and Stelwagen (1985) found that this was a profitable strategy.

With regard to herd health parameters, cattle exhibiting a unit higher one somatic cell count score than the average somatic cell count score were 0.423 percent more likely to be culled than the cow represented by the baseline situation. This is not surprising as high somatic cell count scores decreases both the milk price per hundredweight as well as the amount of milk produced per cow. To reduce somatic cell count and mastitis induced culling, methods to reduce somatic cell count score need to be profitably implemented. Such methods may include implementing or improving udder preparation and post milking care, using dry cow treatments at dry off, proper equipment sanitation, and/or proper milking equipment maintenance.

The other herd health parameter, the number of services per conception in the previous lactation, also significantly increased the likelihood of a cull. Cattle that had to be serviced one more time than the average of its herd mates in the previous lactation were 0.211 percent more likely to be culled in the current lactation (p-value < 0.0001). To reduce culling for reproductive failure, producers should consider profitable strategies to reduce reproductive failure. Such strategies may include devoting more time to heat detection activities, training more employees to detect estrus, providing training to improve artificial insemination techniques, or using estrus synchronization techniques.

It was hypothesized that cattle with a higher genetic capability to produce milk, butterfat, and milk protein would stay in the herd longer than those with lower genetic capability. The opposite proved true. Midwestern dairy cattle exhibiting a one unit higher genetic ability to transmit milk, milk fat, and milk protein production traits were 0.009, 0.1730 and 21.796 percent more likely to be culled respectively.

The Cow PTA Milk and Cow PTA Protein results seem to conflict with those of the actual milk and milk protein production. Nevertheless, Kelm (2003) noted that there was a strong positive correlation between Type (how closely the cow appears to meet the breed's ideal structural standard), Cow PTA Milk, and Cow PTA Protein and a strong negative correlation between Type and Longevity. Hansen (2002) also noted a strong negative correlation between type and longevity. These results indicate that placing too much emphasis on milk and milk protein genetics can decrease cow longevity. The positive correlation between the ability to transmit milk fat production and culling probability concurred with the correlation of actual milk fat yield and culling probability. The fact that cattle with a higher ability to transmit milk fat production is positively correlated with culling likelihood may indicate that dairy farm managers are de-emphasizing fat production. Whether this is the correct decision from an economic perspective should be assessed as fat production is still a major component of milk price determination.

Cattle breed did seem to influence the culling probability of Midwestern dairy cattle. If a cow was a Guernsey, it was 0.751 percent more likely to be culled than a Holstein. Jersey cattle were 0.884 percent less likely to be culled than a Holstein (p-value < 0.0001). Dairy cattle breeds other than Guernsey, Jersey and Holstein were 0.823

percent less likely to be culled than Midwestern Holstein cattle (p-value < 0.0001). If researchers and dairy farm managers desire to improve the culling likelihood of Holstein and Guernsey cattle, there appears to be justification to compare and contrast their longevity characteristics with those of the Jersey and the "other" dairy breeds.

Whether a cow was from a registered herd did affect the probability of a cull. Cattle from registered herds were 0.235 percent less likely to be culled for reasons other than being sold for dairy purposes (p-value < 0.0001). As dairies with registered cattle are typically involved in the sale of cattle for dairy and genetics purposes, maintaining the health of these cattle is very important. An animal that is a below average producer, lame, or mastitic is not very desirable to a cattle buyer. As such, Midwestern managers of registered cattle may give more individualized attention to their registered cattle than commercial dairy managers.

The average first lactation cow in Illinois, Iowa and Wisconsin were less likely to be culled than similar cattle in Indiana. Illinois first lactation Holstein cattle were 2.532 percent less likely to be culled than their Indiana counterparts (p-value < 0.0001). Iowa first lactation cattle were 1.957 percent less likely to be culled (p-value = 0.0126). Wisconsin cattle were 2.552 percent less likely to be culled than Indiana cattle (p-value = 0.0003).

The effect of herd size on the likelihood of a cow being culled were significant but small. A one cow increase in herd size from the average resulted in a 0.001 percent decrease in the likelihood of a cull (p-value = 0.0001). This means that for every 100 cow increase in herd size, the cattle on that farm were 0.10 percent more likely to be culled. This may be caused by a variety of factors. Managers of smaller farms generally have to be a jack-of-all trades. Although they may give more individualized attention to each cow in their herd, the manager of a smaller herd may be too constrained by other activities, such as crop planting and harvesting, to give more individualized attention. The negative correlation may also indicate that larger farms have an advantage in attracting more specialized labor. Thus, being of a certain herd size may permit a farm to hire better herd managers, on-staff veterinarians, and laborers. The negative correlation between herd size and culling rates may also indicate that managers tend to increase their farm's herd size as their management ability improves.

The effect of expanding to a larger herd size on the likelihood of a cull were mixed, however. For the smaller category of expansions (an increase in herd size of less than or equal to 300 percent), the effect of the initial expansion year on the probability of a cull was positive but insignificant. Cattle in the second expansion year were 1.234 percent more likely to be culled (p-value = 0.0885). The likelihood of a cull increased in the third and fourth years, but the results were statistically insignificant. The correlation between the fifth year of a small expansion and the likelihood of a cull was negative but also statistically insignificant.

For herds that had a large increase in herd size (a herd size increase of more than 300 percent), the first large expansion year was positively correlated with culling likelihood but insignificant. During the second year of a large expansion, the culling rate actually decreased by 1.645 percent (p-value = 0.0885). The probability of a cow being culled in the third major expansion year increased by 2.695 percent (p-value = 0.0318). The effect of the fourth major expansion year was negative but insignificant. The likelihood of a cull increased by 4.105 percent (p-value = 0.004) during the fifth expansion year.

There seems to be little statistical support suggesting that expansion of Midwestern DHIA dairy farms increased their overall culling rates. However, it is likely that managers, lenders and advisors involved in expansion will see increased culling rates in year 2 of a small expansion and years 3 and 5 of a large expansion and should budget their expansions accordingly.

For Midwestern DHIA herds, the effect of the current year heifer ratio on the likelihood of a cow being culled was negative and insignificant. However, the effect of the prior year's heifer ratio on culling likelihood was positive but small (0.0228 percent). The effect of the remaining heifer ratios on culling probability were insignificant. Thus, there is little evidence suggesting that the number of heifers available influences culling rates, and, when there is such evidence, the effect on culling probability is small. Producers may sell some of the additional heifers and/or some of these heifers are lost due to health problems prior to entering the milking herd.

The effects of the relative price of milk to feed on the probability that a Midwestern dairy cow will be culled were mixed but mostly negative as hypothesized. The marginal effect of a one unit increase in the price of milk relative to feed prices for months one through six were negatively correlated with culling rates (p-value < 0.0001). The milk to feed price ratio for lactation months 8 and 11 were also negative and statistically significant. The decreases in the likelihood of a cull for the significant lactation months ranged from 0.085 percent to 0.995 percent. This shows that producers are milk and variable input price responsive when making their culling decisions for 8 of the 12 lactation months analyzed. However, these results conflict with those of earlier researchers who indicated that the effect of milk and variable input prices on optimal culling rates should be, at the most, small. While the results of this study may be influenced by cattle that are culled without replacement (in the case of a herd size contraction or dispersal), it could also indicate that producers erroneously adjust culling rates to the price of milk and variable inputs. Producer education programs may be warranted to correct these erroneous decisions.

All of the cull cow price to the replacement heifer price ratio marginal effects were surprisingly negative except for the ratio of lactation month twelve and beyond (CRR 12). In lactation month twelve, a one tenth increase in the cull cow to replacement heifer price ratio increased the likelihood that a cow would be culled by 2.789 percent. The fact that this lactation month ratio is positively correlated with culling probability makes intuitive sense. Cattle that have been lactating for twelve months or more are generally cattle who are less fertile than their herd mates. As the price of cull cattle goes up relative to the price of replacement dairy heifers, it becomes less expensive from a capital expenditure perspective to replace the animal. It is interesting, however, that the cull cow price to replacement heifer price ratio for the other lactation months with critical decision point potential (calving, peak milk production, first and second services, and mid-lactation) were insignificant.

With the exception of 1997, the likelihood of a Midwestern dairy cow being culled during the period of 1996 through 1999 was lower than the likelihood of being culled in 1995. Cattle milking in 1996 were 1.001 percent less likely to be culled than cattle milking in 1995 (p-value = 0.0869). In 1997 the likelihood of a cow being culled increased by 1.936 percent. In 1998 and 1999 the likelihood of a cow being culled on Midwestern dairy farms as compared to 1995 decreased by 0.314 and 0.509 percent respectively. Thus, there is little evidence suggesting that there is a trend of increasing culling rates for years 1995 through 1999.

The Northeastern Estimation

The probit dairy cattle culling model was estimated for dairy cattle from Northeastern DHIA dairy farms in Maine, New Hampshire, New York, Pennsylvania, and Vermont. The overall model results are summarized in Table 19. There were 225,987 culling events and 106,339 culling nonevents that took place in the 332,326 observations. The estimation had to drop 3,525,912 observations due to missing information regarding the independent or dependent variables.

The estimation had a R-square of 0.4879. When testing the global null hypothesis that all $\beta_n = 0$, the likelihood ratio chi-square score was 222,393 (p-value < 0.0001) with 3,933 degrees of freedom. Using a probability level of 0.60 as a threshold value to

Table 19. Overall Results for the Probit Model Estimation of the Likelihood that a Cow Will Be Culled on Northeastern Dairy Farms

Observations	332,326
R-Square	0.4879
Likelihood Ratio Test Chi-Square	222,393.588
Wald Test Chi-Square	103,962.630
Degrees of Freedom	3,933
Number of Correct Culling Events Predicted	198,982
Number of Correct Culling Non-events Predicted	91,636
Percentage Correct	86.7

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distinguish a culling event from a culling nonevent, the model was able to successfully classify 86.7 percent of the culling events and nonevents.

Table 20 displays the coefficient estimate results for the culling probability model using the data from Northeastern herds. The baseline situation for the Northeastern estimation consisted of a first lactation Holstein cow calving on a particular farm in Vermont in the Spring of 1995 with the sample average milk production capability, milk quality, reproductive efficiency and genetics. The farm this representative cow came from was equal in size to the sample average herd size of 200 cows and had not undergone an expansion prior to or during the 1995 – 1999 time period. The representative farm had a current year heifer ratio that was equal to the sample average of 0.4830. For the baseline situation, there was an 18.08 percent chance that a first lactation, average producing Holstein cow would be culled during or at the termination of the first lactation on a particular farm in Vermont.

Calving season variables did play a significant role in contributing to the likelihood of a cow being culled. As compared to the Spring calving season (March, April, and May), calving in Winter (December, January, and February) increased the probability of a cull by 12.608 percent (p-value < 0.0001). Calving in Summer decreased the likelihood of a cull by 0.768 percent but was statistically insignificant (p-value = 0.1369). Calving in the fall (September, October, November) increased the likelihood of a cow being culled by 1.131 percent (p-value = 0.0805). Thus, there were apparent differences between the Midwestern and Northeastern regions as to how calving season effects the likelihood of cow being culled. In the Midwestern region estimation, cattle that calved in the Fall were less likely to be culled than those that calved in Spring. As

Table 20.

Parameter	
Intercept	
Winter Calving	
Summer Calving	
Fall Calving	
Lactation 2	
Lactation 3	
Lactation 4	
Lactation 5	
Lactation 6	
Lactation 7	
Lactation 8	
Lactation 9	
Lactation 10	
305 ME Milk Difference	-
305 ME Fat Difference	0
305 ME Protein Difference	-0
Persistency Percent	-0
Somatic Cell Count Score Difference	0
Previous Services Per Conception Differences	0
PTA Milk	0
PTA Fat	-0
PTA Protein	-0
Guernsey	0
Jersey	-0

Table 20. Coefficient Estimate Results for the Probit Model Estimation of the Likelihood that a Cow Will Be Culled on Northeastern Dairy Farms

Parameter	Estimate	Standard Error	Wald Chi-Square	Test [1]	p-value [2]	Marginal Effect (%)
Intercept	1.4084	0.4862	8.3910	2	0.0038	
Winter Calving	0.4076	0.0207	387.5490	2	<0.0001	12.6080
Summer Calving	-0.0296	0.0199	2.2120	2	0.1369	-0.7680
Fall Calving	0.0422	0.0241	3.0557	2	0.0805	1.1310
Lactation 2	0.4461	0.0092	2337.3264	2	<0.0001	13.9750
Lactation 3	0.6102	0.0101	3662.1091	2	<0.0001	20.0500
Lactation 4	0.7028	0.0115	3705.7337	2	<0.0001	23.6240
Lactation 5	0.8139	0.0139	3443.7830	2	<0.0001	28.0010
Lactation 6	0.9010	0.0178	2570.1815	2	<0.0001	31.4700
Lactation 7	0.9307	0.0241	1487.7339	2	<0.0001	32.6530
Lactation 8	1.0019	0.0360	773.9011	2	<0.0001	35.4910
Lactation 9	1.1254	0.0535	442.3278	2	<0.0001	40.3580
Lactation 10	1.2021	0.0636	357.8267	2	<0.0001	43.3230
305 ME Milk Difference	-0.0057	0.0002	535.9905	1	<0.0001	-0.1480
305 ME Fat Difference	0.00003	0.00004	0.3617	1	NS	0.0010
305 ME Protein Difference	-0.0008	0.00009	83.0444	1	<0.0001	-0.0210
Persistency Percent	-0.0092	0.00009	10089.4595	1	<0.0001	-0.2400
Somatic Cell Count Score Difference	0.0588	0.0020	907.6232	1	<0.0001	1.5900
Previous Services Per Conception Differences	0.0222	0.0022	103.8017	1	<0.0001	0.6810
PTA Milk	0.0008	0.0001	38.7815	1	NS	0.0220
PTA Fat	-0.0684	0.0274	6.2550	1	0.0062	-1.7430
PTA Protein	-0.0601	0.0531	1.2799	1	NS	-1.5380
Guernsey	0.4202	0.1017	17.0586	2	<0.0001	13.0530
Jersey	-0.1731	0.0416	17.3391	2	<0.0001	-4.1930

Table 20 (cont

Other Breed	
Registered Herd	
Maine	
New Hampshire	
New York	
Pennsylvania	
Herd Size	
Expansion Year 1	
Expansion Year 2	
Expansion Year 3	
Expansion Year 4	
Expansion Year 5	
Large Expansion Year 1	
Large Expansion Year 2	
Large Expansion Year 3	-
Large Expansion Year 4	-
Large Expansion Year 5	(
Heifer Ratio Year 0	-(
Heifer Ratio Year -1	-(
Heifer Ratio Year -2	(
Heifer Ratio Year -3	-0

Table 20 (cont'd).

Other Breed	-0.2878	0.0458	39.5731	2	<0.0001	-6.5750
Registered Herd	0.1138	0.0421	7.3115	2	0.0069	3.1490
Maine	0.7255	0.8444	0.7381	2	NS	24.5110
New Hampshire	-0.4707	0.4346	1.1727	2	NS	-9.7470
New York	-0.6989	0.4968	1.9793	2	NS	-12.7230
Pennsylvania	-1.2666	0.4294	8.7016	2	0.0032	-16.6130
Herd Size	0.0009	0.00004	690.8677	2	<0.0001	0.0250
Expansion Year 1	0.4124	0.2028	4.1352	1	0.0210	12.7760
Expansion Year 2	-0.3461	0.1981	3.0526	1	NS	-7.6680
Expansion Year 3	0.2014	0.1959	1.0565	1	NS	-0.8611
Expansion Year 4	0.1438	0.1791	0.6448	1	NS	5.7770
Expansion Year 5	0.1752	0.1977	0.7851	1	NS	4.0300
Large Expansion Year 1	0.0332	0.2079	0.0256	1	NS	4.9730
Large Expansion Year 2	0.0096	0.2076	0.0022	1	NS	0.2550
Large Expansion Year 3	-0.0332	0.2126	0.0244	1	NS	-0.8610
Large Expansion Year 4	-0.0588	0.2320	0.0642	1	NS	-1.5050
Large Expansion Year 5	0.3730	0.2141	3.0346	1	0.0408	11.4030
Heifer Ratio Year 0	-0.0050	0.0229	0.0470	1	NS	-0.0130
Heifer Ratio Year -1	-0.0543	0.0171	10.0431	1	NS	-0.1420
Heifer Ratio Year -2	0.0757	0.0127	35.6629	1	<0.0001	0.2000
Heifer Ratio Year -3	-0.0094	0.0058	2.6397	1	NS	-0.0250

Table 20 (cont'd)

Heifer Ratio Year -4	0.00169	0.0118	0.0205	1	NS	0.0050
MFR 1[3]	0.1958	0.0196	99.7975	1	NS	5.6050
MFR 2	-0.3196	0.0271	138.7345	1	<0.0001	-7.1810
MFR 3	-0.0451	0.0271	2.7664	1	0.0482	-1.1610
MFR 4	-0.0146	0.0297	0.2403	1	NS	-0.3810
MFR 5	-0.2648	0.0302	77.0879	1	<0.0001	-6.1220
MFR 6	-0.2407	0.0305	62.4280	1	<0.0001	-5.6340
MFR 7	0.0215	0.0322	0.4446	1	NS	0.5710
MFR 8	-0.0965	0.0273	12.4946	1	0.0002	-2.4270
MFR 9	-0.0816	0.0286	8.1320	1	0.0022	-2.0660
MFR 10	-0.3152	0.0275	131.5070	1	<0.0001	-7.0980
MFR 11	0.1936	0.0286	45.9638	1	NS	5.5360
MFR 12	0.0654	0.0245	7.1126	1	NS	1.7730
CRR 1[4]	2.8787	0.4749	36.7377	1	<0.0001	8.5370
CRR 2	-5.1431	0.6240	67.9257	1	NS	-10.3960
CRR 3	2.9584	0.6123	23.3413	1	<0.0001	8.7990
CRR 4	1.3797	0.5849	5.5635	1	0.0092	3.8570
CRR 5	-0.8484	0.5957	2.0282	1	NS	-2.1450
CRR 6	2.3845	0.5598	18.1418	1	<0.0001	6.9400
CRR 7	-6.3887	0.5028	161.4687	1	NS	-12.0370
CRR 8	-1.6454	0.4960	11.0054	1	NS	-4.0030
CRR 9	-2.0191	0.4699	18.4675	1	NS	-4.8210
CRR 10	-1.4617	0.5223	7.8334	1	NS	-3.5880
CRR 11	2.8043	0.5714	24.8044	1	<0.0001	8.2930
CRR 12	9.7353	0.4382	493.5659	1	<0.0001	34.3610
Year 1996	1.5403	0.0316	2381.9073	2	<0.0001	55.4210
Year 1997	1.4389	0.0306	2215.2520	2	<0.0001	51.9960
Year 1998	2.0315	0.0234	7519.0573	2	<0.0001	68.7670
Year 1999	1.0711	0.0164	4261.7793	2	<0.0001	38.2270

[1] A "1" indicates the test was a one-tailed test. A "2" indicates the test was a two-tailed test.
[2] A "NS" indicates that the parameters effect was not significant (p-value ≤ 0.1000).
[3] "MFR n" refers to the milk feed price ratio for lactation month n.
[4] "CRR n" refers to the cull cow replacement heifer price ratio for month n.

the marginal effects refer to a specific situation, the differences in calving season effects may be caused by the climate differences between Vermont and Indiana or the differences in facility technology between Vermont and Indiana farms.

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A cow surviving to lactation 2 was 13.975 percent more likely to be culled than in lactation 1 (p-value < 0.0001). Cattle in lactation 3 were 20.050 percent more likely to be culled than first lactation cattle (p-value < 0.0001). Cattle in lactations 4 through 10 also exhibited a significant increased likelihood of being culled. Cattle in lactation 4 exhibited a 23.624 percent higher likelihood of being culled than their first lactation counterparts. Cattle in their tenth lactation experienced a 43.323 percent higher likelihood of being culled that first lactation cattle. Cattle age significantly increased the likelihood of a cow being culled as expected. The Northeastern cow age parameter marginal effects were larger than those of the Midwestern estimation. The discrepancy may be explained by how the baseline situations were described using specific farms in specific states.

The difference in milk production between a Northeastern cow and its herd mate significantly affected the probability of a cow being culled (p-value < 0.0001). A cow that produced one additional hundredweight more than the average 305 ME Milk yield was 0.148 percent less likely to be culled than the average producing cow. Higher fat production actually increased the likelihood of a cow being culled but the effect was very small (0.001 percent). Cattle whose average difference in 305 ME Protein were one pound higher than the average producing cow were 0.021 percent less likely to be culled (p-value <0.0001). Cattle that were one persistency unit higher than the average producing cow were 0.240 percent less likely to be culled (p-value < 0.0001). The direction of these marginal effects concur with those of the Midwestern estimation. As such, Northeastern managers may also need educational programs that are designed to inform them of the economic importance of milk fat production and the importance of looking at the e

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looking at the entire lactation as opposed to how persistent the cow's production is at the end of the lactation.

Like the Midwestern estimation, cattle that had higher somatic cell count scores were more likely to be culled. Northeastern cattle that exhibited a one unit higher somatic cell count score than the average somatic cell count score were 1.590 percent more likely to be culled than the cow represented by the baseline situation. The other herd health parameter, the number of services per conception in the previous lactation, also significantly increased the likelihood of a cull. Cattle that had to be serviced one more time than the average of its herd mates in the previous lactation were 0.681 percent more likely to be culled in the current lactation (p-value < 0.0001). To reduce culling for reproductive failure, producers should consider profitable strategies to lower somatic cell count scores and reduce the incidence of reproductive failure.

Northeastern cattle that exhibited a one unit higher ability to transmit traits that promote milk production were 0.022 percent more likely to be culled than the average cow. Cows that had a PTA Fat that was one unit higher were 1.743 percent less likely to be culled (p-value = 0.0124). Cattle that had a higher ability to transmit milk protein traits were less likely to be culled but the results were insignificant. As was the case with the Midwestern estimation, cattle that are bred to transmit more milk production traits are more likely to be culled. Producers may want to determine if the financial rewards associated with high Cow PTA Milk values are worth the financial costs associated with culling.

Northeastern Guernsey cattle were 13.053 percent more likely to be culled than Holstein cattle (p-value < 0.0001). Jersey and "Other" dairy cattle breeds were 4.193 and

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6.575 percent less likely to be culled than Holsteins respectively (p-value < 0.0001). Once again, breeders of Guernsey and Holstein cattle may want to compare and contrast the longevity traits associated with Jersey and the "other" dairy cattle breeds in order to determine if profitable improvements can be made in the breeds to increase longevity.

Unlike Midwestern cattle, cattle from registered dairy farms were more likely to be culled. Northeastern dairy cattle were 3.149 percent more likely to be culled than Northeastern cattle on commercial dairies (p-value = 0.0069). Determining why this difference between registered dairy farms in the two regions exist is beyond the scope of this research; however, it would be an interesting to determine why these differences exist in order to see if improvements are warranted in either region.

Also unlike Midwestern farms, cattle from larger Northeastern farms were more likely to be culled. For every cow over the sample average herd size of 200 cows, the probability of a cow being culled increased by 0.025 percent (p-value < 0.0001). This may indicate that the resource endowments of Northeastern farms favor offering more individualized cow care than on the more diversified Midwestern dairy farms.

Cattle in the first year of a small expansion (a herd size increase greater than 20 percent but less than 300 percent) in the Northeastern region were 12 .776 percent more likely to be culled (p-value = 0.0420). Cattle in Northeastern herds one year after a small expansion were 7.668 percent less likely to be culled (p-value = 0.0806). The marginal effects of small expansion years 3 – 5 were insignificant. Extension programs concerning expansion management may be needed to help Northeastern dairy farm managers to lower the likelihood of a cull during the first expansion year.

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The marginal effects of the large expansion parameters were insignificant except for large expansion year 5. In that year, there was an 11.403 percent increase in the likelihood of a cow being culled. This may indicate that dairy farm managers in the Northeast who expand their herds by more than 300 percent try to maintain cattle in the herd longer than farm managers who did not expand or expanded by a smaller increment.

The effect of the heifer ratio on the likelihood of a Northeastern cow being culled were mixed. The marginal effect of a one tenth increase in the current (Heifer Ratio Year 0) was insignificant. Nevertheless, a one tenth increase in the previous year's heifer ratio (Heifer Ratio Year -1) caused a 0.142 percent decrease in the likelihood that a Northeastern cow will be culled in the current year. A one tenth increase in the Heifer Ratio Year -2 caused a 0.200 percent increase in the culling rate of the current year. Both the Heifer Ratio Year -3 and -4 parameter estimates were insignificant. Overall, the two most recent lagged heifer variables had a significant impact on culling likelihood. Nevertheless, the marginal effects were small. Thus, producers do not totally adjust their culling rates to totally accommodate higher replacement heifer inventories.

There were mixed effects concerning the milk to feed price ratio parameters. From an overall perspective, however, the results were similar to those of the Midwestern estimation as most of the marginal effects of the parameter estimates were negatively correlated with the likelihood of a cow being culled. Although this was hypothesized, this indicates a possible need for producer education as past researchers have determined that milk and variable input prices should not influence culling decisions.

The first lactation month's cull cow price to replacement dairy heifer price ratio was significant. A one-tenth increase in this ratio caused the likelihood of a cow being culled to incre

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culled to increase by 8.537 percent (p-value < 0.0001). The cull cow price to replacement dairy heifer price ratio for lactation months 3 and 4 were also significant and positive with a one-tenth increase causing a respective 8.799 (p-value < 0.0001)and 3.857 (p-value = 0.0183) percent increase in the probability of a cow being culled. The cull cow price to replacement heifer price ratio was also significant for lactation month 6 with a one-tenth increase generating 6.94 percent increase in the likelihood that a cow will be culled (p-value < 0.0001) The cull cow price to replacement dairy heifer price ratio was also significant for lactation months 11 and 12. A one-tenth increase in the ratio would cause the probability of a cow being culled to increase by 8.293 percent in month 11 (p-value < 0.0001) and 34.361 percent in lactation month 12 (p-value < 0.0001). Northeastern dairy farm managers seem to be more cull cow and replacement dairy heifer price responsive with regard to culling decisions as compared to Midwestern dairy farm managers. The significant cull cow price to replacement heifer price ratios for the Northeastern dairy cattle coincide with those associated with calving, peak milk production, initial artificial insemination service, initial pregnancy examination. the lactation midpoint, and the lactations end. All of these periods are conducive for a manager to decide whether to cull a cow, and it makes economic sense that an increase in the cull cow price to replacement heifer price ratio would increase the likelihood of a cull during these lactation months. With Midwestern farmers, only the parameter for lactation month 12 and beyond was significant.

Unlike the Midwest, dairy cattle were more likely to be culled from 1996 through 1999. In 1996, a dairy cow was 55.421 percent more likely to be culled than in 1995. In 1997, Northeastern dairy cattle were 51.996 percent more likely to be culled than in

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1995. The likelihood increased by 68.767 percent in 1998 prior to decreasing to a 38.227 increased culling likelihood in 1999.

IV. Summary and Conclusions

A probit model was developed to determine how individual cow and herd level characteristics affect the likelihood of a cull of Midwestern and Northeastern dairy cattle. This model was able to predict culling events and nonevents in the Midwest and Northeast at an 80.4 and 86.7 percent accuracy rate respectively.

Both Midwestern and Northeastern cattle that calved during winter were more likely to be culled than cattle that calved in Spring. For Midwestern dairy farms, cattle that calved in Summer and Fall were less likely to be culled than cattle that calved in Spring. In the Northeast, fall calving cattle were more likely to be culled than spring calving cattle. Midwestern dairy farm managers may want to consider scheduling their heifer calvings to accommodate the increased likelihood that more Spring and Winter calving animals will have to be culled. Northeastern dairy farm managers may want to schedule their heifer calvings to counterbalance the increased culling probability associated with calving in Fall and Winter.

Both Midwestern and Northeastern cattle experienced an increased culling probability as they aged. Nevertheless, the increase in culling probability for each lactation differed in the two regions. These results may be influenced by how the marginal effects were calculated using a baseline situation referencing specific farms in specific states.

Differences in fluid milk and milk protein production were negatively correlated with culling likelihood in both the Midwestern and Northeastern estimations. The difference in r

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difference in milk fat production were insignificant in each region. Dairy farm managers in both regions may be erroneously ignoring the economic returns associated with a cow's fat yield when making culling decisions. Cow persistency had a greater effect on culling probability than actual fluid or milk component yield in both regions. This may indicate that managers may improperly make culling decisions based on immediate short term financial concerns instead of future expected profits. If this is true, it is possible that more profitable but less persistent cattle are being culled.

Differences in the somatic cell count score and previous lactation services per conception were positively correlated with the probability of a cull in both regions. Dairy farmers may want to incorporate programs, such as better dry cow treatments or estrus synchronization, to reduce the somatic cell count score and services per conception variance between cows.

In the Midwest and Northeastern regions, PTA Milk was positively correlated with culling likelihood. In the Midwest, the likelihood of a cull increased with PTA Protein. While this seemingly disagrees with the marginal effects of actual milk and milk protein production, these results are similar to genetic research on the correlations between type, PTA Milk, PTA Protein, and longevity.

Midwestern and Northeastern Guernsey cattle were more likely to be culled than Holstein cattle. Midwestern and Northeastern Jersey cattle and the "Other" dairy cattle breeds were less likely to be culled. If increased longevity is financially important for Holstein and Guernsey breeders, they may want to consider comparing and contrasting the traits of Holstein and Guernsey cattle with those of the Jersey and "Other" dairy cattle breeds.

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There were mixed results concerning the marginal effect of a cow being from a registered herd on the likelihood of it being culled. Cattle from Midwestern registered herds were less likely to be culled. Cattle from Northeastern registered herds were more likely to be culled.

The effect of herd size on culling probability were mixed. Size was negatively correlated with the likelihood of a cull in the Midwest but positively correlated in the Northeast. This may indicate that larger Midwestern farms may be able to procure more specialized labor, whereas the resource availability in the Northeast allows smaller farms the ability to offer better individualized care. One could not conclude conclusively that expansion caused increased culling rates except in select expansion years. It did appear, however, that managers who engaged in a large expansion in the Northeast retained cattle longer.

The availability of replacement heifers relative to the number of cattle in the milking herd a year prior to the observation year slightly increased the probability of a cull. This indicates that producers do not totally adjust their culling rate to accommodate all of the available replacement heifers. Instead, producers must either sell most of their surplus heifers to other farmers, or the surplus animals are culled due to health reasons prior to entering the milking herd.

The milk feed price ratio parameters were mostly negatively correlated with culling likelihood. Educational programming on culling cattle may be warranted as prior research clearly indicates that milk and variable input prices should not effect culling rates. As the milk price and variable production costs are equal for both, the milk feed price ratio should have little effect on culling rates.

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Midwestern dairy producers were not price responsive with regard to the price of cull cows relative to the price of replacement heifers except in the last lactation month parameter. Northeastern dairy managers were more price responsive. Significant cull cow price to replacement dairy heifer price ratio parameters coincided the calving month, peak milk production, critical breeding dates and dry off, all of which are reasonable months to contemplate a culling decision.

In the Midwest, the effect of observation year and culling likelihood were mixed. Midwestern cattle in 1996, 1998 and 1999 were less likely to be culled than in 1995. However, in the Northeast, cattle were more likely to be culled in 1996 through 1999 as opposed to 1995.

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CHAPTER 4.

MODELS TO DETERMINE THE EFFECTS OF SELECT MANAGEMENT FACTORS ON DAIRY CATTLE HEALTH CULLING RATES

I. Introduction

As most cattle are culled due to health problems, one method to reduce culling rates is to adopt management strategies to prevent or treat the underlying health problems. In order to do this, one must understand how management programs contribute to the proportion of cattle culled for health. Four ordinary least squares models were developed and estimated to determine the effect that management programs – such as estrus synchronization, BST, soft textured walking surfaces, and employing on-staff veterinarians – have on udder and mastitis, lameness and injuries, disease, and reproduction health culls.

II. Data

Data for this study were collected from the USDA National Animal Health Monitoring Service's (NAHMS) Dairy '96 Survey. This survey involved interviewing farmers in major dairy producing states about farm descriptive statistics, farm performance, technology adoption, management programs implemented, and the incidence of herd health problems as of January 1, 1996. The survey was conducted using a stratified random sample design. The stratified random sample was designed to be representative of the entire U.S. dairy farm industry except those milking less than 30 cows.

One important variable for this research, the number of days a dairy employed an on-staff veterinarian, had only 57 entries. In order to avoid having a very limited sample size, it wa

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size, it was assumed that a missing entry meant that the farm did not employ an on-staff veterinarian and a value of zero days was assigned to those observations.

III. Methods and Model Development

Four ordinary least squares models were developed to determine the effect that management factors had on culling rates due to specific health issues: the udder and mastitis culling rate, the lameness and injury culling rate, the disease culling rate, and the reproduction culling rate. These models are describe in the following subsections.

The Udder and Mastitis Culling Rate Model

The first model determines the effect of select management controlled factors on the udder and mastitis culling rate. Udder and mastitis problems are costly. Wells, Ott, and Heillberg Seitzinger (1998) estimated that the aggregate producer cost of mastitis was between 1.5 and 2 billion dollars per year. The aggregate producer costs associated with subclinical mastitis were estimated to be 960 million dollars per year. Miller et al. (1993) found that Ohio producers spent $14.50 per cow per year for mastitis prevention programs and $37.91 per cow per year for costs associated with clinical mastitis cases. Mastitis and subclinical mastitis may also have other indirect costs through its association with other herd health problems. Scrick et al. (2001) linked mastitis to reproductive efficiency problems such as increased days to first service, increased days open, and increased services per conception. When ranking

herd health problems on the basis of production loss, zoonotic potential, international trade and animal welfare issues – mastitis was determined to be the most important herd health issue facing the U.S. dairy industry (Wells, Ott, Hillberg Seitzinger, 1998).

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The general management factor categories included as independent variables in the udder and mastitis culling rate model included the use of an employee handbook, dry cow management, milking procedures, housing type, herd size, BST use, veterinarian use, and biosecurity factors. The udder and mastitis culling rate independent variable descriptions are displayed in Table 21.

Table 21. The Udder and Mastitis Culling Rate Model Independent Variable Descriptions

Independent Variable	Description
Handbook	Indicates if a farm uses an employee handbook
Incentives	Indicates if a farm uses employee incentive programs
Handbook and Incentives	Indicates if a farm uses both an employee handbook ***and*** incentive programs
Dry Treatment	Indicates if a farm dry treats all four udder quarters on almost all cows at the end of a lactation
Wash Pen	Indicates if a farm has a pre- milk wash pen
Pre-Dip	Indicates if a farm pre-dips all teat ends prior to milking
Post Dip	Indicates if a farm post dips all teat ends prior to milking
Pre- and Post Dip	Indicates if a farm either has a pre-wash pen or pre-dips all teat ends prior to milking ***and*** post dips all teat ends after milking
Free Stall Facility	Indicates if a farm uses free stall facilities
Multiple Animal Facility	Indicates if a farm uses multiple animal housing
Herd Size	The size of the milking and dry cow herd
Sand Bedding	Indicates if a farm uses sand bedding
Wood Bedding	Indicates if a farm uses wood-based bedding
Compost Bedding	Indicates if a farm uses composted manure bedding
Rubber Mat Bedding	Indicates if a farm uses rubber mat bedding
Tire Bedding	Indicates if a farm uses tire bedding
Newspaper Bedding	Indicates if a farm uses newspaper bedding
Mattress Bedding	Indicates if a farm uses mattress bedding
Stalk Bedding	Indicates if a farm uses corn stalk bedding
Other Bedding	Indicates if a farm uses other bedding types
BST	Indicates if a farm uses BST
Veterinary Visits	Refers to the number of veterinary visits needed
Staff Veterinarian Day	Refers to the number of days a veterinarian was on staff
Milk Quality Test	Indicates if a farm requires a somatic cell count score or milk culture test prior to purchasing a cow

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A properly prepared employee handbook enhances farm performance in at least two ways. First, having to write an employee handbook encourages a manager to determine the best practices for each task on the farm. This may involve analyzing how these tasks are being performed currently and determining if there are better alternative methods. Once the best methods have been chosen for each task and composed into handbook form, the handbook can then serve as a reference to show employees how to do their job tasks properly and to inform them why it is important to do these tasks in the prescribed manner. A handbook informs employees how to use, clean and maintain the parlor equipment, how to prepare each cow for milking, how to check for mastitis, how to monitor the milking, how to care for each cow after milking, and what to do when problems arise. It is expected that farms with employee handbooks will have less udder and mastitis related problems than those that do not.

Performance based employee incentive programs are used to encourage employees to improve their performance. Employee incentive programs help insure that employees will strictly follow milking protocols. The marginal effect of using employee incentive programs is expected to be negatively correlated with the udder and mastitis culling rate.

Having both a handbook and an incentive program can further enhance employee performance beyond what each would alone. A handbook describes to employees how to conduct activities to enhance udder health, and employee incentive programs help insure that these protocols are followed. Farms with both an employee handbook and an employee incentive program are expected to have lower udder and mastitis culling rates than those without.

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At a lactation's completion, a standard protocol on many dairy farms is to dry treat dairy cattle because the infection rate for mastitis is higher during the dry period than when the cow is lactating (Hoards Dairyman, 1990). Dry treating involves infusing the udder with antibiotics within one week of a cow's last milking. A farm that dry treats cattle is expected to have a lower mastitis incidence than those that do not.

It is important to clean and sanitize the udder and teat ends of the cattle in order to reduce mastitis. One method is to have the cattle enter a wash pen prior to milking. In the pens, water is sprayed upward to clean the udder. Dipping or spraying the cow's teat ends with a sanitizing liquid is another method of reducing the incidence of mastitis. These treatments occur before (predipping) and/or after (postdipping) each milking (Hoards Dairyman, 1990). It is expected that producers who use wash pens, predipping or postdipping technologies will have less udder and mastitis culls. Producers who utilize either wash pens or pre-dipping protocols in conjunction with post dipping protocols are also expected to experience fewer udder and mastitis culls.

Cattle housing may also affect udder and mastitis culls. There are three primary types of housing facilities: tie stalls, free stalls and multiple animal facilities. Tie stalls (or stanchion) barns tend to be older facilities whereby the cows are kept in a stall (except for exercise) either by a tether or a head chute. Feed and milking units are brought to the cows in a tie stall facility. Free stall facilities tend to be more modern facilities where cattle are free to enter and leave any stall and to go to a feed bunk to eat. The cattle are moved to a milking parlor to be milked. Multiple animal housing can either be loafing sheds (essentially free stall facilities without stalls) or western-style dry lots. It is difficult to tell which facility type will have an advantage as far as udder and mastitis problems are concerne

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are concerned. Free stall facilities are a newer technology than tie stall facilities. As such, they may have an advantage concerning udder and mastitis culls. Alternatively, the herd size associated with tie stall facilities tend to be smaller than free stall facilities, and there may be more individualized attention given to cattle by the milkers, thereby reducing subclinical and clinical mastitis episodes. As such, the correlation of udder and mastitis culls and facility type cannot be hypothesized. In the model, free stall and multiple animal facility types were differentiated by using two dummy variables. When both of these dummy variables are set to zero, the udder and mastitis culling rate model's equation defaulted to represent a farm with tie stall facilities.

It is also difficult to hypothesize how herd size will affect udder and mastitis culls. Although it was inferred in the previous paragraph that smaller herd size may be associated with more individualized care that is conducive to better herd health, larger herds may be able to hire more specialized labor or adopt technology because of their size. More specialized labor or better technology may also reduce udder and mastitis culling rates.

The materials used to bed cattle stalls may also affect mastitis. Ten bedding types were assessed to determine the effect of bedding types on udder and mastitis culls: sand, wood-based, composted manure, rubber mats, tire, newspaper, mattress, corn stalk, straw and other bedding. Straw bedding was represented in the baseline situation of the regression when the other bedding dummy variables were set to zero.
While bedding type is expected to affect the udder and mastitis culling rate, its correlation is difficult to predict.

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BST increases milk yield in the latter half of a cow's lactation. It could be hypothesized that this additional milk yield places undue stress on the cow, increasing the likelihood of udder and mastitis problems. Nevertheless, Collier et al. (2001) found that BST had no effect on mastitis. Baumann et al. (1999) and Ruegg, Fabellar, and Hintz (1996) found that BST did not significantly affect overall culling rates. BST may enable a cow with subclinical mastitis to increase its production enough to remain in the herd for longer periods of time, giving the manager more time to treat the animal and less economic reasons for culling the cow for udder and mastitis problems. It is hypothesized that the proportion of health culls caused by udder and mastitis problems decreases with BST use.

Veterinary services can be both preventive or diagnostic and treatment in nature. The number of preventive visits should be negatively correlated with udder and mastitis culls. Conversely, the number of treatment and diagnostic visits are expected to be positively correlated with udder and mastitis culls. While the number of veterinary visits on the survey farms was determined, the number of preventive veterinary service calls and diagnostic and/or treatment veterinary service calls were not, which makes predicting the effect that veterinary service calls have on udder and mastitis culls difficult. Nevertheless, Weiglar et al. (1990) found that disease events accounted for 89 percent of California dairy veterinary farm expense from 1988 to 1989. This may indicate that producers primarily use non-staff veterinarians for diagnostic and treatment work rather than disease prevention programming. Udder and mastitis culls are expected to be positively correlated with veterinarian service calls.

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Veterinarians who are employed by farms should spend more time on that farm than a non-staff veterinarian. The additional time can be used for disease prevention activities. It is expected that udder and mastitis culls are negatively correlated with the number of days a farm employs an on-staff veterinarian.

Mastitis problems can be contagious. Pritchard (2000) suggests that dairy farmers follow a mastitis biosecurity program when purchasing new cows. One component of such a program is to receive verification of the potential new cow's mastitic state. The NAHMS Dairy 1996 survey asked producers if they insisted upon having individual cow somatic cell count tests and/or individual cow milk culture sample tests prior to buying a cow. Producers who practice this procurement policy are expected to have lower udder and mastitis culls.

The Lameness and Injury Culling Rate Model

Cook (2003) estimated that over 23 percent of dairy cows are lame in the United States. Warnick et al. (1995) found that the 305 day mature equivalent milk yield of lame cattle was 705 pounds less than non-lame herd mates. Lameness cost estimates vary. Total lameness treatment and prevention costs averaged $7.83 per cow per year for California herds in 1988 – 1989 (Weigler et al., 1990). New York researchers determined that lameness costs New York producers $900 per cow per year (Wallace, 2003). Lameness and injuries may also have spillover effects concerning reproduction. Sutton (2003) reported that lame cattle remain unbred for 28 days longer than healthy cattle. In a study of a single lactation for 5,000 New York cows, forty-four percent of the cattle with laminitis lesions were culled while only twenty-five percent of the cattle without laminitis were culled (Cattell, 2001).

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The second model estimates the effect of management factors on the lameness and injury culling rate. General management controlled factors included surface and facility technologies, hoof conditioning practices, veterinary care, milk production and BST use. The infectious agent factor was the proportion of cattle that showed signs of hairy heel wart. The independent variable descriptions of the injury and culling rate model can be seen in Table 22.

Table 22. The Lameness and Injury Culling Rate Model Independent Variable Descriptions

Independent Variable	Description
Hairy Heel Wart	The proportion of cattle with hairy heal warts
Footbath	Indicates if a farm uses a footbath regularly throughout the year
Hoof Trim	Indicates if a farm trims the hooves of nearly all the cattle during a year
Footbath and Hoof Trim	Indicates if a farm regularly uses a footbath ***and*** trims the hooves of nearly all the cattle during a year
Free Stall	Indicates if a farm houses its cows in a free stall facility
Multiple Animal Facility	Indicates if a farm houses its cows in multiple animal housing
Exercise Lot	Indicates if a farm has an exercise lot
Soft Surface	Indicates if a farm's cattle primarily stand on a soft surface
Textured Concrete Surface	Indicates if a farm has textured concrete cattle walking surfaces
Sand Bedding	Indicates if a farm uses sand bedding
Wood Bedding	Indicates if a farm uses wood-based bedding
Compost Bedding	Indicates if a farm uses composted manure bedding
Rubber Mat Bedding	Indicates if a farm uses rubber mat bedding
Tire Bedding	Indicates if a farm uses tire bedding
Newspaper Bedding	Indicates if a farm uses newspaper bedding
Mattress Bedding	Indicates if a farm uses mattress bedding
Stalk Bedding	Indicates if a farm uses corn stalk bedding
Other Bedding	Indicates if a farm uses other bedding types
Veterinary Visit	The number of veterinary visits needed on a farm
Staff Veterinarian Day	The number of days a veterinarian was on staff
Rolling Herd Average	The rolling herd average of the herd
BST	Indicates if a farm uses BST

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Hairy heel wart, digital dermatitis, is an infectious condition where a lesion forms on the heel of cattle. As these lesions grow, they can cause the animal to become lame. Hairy heel warts induce lameness on 40 percent of the Midwest dairy farms, and infected cattle can experience a decrease in milk yield of 20 to 50 percent (Wallace, 2003). As the proportion of infected cows increases in a herd, the proportion of cattle culled due to lameness and injury is expected to increase.

Hoof care is thought to help reduce the incidence of lameness and injuries by promoting better hoof conditioning. Medicated footbaths and/or hoof trimming are recommended protocols on many farms. Footbaths are thought to improve hoof condition, decrease the incidence of hoof infections, and are used by many to prevent and treat hairy heel wart. Footbaths need to be used more than once a month to be effective (Wallace, 2000). Managers who use footbaths regularly should see less lameness and injury culling. Farms that trim hooves regularly are expected to have more animals with correct hoof structure, thereby reducing lameness and injuries. Additionally, hoof trimming can lead to the early detection of poor hoof health and identify ex-post periods of laminitis, a nutrition problem which has hoof health repercussions. It is expected that regular hoof trimming is negatively correlated with lameness and injury culls. Farms that regularly use footbaths ***and*** regularly trim hooves are expected to experience lower lameness and injury culling rates than firms who do not or those farms that only implement one of the preventive measures.

As inferred earlier in this section, facility type may also contribute to lameness. Cook (2002) found that there was no significant difference between tie stall and free stall barns concerning lameness episodes. As such, it is unlikely that free stall technology will

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have a significant advantage over tie stall facilities. Multiple animal facilities may have less lameness and injury problems, however, as the cattle typically stand on a dirt pack. Cattle from multiple animal facilities are expected to have lower lameness and injury culling rates than cattle from tie stall facilities.

Cattle housed in tie stall facilities typically spend much of the day tethered to a stall, especially in winter. Even though a bedding is provided, the surface below the bedding is hard, usually concrete. Cattle that are housed in free stalls, even though they can get up and move around their barn, predominantly stand on concrete. Having an exercise lot (either dry lot and/or pasture) allows a cow to get more exercise and to be able to stand on a softer surface than concrete. Cattle that have access to exercise lots are expected to be less prone to lameness and injuries.

Cattle that predominantly stand on softer (as opposed to hard concrete surfaces) textured surfaces, such as pasture and dirt, should have less pressure on their hooves and less hoof wear. Bray, Giesey and Bucklin (2002) found that cattle were 43 percent less likely to have a foot health problem when a rubberized walking surface was used as opposed to concrete surfaces. While the Nahms Dairy '96 survey did not ask producers about the use of rubberized surfaces, the producers were asked to distinguish if their primary surface for the cattle was concrete or pasture or dirt pack. As pasture and dirt pack are softer than concrete, cattle that predominantly stand on those surfaces are expected to be less likely to be culled for lameness and injuries.

Smooth concrete surfaces can be slippery. It is hard to avoid wet and slippery conditions in dairy housing facilities. Cattle that lose their footing may become injured and lame. Roenfeldt (2001) reported that Kansas operations that used slip-form concrete surfaces in t

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surfaces in their new facilities had lower than expected lameness episodes. Having a textured concrete surface is expected to reduce the problem of cattle slipping on dairy surfaces and reduce the number of cattle culled due to lameness and injury.

The materials used to bed cattle stalls may also affect lameness and injury culling rates. Ten bedding types were assessed to determine the effect of bedding types on udder and mastitis culls: sand, wood-based, composted manure, rubber mats, tire, newspaper, mattress, corn stalk, straw and other bedding. Straw bedding was represented in the baseline situation of the regression when the other bedding dummy variables were set to zero. As each bedding type has its advantages and disadvantages, the correlation of the various bedding types could not be hypothesized.

Assuming that veterinarians are called to primarily diagnose and treat cattle, the number of veterinarian visits is expected to be positively correlated with lameness and injury health culls. On staff veterinarians, however, may be better able to implement hairy heel wart, laminitis, and poor hoof condition prevention programs in place as they can devote more time to prevention protocols. Thus, the number of days a veterinarian was on staff is expected to be negatively correlated with lameness and injury culls.

In an effort to obtain higher production levels, dairy cattle may be fed diets that are too rich in grain and protein. In this situation, a cow may develop laminitis and become lame (Hoard's Dairyman, 1990). It was hypothesized that the effect of rolling herd average is positively correlated with lameness and injury culling.

Collier et al. (2001) determined that although BST was correlated with increased lameness incidents, it did not affect the total number of animals culled for lameness. As was hypothesized with udder and mastitis culling rates, BST may increase lame cattle milk produc

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milk production enough to make it more profitable to treat the animals rather than to replace them. BST is expected to reduce the culling rates associated with lameness and injury culling.

The Disease Culling Rate Model

Wiegler et al. (1990) estimated that California producers spent $28.20 per cow per year to prevent and treat diseases from 1988 and 1989. One disease in particular, Johne's Disease, cost U.S. producers an estimated 222 million dollars in 1995 (Wells, Ott, Hillberg Seitzinger, 1998). Herds infected with Johne's Disease can have up to $200 per cow per year higher veterinary costs (Wells, 2000). If a cow that contracts a disease has to be culled prematurely, the cost of disease to producers increases.

In this section, we estimate how management factors affect the disease culling rate. The management factors include biosecurity related factors, facility technologies, production, BST use, and veterinary use. The infectious agent examined was Johne's Disease or paratuberculosis. The disease culling rate model's independent variables are described in Table 23.

As a farm's dependence on purchased dairy replacements increases, dairy farmers may be forced to procure animals from multiple sources. The commingling of these animals may cause a major biosecurity breach, a disease outbreak, if not properly managed. Dairy farms with a high proportion of purchased cattle are expected to exhibit more disease culls.

There are various methods of reducing the threat of disease. Youngstock can be kept separate from cattle and other species to limit the spread of disease by nose-to-nose

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Staff Veterinarian Day
Herd Size
Free Stall Facility

Table 23. The Disease Culling Rate Model Independent Variable Descriptions

Independent Variable	Variable Description
Purchase Cows	The proportion of the herd that was purchased
Nose-to-Nose Cow Contact	Indicates if nose-to-nose contact between heifer calves and other cattle is prevented
Nose-to-Nose Other Contact	Indicates if nose-to-nose contact between heifer calves and other species is prevented
Vaccines Used	The proportion of the vaccinations listed in the NAHMS Dairy '96 Survey used by a farm
Vaccines Required	Indicates if a farm requires that purchase cattle have sixty percent or more of the vaccines listed in the NAHMS Dairy '96 Survey
Tests Required	Indicates if a farm requires that purchase cattle be tested for sixty percent or more of the diseases listed in the NAHMS Dairy '96 Survey
Quarantine	Indicates if a farm has quarantine protocols
Vaccines, Tests and Quarantine	Indicates if a farm requires purchased animals to be vaccinated by sixty percent of the vaccines listed in the NAHMS Dairy '96 Survey ***and*** requires that purchase animals be tested for sixty percent of the diseases listed in the NAHMS Dairy '96 Survey ***and*** has quarantine protocols
Vaccines and Tests	Indicates if a farm requires purchased animals to be vaccinated by sixty percent of the vaccines listed in the NAHMS Dairy '96 Survey ***and*** requires that purchase animals be tested for sixty percent of the diseases listed in the NAHMS Dairy '96 Survey
Vaccines and Quarantine	Indicates if a farm requires purchased animals to be vaccinated by sixty percent of the vaccines listed in the NAHMS Dairy '96 Survey ***and*** has quarantine protocols
Tests and Quarantine	Indicates if a farm requires that purchase animals be tested for sixty percent of the diseases listed in the NAHMS Dairy '96 Survey ***and*** has quarantine protocols
Johne's Positive	Indicates if a farm has cattle that have tested positive for Johne's Disease
Veterinary Visits	The number of veterinary visits needed on a farm
Staff Veterinarian Day	The number of days a veterinarian was on-staff
Herd Size	The size of the milking and dry cow herd
Free Stall Facility	Indicates if a farm houses its milking herd in a free stall facility

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Table 23 (cont'd)

Multiple Animal Facility	Indicates if a farm houses its milking herd in multiple animal housing
Rolling Herd Average	The rolling herd average of the herd
BST	Indicates if a farm uses BST

contact. A comprehensive vaccination program can be implemented. Animals purchased from other farms can be quarantined and observed for disease symptoms.
Farm managers can insist that potential replacement cattle be vaccinated and tested for diseases prior to purchasing them. Farms that engage in these individual practices are expected to have less disease culls than those that do not. Of course, those who implement these programs in conjunction with the other programs may see an even higher benefit.

The clinical signs of Johne's Disease include watery diarrhea, milk loss, weight loss, and even death. It is highly contagious. Cattle can contract the disease as youngstock but not show clinical symptoms until between two and five years of age. The problem is compounded by the fact a subclinically Johne's infected heifer can shed the disease to other youngstock (Stabel, 1998). As such, the presence of an animal that tests positive for Johne's disease increases the likelihood that the farm will have to cull for disease problems.

Like the previously discussed health cull types, the correlation of the number of veterinary visits and the disease culling rates should be positive as producers use the veterinarian predominantly for diagnostic and treatment purposes. Having a veterinarian as a farm employee, however, increases the likelihood that the farm veterinarian will be able to dev

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able to develop and implement disease reduction protocols on the farm. The number of days worked by an on-staff veterinarian is expected to be negatively correlated with the disease culling rate.

Cattle grouped together in any facility type offer an opportunity for disease outbreaks. Nevertheless, some respiratory diseases may be minimized if adequate air flow is available. In general, tie stalls have poorer ventilation than most modern free stall and multiple animal facilities. As such, it is expected that less culling due to disease will occur in free stall and multiple animal facilities.

The effect of rolling herd average is difficult to predict. Healthier herds are expected to produce more. There is a common belief, however, that cattle that are "pushed" to produce more will have an increased likelihood of contracting a disease. While it was hypothesized that milk production levels would significantly affect the proportion of health culls culled for disease, the correlation of rolling herd average and disease culls could not be hypothesized.

BST is one method to increase milk production. Collier et al. (2001) showed that BST was not associated with increase incidences of disease. With the previous health cull types, it was hypothesized that BST may help lame and mastitic cows produce enough to make it more economical for the producer to treat the animals instead of culling them. With disease problems, however, the risk of spreading the disease may be too great to keep sick dairy cattle in the herd despite their production level. Accordingly, BST may not help diseased animals remain in the herd.

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The Reproduction Culling Rate Model

Cows that have problems conceiving will not stay in a herd for very long. There are management controlled factors that can increase or decrease the likelihood of reproduction culls. Such factors include having an employee handbook, the herds rolling herd average, herd size, facility technology, veterinary use, estrus synchronization and bull use.

Although Galton (1997) concluded that longer calving intervals may be profitable with high producing herds using BST, Jones (2001) reported that calving intervals beyond 390 days were less profitable for high producing cows. Keown (1986) reported that calving intervals beyond 395 days costs $3.00 per day per extended calving interval cow. Cassell (2002) noted that less fertile cows get culled sooner than more fertile herd mates. A model was developed to determine the effectiveness of management controlled factors that can improve reproduction efficiency and decrease the proportion of health culls caused by reproduction problems. Such factors include having an employee handbook, the herds rolling herd average, herd size, facility technology, veterinary use, estrus synchronization and bull use. The reproduction culling rate model independent variables are describe in Table 24.

An employee handbook should show employees how to detect if a cow is in estrus and outline the procedures for informing the manager about the cow. For employees with artificial insemination duties, the handbook should also explain the protocols to use when breeding and testing for pregnancy. The existence of an employee handbook should

Table 24.

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Table 24. The Reproduction Culling Rate Model Independent Variable Descriptions

Independent Variable	Description
Handbook	Indicates if a farm uses an employee handbook
Incentive	Indicates if a farm uses an employee incentive program
Handbook and Incentive	Indicates if a farm uses an employee handbook ***and*** an employee incentive program
RHA	The farm's rolling herd average
Herd Size	The farm's milking and dry cow herd size
BST	Indicates if a farm uses BST
Veterinary Visits	The number of veterinary visits needed on a farm;
Staff Veterinarian Day	The number of days a veterinarian was on-staff
Free Stall Facility	Indicates if a farm houses its cattle in a free stall facility
Multiple Animal Facility	Indicates if a farm houses its milking herd in multiple animal housing
Synchronization	Indicates if a farm uses estrus synchronization techniques
Bull Low	Indicates if a farm exposed greater than zero but less than ten percent of their cattle to a herd bull
Bull Medium	Indicates if a farm exposed more than ten percent but less than or equal to thirty percent of their cattle to a herd bull
Bull High	Indicates if a farm exposed more than thirty percent of their cattle to a herd bull

decrease the proportion of health culls due to reproduction problems. Providing employees with incentives for estrus detection and achieving higher-than-anticipated pregnancy rates can also decrease reproduction culling rates. Reproduction culling rates are expected to be lower on farms that use both of these management tools as opposed to those who do not.

Artificial insemination requires specialized labor. In general, the larger a farm is the more it can afford to utilize specialized labor. A larger herd size also allows farms to avail themselves to other reproductive technologies such as pedometers and estrus and ovulation synchronization. Herd size is expected to be negatively correlated with the reproduction culling rate.

It is more difficult to get dairy cattle to conceive as they produce more. Howard et al. (1992) reported that a manager can expect a 1.5 days open increase for every genetically induced 785 pound increase in rolling herd average. Fleiscer et al. (2000) noted that retained placentas and cystic ovaries, conditions with adverse reproduction repercussions, are positively correlated with milk yield. Cows that produce more milk are expected to have a higher reproduction culling rate.

Collier et al. (2001) found that BST had no effect on pregnancy rates, days open, cystic ovaries or abortions. BST promotes production in the latter half of lactation. Cattle that have difficulty conceiving may be more profitable to keep longer using BST than without BST. This enables the manager more opportunities to breed the animal or to keep the cow profitably open for longer periods of time. The reproduction culling rate is expected to be negatively correlated with BST use. Veterinarians work closely with managers concerning reproduction issues. As most veterinarians visit farms monthly to check animals for pregnancy, the veterinarians can quickly respond to reproductive problems. As such, it is expected that less animals will be culled as the number of veterinary visits or the number of days a veterinarian is on staff should increase.

While tie stall facilities do allow producers to provide very individualized care to each animal, they are less conducive to estrus detection. Upper Midwest dairymen who participated in a study on the before and after effects of expansion commented that heat detection significantly improved on farms when they moved into their expanded dairy free stall facilities (Hadley, 2001). Free stall and multiple animal facilities are expected to be negatively correlated with the reproduction culling rate.

One of the difficulties of breeding cattle is detecting estrus. Estrus synchronization manipulates the cow's reproductive cycle so that estrus occurs in a predictable manner. Cattle can then be scheduled for breeding. Farms that use synchronization technology are expected to have lower reproduction culling rates.

Some managers find it prudent to have bulls in the herd to breed or "clean up" long open cows. Hadley (2001) noted that some dairy expansion managers started to use bulls for long open cattle rather than to let their average calving intervals increase. While the genetic merit of bull bred offspring and the safety of having bulls on a farm may be debatable, it is commonly thought that bulls are more efficient at breeding dairy cattle. Farms that rely more heavily on natural service are expected to have a lower reproduction culling rate.

IV. Estimation Results

The were 1,352 observations for Model 1, the Udder and Mastitis Culling Rate Model (Table 25). Due to the random stratified sampling technique employed by the NAHMS Dairy '96 Survey, these 1, 352 observations represented 94,150 U.S. dairy farms. On average, 6.23 percent of dairy cattle were culled for udder and mastitis reasons. The R-square for the ddder and mastitis culling rate model estimation was 0.029547. The model was significant (p-value = <0.0001).

Table 25. Overall Results for The Udder and Mastitis Culling Rate Model

Statistic	Value
Observations	1,352
Weighted Observations	94,150
Denominator Degrees of Freedom	1,289
Weighted Mean Response	6.230350

Farms that used handbooks to inform employees about protocols experienced 3.02 percent lower udder and mastitis culling rates than those who did not (Table 26). Although employees handbooks proved beneficial in reducing udder and mastitis culling

Table 26. Parameter Results for The Udder and Mastitis Culling Rate Model

Parameter	Parameter Estimate	Standard Error	Test Type[1]	T - test	P - value
Intercept	4.8831	0.5982	2	8.29	<0.0001
Handbook	-3.0220	0.8831	1	-3.42	0.0003
Incentive	0.0549	0.7207	1	0.08	[2]
Handbook and Incentive	-0.4606	1.1419	1	-0.40	0.3434
Dry Treatment	0.3790	0.6962	1	0.54	[2]
Wash Pen	8.5592	3.7803	1	2.26	[2]
Pre-dip	0.4700	1.7037	1	0.28	[2]
Post Dip	0.6410	0.8474	1	0.76	[2]
Pre- and Post Dip	0.0467	0.5425	1	0.09	[2]
Free Stall Facility	0.0634	0.6047	2	0.10	0.9165
Multiple Animal Facility	0.5428	0.9370	2	0.58	0.5625
Herd Size	-0.0006	0.0007	2	-0.84	0.4007
Sand Bedding	0.9632	0.7690	2	1.25	0.2106
Wood Bedding	-0.4758	0.4745	2	-1.00	0.3162
Compost Bedding	-1.9420	0.8331	2	-2.33	0.0199
Rubber Mat Bedding	0.3519	0.5133	2	0.69	0.4931
Tire Bedding	-0.8582	1.5961	2	-0.54	0.5904
News Paper Bedding	1.1350	0.9183	2	1.24	0.2167
Mattress Bedding	0.4136	0.7441	2	0.56	0.5784
Stalk Bedding	0.1625	0.6570	2	0.26	0.8047
Other Bedding	-0.6165	1.3506	2	-0.46	0.6481
BST	1.1892	1.1078	1	1.07	[2]
Veterinary Visits	0.0181	0.0143	1	1.26	0.1032
Staff Veterinarian Day	-0.0043	0.0088	1	-0.49	0.3122
Milk Quality Test	0.8359	1.6218	1	0.52	[2]

[1] A "1" signifies a one-tailed test. A "2" indicates a two-tailed test.
[2] Insignificant due to an incorrect sign on a one-tail test.

rates, incentives did not. This may support the premise that incentive programs should not be used to improve performance in activities such as milking. Milking activities, especially in larger herds, are generally conducted by multiple employees, making individual performance in multiple employee activities is hard to monitor and reward with incentives.

Surprisingly, none of the udder and teat sanitation parameters (dry treatments, wash pens, pre-dipping, post dipping, pre- and post dipping) were statistically significant. In fact, these parameters carried the wrong sign. These results may be influenced, however, by the cross sectional design of the survey. As such, there was no information concerning the before and after effects of the implementation of these programs on each farm. Secondly, the quality of how these activities were conducted on each farm was not addressed in the survey.

Facility type as well as herd size seemed to have little effect on the udder and mastitis culling rate. For the most part, bedding type also did not effect udder and mastitis culling rates. Only composted manure bedding reduced udder and lameness culling rates. Farms that used composted manure bedding had 1.94 percent lower udder and lameness culling rates (p-value = 0.0199). The effects associated with BST, veterinary visits, staff veterinarian days, and milk quality test parameters were statistically insignificant.

Table 27. Overall Results for The Lameness and Injury Culling Rate Model

Statistic	Value
Observations	1,352
Weighted Observations	94,150
Denominator Degrees of Freedom	1,289
Weighted Mean Response	3.025042

There were 1,352 observations for the lameness and injury culling rate model, representing 94,150 U.S. dairy farms (Table 27). Three percent of all the cattle were culled due to lameness and injury problems. The model had an R-square of 0.110654. The model was significant (p-value < 0.0001).

As the proportion of cattle with hairy heel warts increased, the lameness and injured culling rate increased by 4.47 percent (Table 28). The use of footbaths and/or hoof trimming did not significantly affect the lameness and injury culling rate. Once again, the insignificant results for these parameters may be due to the cross sectional nature of the survey. Although the lameness and injury culling rate on farms with free stall facilities were not significantly different than tie stall facilities, multiple animal facilities had significantly lower (-0.79 percent) lameness and injury culling rates. Cattle that were on farms that provided predominantly soft walking surfaces also experienced significantly lower (-0.53 percent) lameness and injury culling rates. The fact that both multiple animal facilities, which generally have dirt pack surfaces, and farms with predominantly soft cattle surfaces have lower culling rates indicates that the hardness of cattle walking surfaces seems to affect lameness and injury culling rates.

Farms that used composted manure bedding or "other" bedding experienced lower lameness and injury culling rates. Farms using composted manure bedding experienced lameness and injury culling rates that were 1.15 percent less than those who bedded with straw. Farms that used "other" bedding alternatives experienced lameness and injury culling rates that were 1.49 percent less than those that bedded with straw. There was no information provided that described what the "other" bedding types were.

Table 28. Parameter Results for The Lameness and Injury Culling Rate Model

Parameter	Parameter Estimate	Standard Error	Test Type[1]	T - test	P - value
Intercept	0.4547	0.5741	2	0.79	0.4285
Hairy Heel Wart	4.4680	1.1140	1	4.01	0.0001
Footbath	-0.5346	0.5473	1	-0.98	0.1644
Hoof Trim	0.1034	0.4074	1	0.26	[2]
Footbath and Hoof Trim	0.9113	0.8650	1	1.05	[2]
Free Stall Facility	0.4434	0.3630	2	1.22	0.2222
Multiple Animal Facility	-0.7868	0.3042	1	-2.59	0.0049
Exercise Lot	-0.2222	0.4082	1	-0.54	0.2932
Soft Surface	-0.5280	0.4074	1	-1.30	0.0977
Textured Concrete Surface	-0.1324	0.3463	1	-0.38	0.3511
Sand Bedding	-0.5422	0.3674	2	-1.48	0.1402
Wood Bedding	0.1892	0.3405	2	0.56	0.5784
Compost Bedding	-1.1521	0.4788	2	-2.41	0.0163
Rubber Mat Bedding	0.5773	0.3932	2	1.47	0.1423
Tire Bedding	1.6238	1.3145	2	1.24	0.2169
Newspaper Bedding	0.1925	0.8781	2	0.22	0.8265
Mattress Bedding	-0.4434	0.5429	2	-0.82	0.4143
Stalk Bedding	0.7970	0.5382	2	1.48	0.1389
Other Bedding	-1.4906	0.4265	2	-3.49	0.0005
Veterinary Visits	0.0141	0.0079	1	1.79	0.0370
Staff Veterinarian Day	0.0602	0.0118	1	5.09	[2]
RHA	0.0001	<0.0001	1	3.31	0.0005
BST	-0.6770	0.6671	1	-1.01	0.1552

[1] A "1" signifies a one-tailed test. A "2" indicates a two-tailed test.
[2] Insignificant due to an incorrect sign on a one-tail test.

The number of veterinary visits or the number of days a veterinarian was on a farm's staff did not seem to affect the lameness and injury culling rates. Lameness and injury culling rates increased as a farm's production per cow (RHA) increased. Although BST was negatively correlated with lameness and injury culling rate, the effect was not significant at a p-value of 0.10 percent or less.

There were 1,141 observations for the disease culling rate model (Table 25). The sample represented 93,944 U.S. dairy farms. A little over one percent of the cattle inventory were culled due to disease. The model had an R-square of 0.08353. The model was significant (p-value < 0.0001).

Table 29. Overall Model Results for The Disease Culling Rate Model

Statistic	Value
Observations	1,141
Weighted Count	93,944
Denominator Degrees of Freedom	1,076
Weighted Mean Response	1.061111

Although not significant, the incidence of disease actually decreased instead of increased as the proportion of purchase cattle increased on the farms (Table 30). Keeping youngstock away from nose-to-nose contact with other cattle did not significantly reduce disease culling rates at a p-value of 0.1000 or less, but farms that were able to keep youngstock away from nose-to-nose contact with other species experienced 1.59 percent lower disease culling rates. Individually or in combination with each other, the proportion of vaccines used on a farm, the proportion of vaccines required prior to purchasing a cow, the proportion of tests required prior to purchasing a cow, and the presence of a quarantine did not significantly reduce disease culling rates at a p-value of 0.1000 or less. Farms that had cows that tested positive for Johne's Disease experienced 0.96 percent higher disease culling rates. The number of veterinary visits and the number of days worked by an on staff veterinarian did not significantly affect the disease culling rates. The descriptive farm and production variables also did not significantly affect disease culling rates.

Table 30. Parameter Results for The Disease Culling Rate Model

Parameter	Parameter Estimate	Standard Error	Test Type[1]	T - test	P - value
Intercept	-0.5269	0.8319	2	-0.63	0.5266
Purchase	-0.1804	0.4158	1	-0.43	[2]
Nose to Nose Cow Contact	-0.9290	0.9382	1	-0.99	0.1612
Nose to Nose Other Contact	-1.5858	0.8895	1	-1.78	0.0375
Vaccines Used	-1.5966	1.3180	1	-1.21	0.1130
Vaccines Required	-0.1101	0.4971	1	-0.22	0.4124
Test Required	-0.5141	1.0260	1	-0.50	0.3083
Quarantine	-0.6476	0.7218	1	-0.90	0.1849
Vaccines and Tests	-0.5284	0.5142	1	-1.03	0.1522
Vaccines and Quarantine	-0.8767	0.8189	1	-1.07	0.1423
Tests and Quarantine	-3.5862	2.8452	1	-1.26	0.1039
Vaccines, Tests and Quarantine	0.3113	0.5511	1	0.56	0.2862
Johne's Positive	0.9551	0.5925	1	1.61	0.0536
Veterinary Visits	-0.0017	0.0076	1	-0.22	[2]
Staff Veterinarian Day	0.0076	0.0063	1	1.20	[2]
Herd Size	0.0002	0.0006	2	0.26	0.7941
Free Stall	-0.0669	0.2916	1	-0.23	0.4093
Multiple Animal Facility	2.8781	3.1988	1	0.90	[2]
RHA	0.0001	0.0001	2	1.07	0.2830
BST	0.2219	0.7468	2	0.30	0.7664

[1] A "1" signifies a one-tailed test. A "2" indicates a two-tailed test.
[2] Insignificant due to an incorrect sign on a one-tail test.

There were 1,337 observations used in the reproduction culling rate model estimation (Table 31). The 1,337 observations represented 92,642 U.S. dairy farms. The farms culled 6.7 percent of their cattle due to reproductive problems. The R-square for the model was 0.057797, and the model estimation was significant (p-value < 0.0001).

Table 31. Overall Results for The Reproduction Culling Rate Model

Statistic	Value
Observations	1,337
Weighted Count	92,642
Denominator Degrees of Freedom	1,289
Weighted Mean Response	6.713675

Table 32 shows that individually having a handbook or incentive program did not significantly reduce reproduction culling rates, but, farms that used both experienced 1.23 percent fewer culling rates. As herd size increased, the reproduction culling rate decreased. This could possibly be due to the ability of larger farms to hire more specialized labor and adopt more costly reproduction technology. As expected, reproduction culling rates increased as rolling herd average increased.

Veterinary visits, on staff veterinarian days, facility type, and the use of estrus synchronization did not significantly affect reproduction culling rates. However, bull use did significantly reduce reproduction culling rates. Herds that used bulls but exposed less that 10 percent of their cattle to the bulls experienced 2.37 percent lower reproduction culling rates. Farms that exposed between 10 and 30 percent of their cattle to bulls experienced 2.24 percent lower reproduction culling rates. Herds that used bulls on more than 30 percent of their cattle experienced 2.80 percent fewer culling rates.

Table 32. Parameter Results for The Reproduction Culling Rate Model

Parameter	Parameter Estimate	Standard Error	Test Type[1]	T - test	P - value
Intercept	1.6437	2.1955	2	-0.63	0.5266
Handbook	-1.5612	1.9012	1	-0.82	0.2059
Incentive	-0.8954	0.7517	1	-1.19	0.1169
Handbook and Incentive	-1.2254	0.8742	1	-1.40	0.0806
Herd Size	-0.0036	0.0024	1	-1.46	0.0722
Rolling Herd Average	0.0003	0.0002	1	1.79	0.0370
BST	-1.4624	1.7026	1	-0.86	0.1953
Veterinary Visits	0.1202	0.1086	1	1.11	[2]
Staff Veterinarian Day	0.0036	0.0212	1	0.17	[2]
Free Stall Facility	-0.1937	1.0913	1	-0.18	0.4296
Multiple Animal Facility	-0.5307	0.9629	1	-0.55	0.2908
Synchronization	-1.0605	2.7820	1	-0.38	0.3516
Bull Low	-2.3653	1.7585	1	-1.35	0.0894
Bull Medium	-2.2354	1.4193	1	-1.57	0.0578
Bull High	-2.8015	1.0821	1	-2.59	0.0049

[1] A "1" signifies a one-tailed test. A "2" indicates a two-tailed test.
[2] Insignificant due to an incorrect sign on a one-tail test.

V. Summary and Discussion

Four ordinary least squares were developed to determine the effect that select management factors had on reducing the udder and mastitis, lameness and injury, disease, and reproduction culling rates. Only a few of the management factors significantly contributed to the udder and mastitis, lameness and injury, disease and reproduction culling rates at a p-value of 0.1000 or less. It is important to remember, however, that the survey was cross sectional. As such, the before and after effects of implementing the management programs and protocols could not be assessed. Additionally, how well the management programs and policies were implemented was not assessed in the survey. If information had been available concerning the before and after effects of implementing management programs and the quality of the management program implementation, some of the management factors, such as the effect of pre-dipping and post dipping on the udder and mastitis culling rate, may have been significant.

Only two management factors significantly affected udder and mastitis culling rates. Although providing employees with an incentive program did not reduce udder and mastitis culling rates, simply providing employees with a handbook reduced udder and mastitis culling rates by 3.02 percent. Farms that used composted manure experienced a 1.94 percent lower udder and mastitis culling rates. Although the biosecurity measures of vaccinations, tests and quarantines did not prove to significantly reduce disease culls, the fact that hairy heel warts and Johne's Disease significantly increased lameness and injury and disease culling rates indicates that producers should limit the exposure of their cattle to these contagious diseases.

Three factors were positively correlated with the lameness and injury culling rate. As the proportion of cattle with hairy heel wart increased, the lameness and injury culling rate increased by 4.47 percent. Thus, it is important for managers to consider hairy heel wart prevention programs. The number of veterinary visits was also positively correlated with lameness and injury culling rate. For every veterinary visit the lameness and injury culling rate increased by 0.01 percent. This probably indicates that producers are primarily using veterinary visits for diagnostic and treatment purposes as opposed to prevention methods. Rolling herd average was also positively correlated with the lameness and injury culling rate. The lameness and injury culling rate increased with Rolling Herd Average.

Farms with multiple animal facilities and farms with soft cattle surfaces had significantly lower lameness and injury culling rates. Farms with multiple animal facilities experienced a 0.79 percent lower lameness and injury culling rate than tie stall farms. Farms with a predominantly soft cattle surface experienced 0.59 percent lower lameness and injury culling rate. As many multiple animal facilities utilize dirt packs, this provides evidence that a farmer should consider providing his or her cattle with a soft walking and standing surface to reduce their lameness and injury culling rate. Composted manure and "other" bedding was also negatively correlated with the lameness and injury culling rate. Farms using composted manure bedding experienced a 1.15 percent lower lameness and injury culling rate. Farms using "other" bedding types experienced a 1.49 percent lower lameness and injury culling rate.

There were only two management programs that significantly affected disease culling rates. Managers who prevented their youngstock from nose-to-nose contact with other species had 1.59 percent lower disease culling rates than managers who did not. Farms that had animals that tested positive for Johne's Disease exhibited 0.96 percent higher disease culling rates.

Employee handbooks were also effective at reducing the reproduction culling rate but only when combined with incentives. Farms that used both handbooks and incentives experienced a 1.23 percent lower reproduction culling rate than farms that did not use handbooks and incentives. Herd size was also negatively correlated with reproduction culling rates, possibly indicating that larger farms are more apt to hire specialized labor and to adopt reproduction technologies. Using herd bulls was an effective method of reducing reproduction culling rates. Farms that use herd bulls on less than 10 percent of the herd experienced 2.37 percent lower reproduction culling rates. Farms using bulls on 10 to 30 percent of their cattle experienced 2.24 percent lower culling rates. Farms that used herd bulls on more than 30 percent of their cattle experienced 2.80 percent lower reproduction culling rates. Rolling herd average was positively correlated with reproduction culling rates.

Although these models indicated which management factors affected health culling rates, it did not provide information concerning whether such programs were financially successful. In the next chapter, a decision support system that will enable advisors and producers to determine the financial benefits of reducing health culling rates is described.

CHAPTER 5.

A CULLING RATE REDUCTION FINANCIAL FEASIBILITY DECISION SUPPORT SYSTEM

I. Introduction

Producers are faced with many decisions. One type of decision is whether to adopt culling rate reduction technologies (rubber cattle walkways to reduce lameness culls, pedometers to reduce reproduction culls, etc.), or management programs (new milking protocols to reduce udder and somatic cell count culls, allocating more labor to repair facilities and stalls to reduce injury culls, etc.). The decision to invest in culling rate reduction technologies or programs can be complex. If the producer over-invests, the financial gains from a culling rate reduction (increased milk revenues, decreased operating expenses, increased surplus replacement heifer sales) are more than offset by the investment and required operating costs associated with the new technology or management program. If the producer under-invests in the technology or program, the producer may not see a sufficient culling rate reduction to justify the expense.

This chapter proposes a decision aid to assist producers in determining the financial merit of culling rate reduction technologies and management programs. This decision support system (DSS) is different than previous culling programs. Rather than determining the economically optimal culling rate, this decision aid determines whether it is financially feasible to reduce a farm's current culling rate to a targeted level.

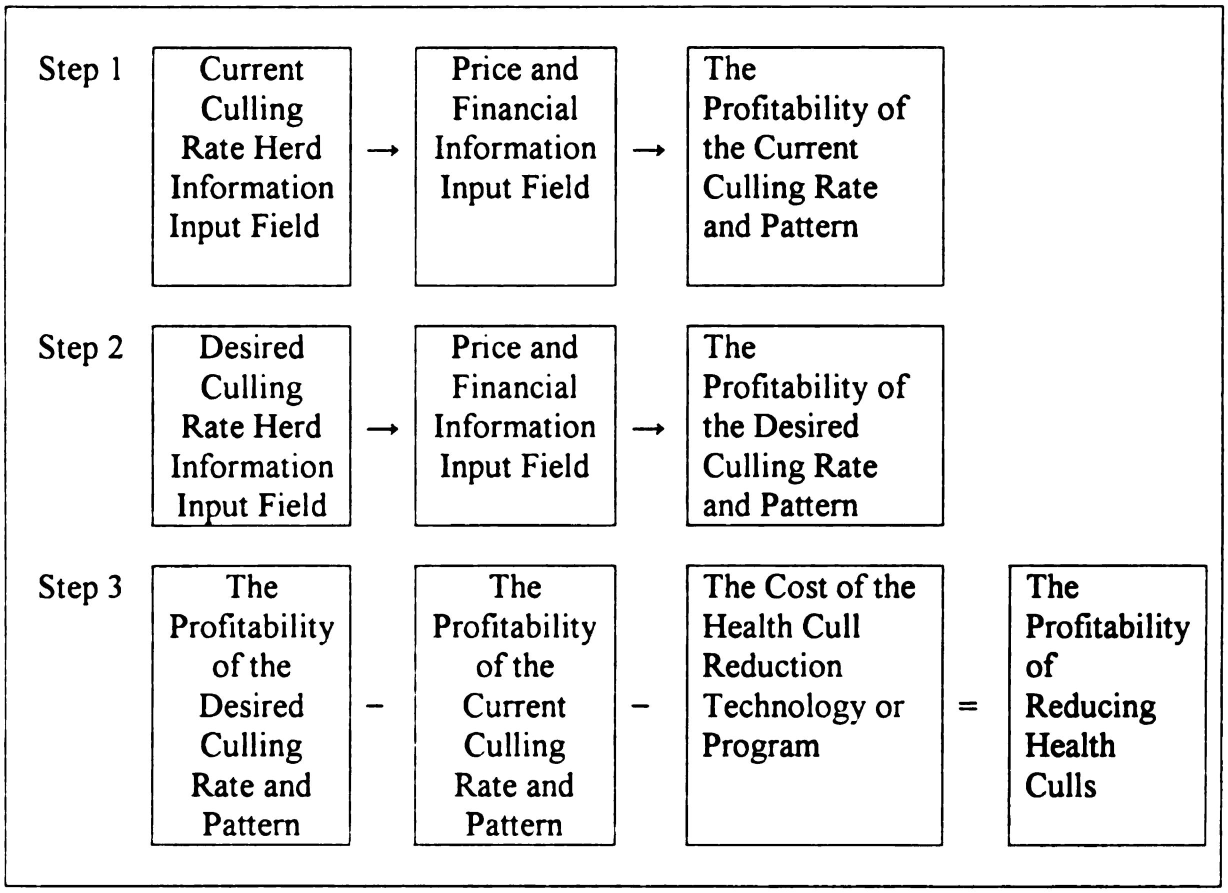
The information needed to run the DSS is discussed in Chapter II. A general overview of the procedure used by the DSS to determine the financial feasibility of reducing culling rates is provided in Section II. Section III discusses the information needed to run the DSS. Section IV details how the financial feasibility calculations are made. Section V describes how to input information into the DSS input fields .The calculations used to determine the DSS output and the output fields themselves are described in Section VI.

II. A General Overview of the DSS

Figure 1 shows a schematic of how the DSS operates. In Step 1, the profitability of the current culling rate and pattern of those culls is determined. First, herd information such as herd size, herd inventory, milk production per lactation, somatic cell counts, lactation specific culling rates, the within lactation removal schedule,[1] and the effect of culling on milk production and somatic cell counts are entered into the DSS. Next, price, cost and other financial information are entered into the DSS. Price information needed includes the expected milk price, somatic cell count premium, heifer and bull calf values, feed, labor and other direct expenses, cull cow prices, replacement heifer prices, and treatment expenses for culls due to udder and somatic cell count problems, infertility, lameness and injury, disease and death. The other financial information includes the farm's debt-to-asset ratio, an opportunity cost of equity capital, the farm's interest rate, marginal tax rate, and capital gains tax rate. Revenues and expenses are assigned to each cow. These assignments are made based upon their lactation, lactation month, and whether they will be culled or retained. The DSS then sums all of the revenues and expenses to determine the profit for that month and are discounted to reflect the time value of money. The monthly values are then summed to determine the present value of the profits for the current culling rate and pattern.

[1] The distribution of when culls occur during a given lactation.

Figure 1. Overview of the DSS



In Step 2, the profitability of a desired culling rate and culling pattern is basically determined in the same manner as the current culling rate and pattern with one exception. Presumably, the user has information about a technology or program that will reduce the user's lactation specific culling rates by some percentage. The user will input this information into the desired herd information input field. The DSS then calculates the monthly profitability of the desired culling rate and culling pattern and discounts these cash flows for the time value of money.

Next, the DSS subtracts both the present value of the profits for the current culling rate and culling pattern and the present value of the cash flows associated with adopting the health cull reduction technology and program from the present value of the profits from the present value of the profits for the desired culling rate and culling pattern. This value represents the net present value associated with reducing the current culling rate and culling pattern to the desired level with the proposed technology or program. If this value is greater than or equal to zero, the technology or program should be adopted. If negative, the technology or program should not be adopted as it is too costly.

III. Information Needed to Run the DSS

To run the DSS, a user will need to have herd and financial records available to input certain information. The needed information is shown in Table 32. *"Critical"* refers to information in which the DSS provides no sample values. *"Helpful"* refers to information whereby the DSS generates sample values, but the DSS estimation results would be more accurate for the user if he or she would input their own information.

Items 1 through 10 can be found by consulting with DHI records or other production and herd health records. Items 11 through 15 can be determined through discussions with milk company representatives, meat industry representatives, or Extension personnel. The expected heifer and bull calf mortality rate can be determined by examining production records. The farm's debt to asset ratio can be found by analyzing the farm's current balance sheet. The producer can obtain the cost of debt by talking with their lender. Determining an expected cost of equity capital can be difficult. The cost of equity capital should be larger than the interest rate. Extension personnel or other professionals who specialize in dairy finance should be able to provide this information. Treatment costs can be obtained by talking with a veterinarian or by analyzing a farm's itemized veterinary expenses. Feed costs, labor costs, and "other" costs can be determined by analyzing income statements. The genetic improvement rate can be ascertained from dairy geneticists. The inflation rate can serve as a proxy for the labor and other expense growth rate if a growth rate for each cannot be determined.

Table 33. Information Needed for the DSS

Information Type	Need Type
1) Average First Lactation Milk Production	Critical
2) Average Production Levels for Other Lactations	Helpful
3) Average First Lactation Somatic Cell Count	Critical
4) Average Somatic Cell Counts for Other Lactations	Helpful
5) Average Annual Culling Rate	Critical
6) Current Herd Inventory	Critical
7) Lactation Specific Culling Rates by Cull Type	Helpful
8) Within Lactation Removal Schedule	Helpful
9) Effect of Culling on Milk Production by Cull Type	Helpful
10) Effect of Culling on Somatic Cell Count by Cull Type	Helpful
11) Expected Milk Price	Critical
12) Expected Somatic Cell Count Premium	Critical
13) Expected Cull Cow Price	Critical
14) Expected Replacement Heifer Price	Critical
15) Expected Heifer and Bull Calf Price	Critical
16) Expected Heifer and Bull Calf Mortality Rate	Critical
17) Debt to Asset Ratio	Critical
18) Expected Interest Rate	Critical
19) Expected Cost of Equity Capital	Critical
20) Expected Treatment Cost Per Health Cull Type	Critical
21) Expected Feed Cost Per Cow	Critical
22) Expected Labor Cost Per Cow	Critical
23) Expected Other Expense Per Cow	Critical
24) Expected Genetic Improvement Rate	Critical
25) Expected Labor and Other Expense Growth Rate	Critical
26) Cull Reduction Technology Purchase and Installation Expense	Critical
27) Tax-based Depreciable Life of the Technology	Critical
28) Operating Expenses Associated with the Cull Reduction Technology or Program	Critical

IV. Determining the Financial Returns Associated with Reduced Health Culling Rates

In Step 1, the DSS estimates how cattle will move in and out of the herd over a 240 month planning horizon using a farm's ***current*** lactation specific culling rate and within lactation removal schedule. The number of cattle removed and replaced as well as the reason for the cull are recorded. All viable cattle at the end of the 240th month are sold in a herd dispersal sale.

Next, the revenues and expenses for both the retained and culled cattle under the ***current*** culling rate and culling pattern are calculated for each month of the planning horizon. The revenue and expense items include:

a) the proceeds associated with selling mature cattle for dairy purposes;

b) cull cow receipts (adjusted for age and whether the cull was lame or injured);

c) calf value credits;

d) milk revenues (adjusted for the genetic milk production improvement rate and whether a cow is retained or culled);

e) somatic count premiums and discounts (adjusted for whether a cow is retained or culled);

f) feed, labor and other variable expenses; and,

g) a charge for the additional veterinary expenses associated with health cull reasons.

These values are assigned based upon the cow's lactation number, the lactation month the cow is in, the typical production for that lactation and lactation month, whether or not the cow is culled in the lactation month or in a future lactation month in the same lactation, and based upon culling reason. Cattle that are culled typically produce less than their herdmates. Cattle that produce less also tend to eat less than their herdmates. As such, both the feed and labor expenses were adjusted per hundredweight produced.

In Step 3, the present value of the cash flows resulting from the ***current*** culling rate and culling pattern, $PV_{Current}$, are determined by the following formula:

$$PV_{Current} = \sum_{n=0}^{240} \{ [((\text{Mature Cattle Sold for Dairy Purposes Receipts}_n + \text{Cull Cow Receipts}_n + \text{Calf Value Credits}_n + \text{Milk Revenues}_n + \text{SCC Premiums}_n) - (\text{Variable Expenses}_n + \text{Additional Veterinary Expenses}_n)) *(1-t)] / (1-k)^n \}$$

where *"t"* is the farm's marginal tax rate or capital gains tax rate if a capital asset, *"k"* is the farm's after tax weighted average cost of capital, and *"n"* is the planning horizon month.

In Step 4, Step 1 is then repeated using the ***desired*** culling rate and culling pattern offered by the new health cull reduction technology or program. In Step 5, the revenues and expenses for both the retained and culled cattle under the ***desired*** culling rate and culling pattern are calculated for each month of the planning horizon. The revenue and expense items of the ***desired*** culling rate and culling pattern are identical to those of the ***current*** culling rate and pattern except that the desired calculations include the increase in surplus replacement heifer sales.[2] In the sixth step, the present value of the cash flows resulting from the ***desired*** culling rate and culling pattern, $PV_{Desired}$, is determined by the following formula:

$$PV_{Desired} = \sum_{n=0}^{240} \{ [((\text{Mature Cattle Sold for Dairy Purposes Receipts}_n + \text{Cull Cow Receipts}_n + \text{Calf Value Credits}_n + \text{Milk Revenues}_n + \text{SCC Premiums}_n + \Delta\ \text{Surplus Replacement}$$

[2] The increase in surplus heifer sales for any given planning horizon month equals the estimated number of cows culled under the current culling rate and culling pattern in that month minus the estimated number of cows culled under the desired culling rate and culling rate pattern in that same month.

$$\text{Heifer Sales}_n) - (\text{Variable Expenses}_n + \text{Additional Veterinary Expenses}_n))*(1\text{-}t)] / (1\text{-} k)^n \}$$

where *"Δ Surplus Replacement Heifer Sales$_t$"* refers to the change in surplus replacement heifer sales.

The DSS then calculates the present value of the cash flows associated with investing in and operating the proposed health cull reduction technology or program, *$PV_{Investment}$*, using the following formula:

$$PV_{Investment} = -I_0 + \sum_{n=0}^{240} \{ [(-I_{n\,(\text{if greater than } n = 0)} - ((\text{Technology Operating Expenses}_n)*(1\text{-}t)) + (\text{Technology Depreciation Expense}_n * t + \text{Technology Terminal Value}_n)] / (1\text{-} k)^n \}$$

where *"I_n"* refers to an initial investment or reinvestment in the capital assets of the health reduction technology or program, *"Technology Operating Expenses$_n$"* refers to the operating expenses associated with implementing the new technology or program in planning horizon month *n*, *"Technology Depreciation Expense $_n$* t"* refers to the depreciation expense tax shield in planning horizon month *t*, and *"Technology Terminal Value$_n$"* refers to the sale of any of the new health reduction technology or programs capital assets in month *n*.[3]

The DSS then calculates the net present value of the culling rate reduction, *$NPV_{Reduction}$*. This value is calculated by using the following formula:

$$NPV_{Reduction} = PV_{Desired} - PV_{Current} - PV_{Investment}.$$

[3] The DSS automatically assumes that all capital assets of the health reduction technology or program will be sold at the end of their depreciable asset and sold so that no capital gains or capital losses occur. The DSS then automatically reinvests in the technology once again at a cost equal to the initial investment adjusted for inflation. At the end of the 240 month planning horizon, the new technology's capital assets are sold for a price so no capital gains or losses occur.

If the $NPV_{Reduction}$ value is greater than or equal to zero, it indicates that the producer would be financially improved by investing in the new health cull reduction technology or program.

The $NPV_{Reduction}$ value represents the net present value of the cash flows for the entire 240 month period. This value may be difficult for a farm manager or advisor to fully understand. As such, the DSS then makes a subsequent calculation to express the $NPV_{Reduction}$ value as a monthly equivalent expression. This is done using the following formula:

$$\text{Monthly Equivalent Returns} = NPV_{Reduction} / \{[1-(1+k)^{-n}]/k\}.$$

V. The DSS Input Fields

A user starts the DSS by first choosing the correct version for his or her average calving interval.[4] The user then enters the herd size and herd inventory information into the *"Herd Size and Herd Inventory Input Fields"* (Figure 1). The herd size includes all milking and dry cows. It does not include replacement heifers that have not calved. The DSS assumes that the manager has enough replacement cattle to satisfy the replacement needs of the herd. The herd inventory details the number of cattle within a given lactation (1 – 10) and lactation month (1- 13 including two dry period months). In Figure 2, the user has 110 head of milking first lactation cows that are evenly distributed between lactation months 1 through 11. Twenty cows that are waiting to start their second lactation are evenly distributed between the two dry period months.

[4] Currently, only a thirteen month version is available; however, a twelve, fourteen and fifteen month version are planned.

Next, the user inputs the expected milk production per cow per lactation into the *"Expected Production by Lactation Input Field"* (Figure 3). Upon inputting the first lactation expected milk production, the DSS displays the typical production level for the second through tenth lactations in the *"Average Production by Lactation Table"* (also Figure 2.). The milk production estimates in the *"Average Production by Lactation Table"* are determined by multiplying the inputted first lactation production level by the percentages displayed in Chapter 2 Table 1 in the 305 Day Actual Milk column. The user can elect to enter these estimated values for lactations 2 through 10 or enter their own expected values. Figure 2 shows that the user's first lactation cattle are averaging 20,000 pounds per lactation. The average production for the remaining lactations are set according the estimates listed in the *"Average Production by Lactation Table."*

Figure 2. Herd Size and Herd Inventory Input Field

Average number of milking and dry cow herd	130

Herd Inventory										
Lactation Month	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
1	10	0	0	0	0	0	0	0	0	0
2	10	0	0	0	0	0	0	0	0	0
3	10	0	0	0	0	0	0	0	0	0
4	10	0	0	0	0	0	0	0	0	0
5	10	0	0	0	0	0	0	0	0	0
6	10	0	0	0	0	0	0	0	0	0
7	10	0	0	0	0	0	0	0	0	0
8	10	0	0	0	0	0	0	0	0	0
9	10	0	0	0	0	0	0	0	0	0
10	10	0	0	0	0	0	0	0	0	0
11	10	0	0	0	0	0	0	0	0	0
12 (Dry Period)	10	0	0	0	0	0	0	0	0	0
13 (Dry Period)	10	0	0	0	0	0	0	0	0	0

Figure 3. Expected Production by Lactation Input Field

Your Expected Production by Lactation	Pounds
Lactation 1	20000
Lactation 2	22308
Lactation 3	23000
Lactation 4	23136
Lactation 5	22950
Lactation 6	22482
Lactation 7	21790
Lactation 8	21158
Lactation 9	20378
Lactation 10	19736

Average DHIA Production by Lactation	Pounds
Lactation 1	20000
Lactation 2	22308
Lactation 3	23000
Lactation 4	23136
Lactation 5	22950
Lactation 6	22482
Lactation 7	21790
Lactation 8	21158
Lactation 9	20378
Lactation 10	19736

Culled dairy cows – whether sold for dairy purposes, low milk production, or poor health – typically produce less milk than their herdmates. The next input field concerns the producer's expectations concerning the anticipated milk production decrease that a culled animal typically experiences prior to being culled. Figure 4 displays the *"Culling Associated Production Effects Input Field."* The user enters expected production decreases associated with health, mortality, production and sold for dairy culls. A *"DHIA Average Culling Associated Production Effects"* is also displayed to assist the user. These percentages are based upon the comparison of the projected 305 day milk production of healthy cattle versus those of cattle that were culled. This comparison was reported in Chapter 2 . The user can choose to enter the average DHIA values or their own expected values. In the example, the user entered the typical values.

Figure 4. Culling Associated Production Effect Input Field

Your Culling Associated Production Effects	Health Culls	Mortality	Production Culls	Sold for Dairy Culls
Lactation 1 Production % Decrease	6	16	26	11
Lactation 2 Production % Decrease	1	7	7	4
Lactation 3 Production % Decrease	0	6	11	3
Lactation 4 Production % Decrease	1	6	11	3
Lactation 5 Production % Decrease	2	11	10	1
Lactation 6 Production % Decrease	0	7	9	1
Lactation 7 Production % Decrease	-2	5	3	1
Lactation 8 Production % Decrease	0	9	8	5
Lactation 9 Production % Decrease	0	11	7	5
Lactation 10 Production % Decrease	6	14	11	6

Average DHIA Culling Associated Production Effects	Health Culls	Mortality	Production Culls	Sold for Dairy Culls
Lactation 1 Production % Decrease	6	16	26	11
Lactation 2 Production % Decrease	1	7	7	4
Lactation 3 Production % Decrease	0	6	11	3
Lactation 4 Production % Decrease	1	6	11	3
Lactation 5 Production % Decrease	2	11	10	1
Lactation 6 Production % Decrease	0	7	9	1
Lactation 7 Production % Decrease	-2	5	3	1
Lactation 8 Production % Decrease	0	9	8	5
Lactation 9 Production % Decrease	0	11	7	5
Lactation 10 Production % Decrease	6	14	11	6

The fifth and sixth input fields concern somatic cell counts (SCC). Figure 5 shows the *"SCC by Lactation Input Field."* In this field, the user inputs their expected first lactation SCC. Upon entering their expected first lactation SCC, the *"Average DHIA SCC by Lactation"* table displays SCC estimates for lactations 2 through 10. These estimates are made by using the SCC percentage adjustment values shown in Table 1 of Chapter 2. Once again, the user can elect to input these values or their own expected values. In this case, the manager decides to enter the average DHIA SCC values.

Figure 5. SCC by Lactation Input Field

Your SCC by Lactation	SCC
Lactation 1	200000
Lactation 2	254850
Lactation 3	285900
Lactation 4	308700
Lactation 5	326460
Lactation 6	346280
Lactation 7	356460
Lactation 8	358480
Lactation 9	363560
Lactation 10	362060

Average DHIA SCC by Lactation	SCC
Lactation 1	200000
Lactation 2	254850
Lactation 3	285900
Lactation 4	308700
Lactation 5	326460
Lactation 6	346280
Lactation 7	356460
Lactation 8	358480
Lactation 9	363560
Lactation 10	362060

Figure 6. Culling Associated SCC Effect Input Field

Your Culling Associated SCC Effects	Health Culls	Mortality Culls	Production Culls	Sold for Dairy Culls
Lactation 1 SCC % Increase	18.75	5.29	28.56	3.84
Lactation 2 SCC % Increase	14.86	-0.51	19.40	1.90
Lactation 3 SCC % Increase	12.92	-1.15	14.80	3.06
Lactation 4 SCC % Increase	12.71	-4.64	11.44	5.93
Lactation 5 SCC % Increase	12.41	-5.15	12.52	7.09
Lactation 6 SCC % Increase	9.35	-9.61	10.19	6.25
Lactation 7 SCC % Increase	8.68	-4.71	5.98	7.37
Lactation 8 SCC % Increase	10.60	-5.71	8.92	7.03
Lactation 9 SCC % Increase	10.96	-6.13	11.48	3.37
Lactation 10 SCC % Increase	7.83	-7.57	11.11	4.67

Average DHIA Culling Associated SCC Effects	Health Culls	Mortality Culls	Production Culls	Sold for Dairy Culls
Lactation 1 SCC % Increase	18.75	5.29	28.56	3.84
Lactation 2 SCC % Increase	14.86	-0.51	19.40	1.90
Lactation 3 SCC % Increase	12.92	-1.15	14.80	3.06
Lactation 4 SCC % Increase	12.71	-4.64	11.44	5.93
Lactation 5 SCC % Increase	12.41	-5.15	12.52	7.09
Lactation 6 SCC % Increase	9.35	-9.61	10.19	6.25
Lactation 7 SCC % Increase	8.68	-4.71	5.98	7.37
Lactation 8 SCC % Increase	10.60	-5.71	8.92	7.03
Lactation 9 SCC % Increase	10.96	-6.13	11.48	3.37
Lactation 10 SCC % Increase	7.83	-7.57	11.11	4.67

Figure 6 displays the *"Culling Associated SCC Effects Input Field"* and its accompanying *"Average DHIA Culling Associated SCC Effects"* table. Cattle that are culled typically have different SCC than their cohorts (Chapter 2). Thus, the user needs to input the expected SCC percentage increase or decrease associated with a health, mortality, production, or sold for dairy cull. The *"Average DHIA Culling Associated SCC Effects"* table lists the typical SCC adjustments discussed in Chapter 2. In this example, the user chooses to enter the "typical" culling induced SCC increases.

The next two input fields concern the lactation specific culling rates. In the *"Current Lactation Specific Culling Rates Input Field"* (Figure 7), the user enters the current total culling rate and the specific problem culling rate for each lactation. The specific problem culling rates include sold for dairy, low production, udder and SCC, reproduction, disease, and mortality culling rates. The *"Non-Death Health Cull Rates"* and *"Total Culling Rate Check"* values are calculated for the user. Culling rates expressed as a percentage of average annual milking and dry cow herd size as shown in the following formulas:

Total Culling Rate = (Total number of animals culled per year / Average annual milking and dry cow herd size)* 100 % ; and,

Specific Problem Culling Rate = (Total number of animals culled per year for a given problem / Average annual milking and dry cow herd size)*100%.

In situations where lactation specific culling rates are unavailable, typical lactation specific culling rate patterns for various total culling rates are provided. The user can choose lactation specific culling rate patterns based upon breed, herd size, and production

Figure 7. Current Lactation Specific Culling Rates Input Field

Current Lactation Specific Culling Rates	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
Total Culling Rate	29.94	46.20	53.96	61.25	67.24	72.76	77.94	81.35	86.04	89.08
Sold for Dairy Purposes	3.09	2.93	2.33	1.99	1.79	1.79	1.64	1.51	1.66	1.73
Low Production	3.82	5.62	5.68	5.84	5.91	6.30	6.73	7.49	7.38	8.75
Udder and SCC	5.18	8.04	10.44	12.59	14.06	15.35	16.17	15.86	15.30	15.20
Reproduction	6.26	10.98	11.87	12.74	13.64	15.03	15.71	17.39	18.29	17.07
Lameness and Injury	7.58	11.57	14.99	18.33	20.96	23.33	26.22	27.56	31.59	32.79
Disease	0.93	1.85	1.74	1.61	1.56	1.29	1.29	1.17	0.87	1.02
Death	3.09	5.22	6.92	8.16	9.33	9.68	10.19	10.38	10.95	12.53
Non-Death Health Culls	19.94	32.43	39.03	45.26	50.21	54.99	59.39	61.97	66.05	66.08
Total Culling Rate Check	29.94	46.20	53.96	61.25	67.24	72.76	77.94	81.35	86.04	89.08

level. In this instance, the manager and advisor chose the "typical" lactation specific culling rate pattern for a Holstein herd with a 40 to 42 percent average culling rate.

In the *"Desired Lactation Specific Culling Rates Input Field"* (Figure 8), the manager and advisor input the specific lactation culling rate pattern they expect to experience with the new programs the veterinarian has developed. Once again, they can input their own values, or use one of several "typical" patterns offered by the DSS. They have chosen a lactation specific culling rate pattern based upon a culling rate pattern that approximates a Holstein herd with an average total culling rate of 31 to 33 percent.

In Figures 9 and 10, the *"Within Lactation Monthly Removal Schedule for Non-Mortality Health Culls Input Field"* and *"Within Lactation Monthly Removal Schedule for Mortalities Input Field"* are shown respectively. In these fields, user inputs the percentage of cull cattle that leave the herd each lactation month. For instance, Figure 9 shows that 5.35 percent of all cull cattle are removed from the herd in the third lactation month. Figure 10 shows that that 4.73 percent of the fifth lactation cattle mortalities occur in the tenth lactation month. The user may use the average DHIA removal schedules that are displayed next to each of the input fields but are not shown here. In this example, the user chose to use the average DHIA values.

Figure 8. **Desired Lactation Specific Culling Rates Input Field**

Desired Lactation Specific Culling Rates	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
Total Culling Rate	22.26	33.65	38.64	43.44	47.39	51.20	54.75	57.23	60.37	62.88
Sold for Dairy Purposes	3.09	2.93	2.33	1.99	1.79	1.79	1.64	1.51	1.66	1.73
Low Production	3.82	5.62	5.68	5.84	5.91	6.30	6.73	7.49	7.38	8.75
Udder and SCC	3.45	5.36	6.96	8.39	9.37	10.23	10.78	10.57	10.20	10.13
Reproduction	4.17	7.32	7.91	8.49	9.09	10.02	10.47	11.59	12.19	11.38
Lameness and Injury	5.05	7.71	9.99	12.22	13.97	15.55	17.48	18.37	21.06	21.86
Disease	0.62	1.23	1.16	1.07	1.04	0.86	0.86	0.78	0.58	0.68
Death	2.06	3.48	4.61	5.44	6.22	6.45	6.79	6.92	7.30	8.35
Non-Death Health Culls	13.29	21.62	26.02	30.17	33.47	36.66	39.59	41.31	44.03	44.05
Total Culling Rate Check	22.26	33.65	38.64	43.44	47.39	51.20	54.75	57.23	60.37	62.88

Figure 9. Within Lactation Monthly Removal Schedule for Non-Mortality Health Culls Input Field

Lactation Month	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
1	8.39	7.93	10.30	11.59	12.38	12.60	12.14	12.39	12.28	10.67
2	7.59	5.07	5.72	5.99	5.88	6.04	6.28	6.05	6.22	5.80
3	6.15	4.85	5.10	5.35	5.58	5.98	5.95	5.94	5.52	6.07
4	5.18	4.90	5.33	5.48	5.88	5.85	6.11	5.82	6.66	6.99
5	4.76	5.20	5.47	5.69	5.96	6.19	6.16	5.65	6.69	7.93
6	4.64	5.58	5.86	5.99	6.18	6.23	6.29	6.82	5.68	6.55
7	4.77	6.06	6.20	6.38	6.47	6.45	6.72	6.56	7.55	5.89
8	4.84	6.73	6.76	6.66	6.79	6.66	6.88	7.29	6.59	7.53
9	5.66	7.33	7.54	7.59	7.16	7.17	7.09	7.10	6.96	6.46
10	7.56	9.08	8.59	8.17	7.80	7.66	7.70	7.33	7.18	8.85
11	40.49	36.77	33.11	30.93	29.91	29.18	28.67	29.05	28.68	27.27
12 (Dry Period)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13 (Dry Period)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 10. Within Lactation Monthly Removal Schedule for Mortalities Input Field

Lactation Month	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
1	23.11	28.04	36.82	41.23	43.84	45.90	46.07	45.40	43.63	43.36
2	9.00	7.70	8.42	7.89	7.69	7.33	6.80	6.67	7.17	6.76
3	6.11	5.43	5.14	5.02	5.02	4.50	5.67	4.89	5.57	7.00
4	4.67	4.44	4.30	4.15	3.96	4.02	3.97	3.46	5.32	4.99
5	4.11	4.15	3.88	3.27	3.42	3.39	3.64	4.14	3.04	3.78
6	4.00	3.95	3.20	3.03	2.97	2.60	2.51	3.12	3.29	2.01
7	3.78	3.75	3.20	2.87	2.89	2.60	2.43	3.29	2.36	3.54
8	4.11	4.05	3.29	2.95	2.82	2.84	2.27	2.45	3.21	2.98
9	4.67	5.13	3.88	3.51	3.42	3.08	3.56	3.46	3.88	3.54
10	7.22	7.40	5.81	5.10	4.73	4.50	4.94	4.97	3.88	3.54
11	29.22	25.67	22.07	20.97	19.25	19.32	18.14	18.57	18.65	18.58
12 (Dry Period)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13 (Dry Period)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 11. Other Production and Financial Information Input Field

Other Production and Financial Information	Value
Interest Rate (%)	7.5
Debt to Asset Ratio (%)	50
Cost of Equity Capital (%)	10
Equity to Asset Ratio (%)	50
Marginal Tax Rate (%)	0
Capital Gains Tax Rate (%)	0
After Tax Weighted Average Cost of Capital (%)	8.75
Replacement Heifer Price ($/cow)	1350
Typical Cull Cow Price ($/cow)	350

Expected Milk Price Received Less SCC Premiums/Discount ($/cwt)	13.5
Expected Heifer Calf Price ($/calf)	200
Heifer Calf Mortality (%)	6
Expected Bull Calf Price ($/calf)	75
Bull Calf Mortality (%)	6
Expected Feed Cost ($/cow)	982
Expected Labor Cost ($/cow)	646
Expected Other Variable Costs ($/cow)	853
Expected Cost per Dry Cow Month ($/cow)	45
Typical Treatment Cost per Udder and Mastitis Health Problem Episode ($/treated cow culled)	133
Typical Treatment Cost per Reproductive Health Problem Episode ($/treated cow culled)	192
Typical Treatment Cost per Lameness Episode ($/treated cow culled)	9
Typical Treatment Cost per Disease Episode ($/treated cow culled)	112
Somatic Cell Premium/Discount ($/cwt)	0.00063
Milk Production Genetic Improvement Rate (% per generation)	1.0
Feed Expense Adjustment Factor Required to Support a 1% Milk Revenue Increase Associated with Genetic Improvement	0.9
Labor Expense Annual Increase (% per year)	0.0
Other Variable Expense Annual Increase (% per year)	0.0

Figure 11 displays the *"Other Production and Financial Information Input Field."* This input field concerns the other pertinent production and financial information needed to run the DSS. Two of the input field items, the Equity to Asset Ratio and the After Tax Weighted Average Cost of Capital are calculated automatically. The Equity to Asset Ratio is calculated by subtracting the Debt to Asset Ratio from 1. The After Tax Weighted Average Cost of Capital (WACC) is calculated according to the following formula:

$$\text{WACC} = \{ [(\text{Debt to Asset Ratio})*(\text{Interest Rate}/100) + (\text{Equity to Asset Ratio})*(\text{Cost of Equity Capital}/100)] * (1- (\text{Marginal Tax Rate }/100) \}$$

In this example, the manager and her advisor have decided to analyze their culling reduction problem on a before tax basis. As such, they have inputted a "0" into the Marginal Tax Rate and Capital Gains Tax Rate input rows.

The purpose of the *"Lactation Expense Adjustment Input Field"* of Figure 12 is to adjust the production costs entered in the *"Other Production and Financial Information Input Field"* for cow age. An *"Average Lactation Expense"* table (also Figure 12) is displayed by the DSS to provide the user with "typical" lactation expense adjustments. The values for the average expense adjustments were developed from work done by Bauer, Mumey, and Lohr (1993). The values listed in the Average Expense Adjustment Table assume that the costs entered in the Other Production and Financial Information Input Field are representative of a second lactation cow.

Figure 12. Lactation Expense Adjustment Input Field

Lactation Expense Adjustment	Value
Lactation 1	0.963
Lactation 2	1.000
Lactation 3	1.022
Lactation 4	1.057
Lactation 5	1.075
Lactation 6	1.112
Lactation 7	1.114
Lactation 8	1.116
Lactation 9	1.119
Lactation 10	1.125

Average Lactation Expense Adjustment	Value
Lactation 1	0.963
Lactation 2	1.000
Lactation 3	1.022
Lactation 4	1.057
Lactation 5	1.075
Lactation 6	1.112
Lactation 7	1.114
Lactation 8	1.116
Lactation 9	1.119
Lactation 10	1.125

Figure 13 displays the *"Health Cull and Mortality Reduction Technology Investment Input Field."* To indicate that a farm will incur additional annual operating expenses or whether an investment in a three-, five-, seven-, or ten year asset is required, the user would enter a "1" in the appropriate cell(s) of the *"New Technology Investment Type"* row. If an increase in annual operating expense or an investment in a specific asset is not required, the user enters a "0" in the appropriate cell(s). In the *"Cost of Purchasing, Installation, and Implementation"* row, the user enters the increase in annual operating expenses and the investment needed in capital assets to achieve the health cull reduction. In this example, the user has entered that the plan to reduce health culls would cost an addition $10,000 per year and that no additional investments will be needed.

Figure 13. Health Cull and Mortality Reduction Technology Investment Input Field

	Additional Annual Operating Expense	Three Year Asset	Five Year Asset	Seven Year Asset	Ten Year Asset
New Technology Investment Type (Yes = 1; No = 0)	1	0	0	0	0
Cost of Purchasing, Installation, and Implementation	$10000	0	0	0	0
Operating Expense Growth Rate (%)	0				

VI. DSS Calculations and Output Fields

This section explains the calculations used by the DSS to determine the financial feasibility of a farm reducing culling rates as well as the output fields the DSS generates. The section will proceed by describing the calculations and output fields for the :

1) herd inventory dynamics for the ***current*** culling rate and culling pattern;

2) financial returns of the ***current*** culling rate and culling pattern;

3) herd inventory dynamics for the ***desired*** culling rate and culling pattern;

4) financial returns of the ***desired*** culling rate and culling pattern;

5) cash flows of the proposed health cull reduction technologies investments and operating costs; and,

6) net present value of the proposed culling rate reduction.

Calculations and Output Fields for the Current Culling Rate

Figure 14 displays the number of cattle of a particular lactation and lactation month that are removed from the herd and retained in the herd during each month of a 240 month planning horizon period. One can see that during month 1 of the 240 month planning horizon that the dairy farm manager will have ten first lactation cows in lactation month 1. During this month, a total of 0.429 of the case study farm's ten lactation 1 month 1 cows are culled for the following reasons:

Sold for Dairy Purposes:	0.155 cows;
Production Culls:	0.035 cows;
Mortalities:	0.071 cows;
Udder and SCC Culls:	0.043 cows;
Reproduction Culls:	0.053 cows;
Lameness and Injury Culls:	0.064 cows; and,
Disease Culls:	0.008 cows.

These numbers were calculated by applying the following formula:

(Number of Lactation *n* Month *t* Cows in Planning Horizon Month *n*)
* (Current Lactation *n* Culling Rate for a Specific Culling Reason)
* (Within Lactation Monthly Removal Percentage for Lactation *n* Cattle)
= Number of Lactation 1 Month 1 Cows Removed for a Specific Reason

All *"Current Lactation n Culling Rate for a Specific Culling Reason"* values are found in Figure 7, the *"Current Lactation Specific Culling Rate Input Field"*. The "*Within Lactation Monthly Removal Percentage for Lactation n Cattle*" values are determined by various methods. It was assumed that cattle sold for dairy purposes are

Figure 14. Current Herd Inventory Dynamics Output Field

Planning Horizon Month:	1	2	→	240	Dispersal Sale
Lactation 1 Month 1 Cows	**10.000**	**2.994**	→	**4.538**	
Sold for Dairy Purposes	0.155	0.046	→	0.070	
Production Culls	0.035	0.010	→	0.016	
Mortalities	0.071	0.021	→	0.013	
Udder and SCC Culls	0.043	0.013	→	0.020	
Reproduction Culls	0.053	0.016	→	0.024	
Lameness and Injury Culls	0.064	0.019	→	0.029	
Disease Culls	0.008	0.002	→	0.004	
Cattle Transferred	9.571	0.050	→	4.363	4.363
Lactation 1 Month 2 Cows	**10.000**	**9.571**	→	**4.344**	
Sold for Dairy Purposes	0.000	0.000	→	0.000	
Production Culls	0.035	0.033	→	0.015	
Mortalities	0.028	0.027	→	0.012	
Udder and SCC Culls	0.039	0.038	→	0.017	
Reproduction Culls	0.048	0.045	→	0.021	
Lameness and Injury Culls	0.058	0.055	→	0.025	
Disease Culls	0.007	0.007	→	0.003	
Cattle Transferred	9.786	9.367	→	4.251	4.251
↓	↓	↓		↓	↓
Lactation 10 Month 11 Cows	**0.000**	**0.000**	→	**0.005**	
Sold for Dairy Purposes	0.000	0.000	→	0.000	
Production Culls	0.000	0.000	→	0.004	
Mortalities	0.000	0.000	→	0.000	
Udder and SCC Culls	0.000	0.000	→	0.000	
Reproduction Culls	0.000	0.000	→	0.000	
Lameness and Injury Culls	0.000	0.000	→	0.001	
Disease Culls	0.000	0.000	→	0.000	
Cattle Transferred	0.000	0.000	→	0.000	0.000
Monthly Totals					
Total Beginning Animals	130.00	130.00	→	130.00	
Total Sold for Dairy	0.31	0.34	→	0.29	
Total Production Culls	0.38	0.40	→	0.51	
Total Mortalities	0.31	0.40	→	0.56	
Total Udder and SCC Culls	0.52	0.54	→	0.83	
Total Reproduction Culls	0.63	0.66	→	0.98	
Total Lameness and Injury Culls	0.76	0.79	→	1.22	
Total Disease Culls	0.09	0.10	→	0.14	
Total Replacements Required	2.99	3.24	→	4.51	
Estimate Annual Culling Rate	27.64	28.79	→	41.87	

sold either in lactation month 1 or at the end of lactation month 11 in all lactations except for Lactation 10. As such, the "*Within Lactation Monthly Removal Percentage for Lactation n Cattle*" value for lactation months 1 and 11 is 50 percent. No cattle are sold for dairy purposes during lactation months 2 through 10. In Lactation 10, all of the sold for dairy purposes culls are removed in the first lactation month. Thus, the "*Within Lactation Monthly Removal Percentage for Lactation 11 Cattle*" is 100 percent. To calculate the number of lactation 1 cattle that are culled for dairy purposes in lactation month 1 and planning horizon month 1, the following calculation is made:

(10 Lactation 1 Month 1 Cows in Planning Horizon Month 1)
* (3.09 Percent Removed for Sold for Dairy Purposes)
* <u>(50 Percent Removed in Lactation Month 1)</u>
0.155 Lactation 1 Month 1 Cattle Removed for Sold for Dairy Purposes in Planning Horizon Month 1.

For production culls, the DSS assumes that there is an equal probability that a production cull can occur at any time during the eleven lactation months. Thus, the "*Within Lactation Monthly Removal Percentage for Lactation n Cattle*" for all cattle is 9.09 percent. For the lactation 1 month 1 cattle in the first planning horizon month of the case study situation there are 0.035 Lactation 1 Month1 cattle culled for production reasons. This value was calculated in the following manner:

(10 Lactation 1 Month 1 Cows in Planning Horizon Month 1)
* (3.82 Percent Culled for Production Reasons)
* <u>(9.09 Percent Removed in Lactation Month 1)</u>
0.035 Lactation 1 Month 1 Cattle Culled for Production Reasons in Planning Horizon Month 1.

For cattle that are culled due to non-mortality health culls, the *"Within Lactation Monthly Removal Percentage for Lactation n Cattle"* can be found in Figure 9, the *"Within Lactation Monthly Removal Schedule for Non-Mortality Health Culls Input Field."* Thus, the number of Lactation 1 Month 1 cattle culled for reproduction is calculated by:

(10 Lactation 1 Month 1 Cows in Planning Horizon Month 1)
* (6.26 percent culled for reproduction reasons)
* (8.39 percent removed in Lactation Month 1)

0.053 Lactation 1 Month 1 Cattle Culled for Reproduction Reasons in Planning Horizon Month 1.

To determine the number of Lactation ***n*** Month ***t*** cattle that die during a particular planning horizon month, the percentage of lactation ***n*** cattle that are removed due to mortalities can be found in Figure 7, the *"Current Lactation Specific Culling Rate Input Field"*. The appropriate *"Within Lactation Monthly Removal Percentage for Lactation n Cattle"* value can be found in Figure 10, the *"Within Lactation Monthly Removal Schedule for Mortalities Input Field."* For Lactation 1 Month 1 Cows, the number of mortalities in Planning Horizon Month 1 is calculated as follows:

(10 Lactation 1 Month 1 Cows in Planning Horizon Month 1)
* (3.09 percent Mortality Rate)
* (23.11 percent removed in Lactation Month 1)

0.071 Lactation 1 Month 1 Cattle Mortalities in Planning Horizon Month 1

This process is repeated for 240 Planning Horizon Months. At the end of the 240th Planning Horizon Month, the surviving cattle are sold for dairy purposes in a dispersal sale.

Figure 15. Current Monthly Cash Flows Output Field

Month:	1	→	240
Sold for Dairy Purposes Cull Proceeds	$403	→	$149,845
Production Cull Proceeds	$134	→	$177
Non-mortality and Non-lame and Injured Health Cull Proceeds	$433	→	$666
Lame and Injured and Aged Cow Health Cull Proceeds	$289	→	$442
Calf Credit Proceeds	$1,210	→	$1,485
Base Milk Returns for Lactation 1 Cattle	$3,984	→	$3,224
↓	↓	→	↓
Base Milk Returns for Lactation 10 Cattle	$0	→	$1
Lactation 1 Sold for Dairy Cull Return Adjustments	-$8	→	-$3
↓	↓	→	↓
Lactation 10 Sold for Dairy Cull Return Adjustments	$0	→	$0
Lactation 1 Production Cull Return Adjustments	-$29	→	-$9
↓	↓	→	↓
Lactation 10 Production Cull Return Adjustments	$0	→	-$1
Lactation 1 Non-mortality Health Cull Return Adjustments	-$25	→	-$7
↓	↓	→	↓
Lactation 10 Non-Mortality Health Cull Return Adjustments	$0	→	$0
Lactation 1 Mortality Return Adjustments	-$14	→	-3
↓	↓	→	↓
Lactation 10 Mortality Return Adjustments	$0	→	$0
Health Cull Treatment Costs	-$241	→	-$421
Net Monthly Returns	**$6,138**	→	**$162,043**
Present Value of Monthly Returns	**$6,093**	→	**$28,338**
Net Present Value of Total Returns	**$1,081,513**		

The DSS then determines the present values of the revenues and expenses associated with the ***current*** culling rate and culling pattern (Figure 15). The ***current*** culling rate and culling pattern has a net present value of total returns of $1,238,817. To calculate this value, the DSS first determined the proceeds for the mature cattle that were sold for dairy purposes. The value for a sold for dairy purposes cow was calculated using the following protocols:

1) If the cow sold for dairy purposes was sold as a lactation 1 month 1 cow, the cow was valued at the replacement heifer price;

2) If the cow was sold for dairy purposes in lactation 10 month 1, the cow was valued at the cull cow price plus \$100;

3) No tenth lactation cattle beyond lactation month 1 can be sold for dairy purposes by the DSS; and,

4) All other sold for dairy purpose values were determined using the following formula:

$$\text{Value}_{\text{Lactation } n} = \text{Value}_{\text{Lactation } n-1} - [(\text{Replacement Heifer Price} - \text{Cull Cow Price} + \$100)] / 10; \text{ and,}$$

5) If the cow was sold in lactation month 11 of any lactation, it was assigned the sold for dairy proceed value of the subsequent lactation.

In the case study, replacement dairy heifers were valued at \$1,350 per cow and the cull cow value was \$350. As such, the Sold for Dairy Purposes Proceeds per cow for each lactation were calculated as they appear in Figure 16.

Figure 16. The Sold for Dairy Proceeds Value Output Field

Lactation Number	Sold for Dairy Proceeds Value (\$/cow)
1	\$1,350
2	\$1,260
3	\$1,170
4	\$1,080
5	\$990
6	\$900
7	\$810
8	\$720
9	\$630
10	\$450

The production and non-mortality health cull proceed values were calculated by the DSS according to the following protocols:

1) Cattle that had milked less than four lactations and were not culled for being lame or injured were assigned the full *"Typical Cull Cow Price"* value (Figure 11);

2) Cattle that had milked more than three lactations but less than seven lactations and were not culled due to lameness and injuries were assigned the typical cull cow price value minus four percent; and,

3) Cattle that had milked more than six lactations or cattle that were culled due to lameness or injury were assigned the typical cull cow price value minus seventeen percent.

These protocols were adapted from the work of Mumey, Bauer, and Lohr (1993). For the case study scenario, the user inputted that the typical cull cow price was $350 per head. Thus, cull cow values were allocated according to Figure 17.

Figure 17. Cull Cow Proceeds Value Output Field

Cull Cow Type	Cull Cow Proceed Value ($/cow)
Less Than Four Lactations Old	$350
More Than Three Lactations Old But Less Than Seven Lactations Old	$336
More Than Six Lactations Old	$291
Lame or Injured Cattle	$291

To determine the Expected Calf Credit, the following formula was used:

Expected Calf Credit = [(1- (Bull Calf Mortality/100))*(Expected Bull Calf Price)] + [(1 – (Heifer Calf Mortality/100))*(Expected Heifer Calf Price)].

In the case study example, the user specified an expected bull calf price of $75, a bull calf mortality rate of 6 percent, a heifer calf price of $200, and an a heifer half mortality of 6 percent. This resulted in an Expected Calf Credit of $121 per cow per lactation.

"Base Milk Returns" (BMR) were calculated for each cow at the beginning of each planning horizon month according to the following formula:

BMR = Milk Revenues(Cows) + SCC Premium(Cows) – Feed Cost – Labor Costs – Other Variable Costs.

The monthly BMR were determined by multiplying the *"Expected Production by Lactation"* (Figure 3) value by the *"Expected Milk Price Received Less SCC Premiums/Discount"* (Figure 11). In order to do this, the Expected Production by Lactation Value had to be divided by eleven months and adjusted by the genetic improvement rate according to the following:

$$\text{Monthly Production} = (\text{Expected Production by Lactation}/11)^{*} (1+\text{MPGIR}/100)^{g},$$

where *"MPGIR"* refers to the Milk Production Genetic Improvement Rate (Figure 11) and *"g"* refers to the cows generation number.[5] SCC premiums were calculated using the following formula:

$$\text{SCC Premium} = ((350-(\text{SCC}/1000))^{*}(\text{Monthly Production}/100)^{*}(\text{ Somatic Cell Premium/Discount}).$$

Feed costs were determined using the feed cost information that the manager and her advisor inputted into Figure 11, the Other Production and Financial Information Input Field. As milk production improved through the Milk Production

[5] For the cattle that are in the herd or enter the herd the first 13 planning horizon months, g always equals 0 throughout their life in the herd. For first lactation animals that enter the herd during planning horizon months 14 – 26, g always equals 1throughout their life in the herd. For first lactation animals that enter the herd during planning horizon months 27 – 39, g always equals 2 throughout their life in the herd. This process is repeated throughout the planning horizon months with the first lactation animals receiving a one unit g increase every fourteen months.

Genetic Improvement Rate, the feed costs were adjusted upward by the *"Feed Expense Adjustment Factor"* (FEAF; Figure 10) and the *"Lactation Expense Adjustment Factor"* (LEAF; Figure 11). Thus, feed costs were calculated using the following formula:

Feed Costs = (Expected Feed Cost)*[(1+[(MPGIR/100)*(FEAF))^{g}] * (LEAF).

Labor and Other Variable Expenses were assigned to each cow based upon the information supplied by the manager and advisor in Figure 11. These values can be adjusted annually to reflect the manager's expected *"Labor Expense Annual Increase,"* the *"Other Variable Expense Annual Increase"* and *"LEAF."*

Once the Base Milk Returns are calculated, the DSS then charges a production loss charge for each type of cull that occurs in the planning horizon month. These are called Return Adjustments in Figure 16. The charges are assigned to the cull cows based upon the information provided by the manager in Figure 4, the *"Culling Associated Production Effects Input Field"*, and Figure 6, the *"Culling Associated SCC Effect Input Field."* A charge is added to the current planning horizon month if a cow in the current month is removed anytime during its eleven month lactation period. For example, if a cow began milking as a lactation 1 month 1 cow and is removed in the 3rd planning horizon month, this charge is assigned to lactation months 1, 2 and 3.

Another charge was added to reflect the increased veterinary charges that may occur with cattle prior to them being culled for health purposes, the Health Cull Treatment Cost. This charge was equal to the number of cattle culled for a particular reason times the appropriate *"Typical Treatment Cost per ___ Episode"* that the dairy farm manager and her advisor listed in Figure 11. The DSS assigns the *"Typical Treatment Cost per Disease Episode"* charge for cattle that die during the planning horizon month. The values for the treatment costs shown in Figure 11 were adapted from the work of Weigler et al. (1990).

The Net Monthly Returns were calculated by adding up the proceeds, returns, return adjustments, and health cull treatment costs. The Net Monthly Returns for each planning horizon month was discounted by the weighted average cost of capital to determine the Present Value of Monthly returns. The formula for accomplishing this is as follows:

Present Value of Monthly Returns$_n$ = Net Monthly Returns$_t$/ $(1+(k/100))^n$.

Next, all of the Present Value of Monthly Returns are added up to determine the Net Present Value of Total Returns for the current culling rate and culling pattern.

Calculations and Output Fields for the Desired Culling Rate

Figures 18 and 19 display the output for the Desired Culling Rate and Culling Pattern. The only difference between these calculations and those for the Current Culling Rate and Culling pattern are the lower lactation specific culling rates and the additional surplus replacement heifer sales.

Figure 18. Desired Herd Inventory Dynamics Output Field

Planning Horizon Month:	1	2	→	240	Dispersal Sale
Lactation 1 Cows Month 1	**10.000**	**2.226**	→	**4.538**	
Sold for Dairy Purposes	0.155	0.0344	→	0.070	
Production Culls	0.035	0.008	→	0.016	
Mortalities	0.048	0.011	→	0.013	
Udder and SCC Culls	0.029	0.006	→	0.020	
Reproduction Culls	0.035	0.008	→	0.024	
Lameness and Injury Culls	0.042	0.009	→	0.029	
Disease Culls	0.005	0.001	→	0.004	
Cattle Transferred	9.652	2.149	→	4.363	4.363
Lactation 1 Cows Month 2	**10.000**	**9.652**	→	**4.344**	
Sold for Dairy Purposes	0.000	0.000	→	0.000	
Production Culls	0.035	0.034	→	0.015	
Mortalities	0.028	0.018	→	0.012	
Udder and SCC Culls	0.039	0.025	→	0.017	
Reproduction Culls	0.048	0.031	→	0.021	
Lameness and Injury Culls	0.058	0.037	→	0.025	
Disease Culls	0.007	0.005	→	0.003	
Cattle Transferred	9.786	9.503	→	4.251	4.251
↓	↓	↓		↓	↓
Lactation 10 Cows Month 11	**0.000**	**0.000**	→	**0.030**	
Sold for Dairy Purposes	0.000	0.000	→	0.000	
Production Culls	0.000	0.000	→	0.026	
Mortalities	0.000	0.000	→	0.001	
Udder and SCC Culls	0.000	0.000	→	0.001	
Reproduction Culls	0.000	0.000	→	0.001	
Lameness and Injury Culls	0.000	0.000	→	0.001	
Disease Culls	0.000	0.000	→	0.000	
Cattle Transferred	0.000	0.000	→	0.000	0.000
Monthly Totals					
Total Beginning Animals	130.00	130.00	→	130.00	
Total Sold for Dairy	0.31	0.33	→	0.27	
Total Production Culls	0.38	0.40	→	0.82	
Total Mortalities	0.21	0.26	→	0.41	
Total Udder and SCC Culls	0.35	0.36	→	0.62	
Total Reproduction Culls	0.42	0.44	→	0.71	
Total Lameness and Injury Culls	0.51	0.53	→	0.92	
Total Disease Culls	0.06	0.07	→	0.10	
Total Replacements Required	2.23	2.39	→	3.84	
Estimate Annual Culling Rate	20.55	21.32	→	33.13	

Figure 19. Desired Monthly Cash Flows Output Field

Month:	**1**	→	**240**
Sold for Dairy Purposes Cull Proceeds	$403	→	$145,506
Production Cull Proceeds	$134	→	$280
Non-mortality and Non-lame and Injured Health Cull Proceeds	$288	→	$461
Lame and Injured and Aged Cow Health Cull Proceeds	$193	→	$359
Calf Credit Proceeds	$1,210	→	$1,426
Milk Returns for Lactation 1 Cattle	$3,984	→	$2,632
↓	↓	→	↓
Milk Returns for Lactation 10 Cattle	$0	→	-$8
Lactation 1 Sold for Dairy Cull Return Adjustments	-$8	→	-$2
↓	↓	→	↓
Lactation 10 Sold for Dairy Cull Return Adjustments	$0	→	$0
Lactation 1 Production Cull Return Adjustments	-$29	→	-$7
↓	↓	→	↓
Lactation 10 Production Cull Return Adjustments	$0	→	-$6
Lactation 1 Non-mortality Health Cull Return Adjustments	-$17	→	-$4
↓	↓	→	↓
Lactation 10 Non-Mortality Health Cull Return Adjustments	$0	→	$0
Lactation 1 Mortality Return Adjustments	-$9	→	-$2
↓	↓	→	↓
Lactation 10 Mortality Return Adjustments	$0	→	$0
Health Cull Treatment Costs	-$161	→	-$312
Returns from Additional Surplus Heifer Sales	$1,036	→	$902
Net Monthly Returns	**$7026**	→	**$158,414**
Present Value of Monthly Returns	**$6,975**	→	**$27,703**
Net Present Value of Total Returns	**$1,204,012**		

Calculations and Output Fields for the Investment Cash Flows

Figure 20 displays the output field that shows the cash flows associated with the health reduction technology or program investment. The figure indicates that the farm will incur $833 in monthly operational expenses to implement the health reduction program. The $833 was calculated by dividing the $10,000 *"Cost of Purchasing, Installation, and Implementation"* value listed in Figure 13 by twelve months. This value was inflated each year throughout the 240 planning horizon months by the *"Operating Expense Growth Rate"* also listed in Figure 13.

Figure 20. The Cash Flows Associated with the Health Cull and Mortality Reduction Technology and Programs Output Field

Health Cull and Mortality Reduction Investments and Expenses	**Initial Investment**	**Month 1**	**→**	**Month 240**
Technology Purchase and Installation	0	0	→	0
After Tax Operating Expenses	0	$833	→	$833
Depreciation Shield	0	0	→	0
Terminal Value	0	0	→	0
Monthly Health Cull and Mortality Reduction Technology and Program Cash Flows	0	-$833	→	-$833
Present Value of Monthly Health Cull and Mortality Reduction Technology and Program Cash Flows	0	-$827	→	-$146
Total Present Value of Health Cull and Mortality Reduction Technology and Program Cash Flows	-$94,299			

The technology purchase and installation value, the after tax operating expenses, the depreciation shield and terminal value were added up in each month to calculate the *"Monthly Health Cull and Mortality Reduction Technology and Program Cash Flows."* These values were discounted by the weighted average cost of capital according to determine the *"Present Value of Monthly Health Cull and Mortality Reduction Technology and Program Cash Flows."* By adding all 240 monthly values up, the *"Total Present Value of Health Cull and Mortality Reduction Technology and Program Cash Flows"* was determined.

The Calculations and Output Fields For the Net Present Value of the Desired Culling Rate Pattern

The NPV $_{\text{Reduction}}$ for the example is $28,200 (Figure 21). As $28,200 is greater than zero, the management program should be adopted because, after discounting all cash flows to today's values, there are $28,200 after accounting for the additional revenues and expenses of the program as well as the opportunity cost of the dairy farm manager's and lender's capital. By converting the NPV to a monthly value, the DSS indicates that the farm manager can expect to return an additional $249 per month after paying off the variable expenses and her and her lender's opportunity cost of capital.

Figure 21. The Financial Implications of the Health Cull and Mortality Reduction Technology and Program Output Field

Financial Implications of the Health Cull and Mortality Reduction Technology and Program	
Present Value of Returns of the Desired Culling Rate Pattern	$1,204,012
Present Value of Returns of the Current Culling Rate Pattern	$1,081,513
Present Value of the Health Cull and Mortality Reduction Technology and Program Cash Flows	-$94,299
Net Present Value of Reducing the Desired Culling Rate Pattern	$28,200
Monthly Equivalent Returns	$249

Figure 22 shows the before and after effects of the proposed program on total culling rate. Without the program, the user expected to have an average estimated culling rate of 41.49 percent. With the proposed program, the user expects to experience an average annual culling rate of 32.40 percent.

Figure 22. The Estimated Annual Culling Rates with and without Adopting the Health Cull and Mortality Reduction Technology and Program Output Field

Culling Rate Type	**Low Estimated Annual Culling Rate (%)**	**Average Estimated Annual Culling Rate (%)**	**High Estimated Annual Culling Rate (%)**
Culling Rate ***with*** the New Health Cull and Mortality Reduction Technology and Program	24.20	32.40	33.46
Culling Rate ***without*** the New Health Cull and Mortality Reduction Technology and Program	32.60	41.49	42.00

This chapter described how to use a prototype DSS to determine whether it is financially feasible to reduce culling rates through the adoption of technological investments or management programs. In Chapter VI, this DSS is applied to determine the potential returns for dairy farms that differ in current culling rate, size, and breed.

CHAPTER 6.

THE FINANCIAL FEASIBILITY OF DECREASING CULLING RATES ON DAIRY FARMS

I. Introduction

A DSS was described in the previous chapter. This DSS enables a manager or advisor to determine whether it is economical to reduce health culling rates. In this chapter, the DSS is used to estimate the maximum amount that managers of dairy farms with various characteristics would be willing to pay per month for a ten percent reduction in their lactation specific health culling rate and for ten percent reductions in specific types of health culls. This monthly amount will be called the breakeven annuity (BEA). The characteristics include the initial lactation specific health culling rates, cattle breed, and herd size of the farms. The DSS will also be used to determine if an investment in two health cull reduction technologies, rubberized floors for cattle walkways to reduce lameness and injury culls and using gonadotropin releasing hormone (GNRH) to reduce reproduction culls, is profitable.

Determining how much a farmer can pay for a health cull reduction is important. If a producer under invests in health culling rate technologies or programs, the costs associated with health culls – production losses, treatment expenses, and the cash flows associated with the replacement of unhealthy cattle – become excessive. On the other hand, if a producer over invests in health cull reduction technology, the resulting lower culling rate will be less profitable than the current higher culling rate. Furthermore, understanding how the BEA varies based upon farm characteristics is important to understand as well. If the marginal BEA is somewhat constant, producers will have little need to run the DSS after each successive health cull reduction. If not, the DSS will need to be run after each successive reduction. If cattle breed and or herd size affects the BEA, advisors will need to make separate BEA estimates for farms that vary by breed and size.

II. General Methods and BEA Estimate Categories

To show how different dairy farm characteristics affect the BEA for a ten percent health cull reduction, a series of estimates were made using the DSS described in Chapter 5. To estimate the BEA, the costs in the Health Cull and Mortality Reduction Technology Investment Input Field were set equal to zero. The resulting equivalent value for the ten percent health culling rate reduction would then represent the maximum amount a farm manager would be willing to pay monthly for the ten percent reduction in health culling rates for a 240 month period.

In the first series of category of estimates, the BEA is calculated for ten example farms. One of the example farms, *"Sample Average,"* exhibited the average lactation specific health culling rates of the DHIA farms in the ten Midwestern and Northeastern states using the DHIA data first shown in Chapter 2. Five of the example farms exhibited from ten to fifty percent higher lactation specific culling rates than the DHIA sample average, and four of the example farms exhibited from ten to forty percent lower health culling rates than the sample average. The methods used to estimate the BEA and the estimation results for the typical Midwestern and Northeastern DHIA farm category are discussed further in Section III.

In Section IV, the BEA is estimated for farms that use three different breeds of cattle: Holstein; Jersey; and Guernsey cattle. Estimates for Holsteins were conducted because the breed is the predominant breed in the United States. Estimates for the Jersey breed were chosen because they exhibit a lower likelihood of being culled (Chapter 3), produce less milk, and yield a higher valued milk than Holstein cattle. Estimates for Guernsey cattle were made because they exhibit a higher likelihood of being culled (Chapter 3), produce less milk, and yield a higher valued milk than Holstein cattle. Estimates were made for ten example farms within each the breed category. One farm, *"Breed Average,"* exhibited the breed average lactation specific health culling rates. Five of the example farms exhibited from ten to fifty percent higher lactation specific health culling rates than the breed average culling rates, and four of the example farms exhibited lactation specific culling rates that were from 10 to 40 percent lower than the breed average. The methods used to estimate the BEA and the estimation results for the breed categories are further discussed in Section IV.

The BEA was then estimated for a category of dairy farms based on herd size. The first group of farms consisted of ten farms with a herd size of 130 cows. The second group of farms consisted of ten, 390 cow dairy farms. The third group of farms in the herd size estimation category consisted of ten, 650 cow dairy farms. The ten farms in each category had lactation specific health culling rates that ranged form 40 percent lower to 50 percent higher than the average lactation specific culling rates for herds with less than 150 cows, farms with herds of 300 to 450 cows, and farms with more than 600 cows. Additional methods used to estimate the BEA and the estimation results for the herd size estimation category are discussed in Section V.

III. The BEA Estimates for Health Culling Rate Reductions Among Midwestern and Northeastern DHIA Dairy Farms

In this section, the BEA for a health culling rate reduction are estimated for ten farms. The farms have initial lactation specific health culling rates that range from forty percent below to fifty percent above the average Midwestern and Northeastern dairy farm. In the estimations, the lactation specific culling rate for sold for dairy purposes and low production were held constant at the breed average level.

Production and Financial Parameters

It was assumed that the typical Midwestern and Northeastern dairy herds would consist of 130 milking and dry cows with a thirteen month calving interval. There were initially 10 first lactation cows in each of the eleven lactation months and 10 cows in two dry period months. The cattle in the two dry period months were waiting for their second lactation to begin.

Table 34. The Expected Rolling Herd Average Per Lactation and Somatic Cell Count Levels Per Lactation Used to Estimate the BEA for a Health Cull Reduction for the Typical Midwestern and Northeastern DHIA Farm Estimation Category

Lactation	Milk Production per Lactation (lbs)	Somatic Cell Count per Lactation
1	20,000	200,000
2	22,308	254,840
3	23,000	285,900
4	23,136	308,700
5	22,950	326,460
6	22,482	346,280
7	21,790	356,460
8	21,158	358,480
9	20,378	363,560
10	19,736	362,060

The ten farms' cattle would have a 20,000 pound first lactation production level and a 200,000 somatic cell count (Table 29). Culled cattle were subject to the production and somatic cell count adjustments shown in Table 30. The adjustments were applied to the entire productive period of the terminal lactation as described in Chapter 5.

Table 35. The Effects of Culling on the RHA and Somatic Cell Count (SCC) Levels of the Culled Cow Used for the BEA Estimation of a Health Cull Reduction

Lactation Culled	Sold for Dairy Purposes		Production Culls		Non-Death Health Culls		Deaths	
	RHA (+/- %)	SCC (+/- %)	RHA (+/- %)	SCC (+/- %)	RHA (+/- %)	SCC (+/- %)	RHA (+/- %)	SCC (+/- %)
1	- 11	+ 4	- 26	+ 29	- 6	+ 19	- 16	+ 5
2	- 4	+ 2	- 7	+ 19	- 1	+ 15	- 7	- 1
3	- 3	+ 3	- 11	+ 15	0	+ 13	- 6	- 1
4	- 3	+ 6	- 11	+ 11	- 1	+ 13	- 6	- 5
5	- 1	+ 7	- 10	+ 13	- 2	+ 12	- 11	- 5
6	- 1	+ 6	- 9	+ 10	0	+ 9	- 7	- 10
7	- 1	+ 7	- 3	+ 6	2	+ 9	- 5	- 5
8	- 5	+ 7	- 8	+ 9	0	+ 11	- 9	- 6
9	- 5	+ 3	- 7	+ 12	0	+ 11	- 11	- 6
10	- 6	+ 5	- 11	+ 11	- 6	+ 8	- 14	- 8

The lactation specific culling rates for this estimation category are shown in Table 31. The average annual lactation specific culling rates ranged from 22.31 percent in the first lactation to 58.57 percent in lactation ten. The primary reason for cattle being culled was lameness or injury. In the first and tenth lactations respectively, 4.97 and 21.38 percent of the cattle were culled due to lameness or injury.

Table 32 shows the within lactation removal schedule for non-death health culls that was used for the typical Midwestern and Northeastern DHIA farm estimations. The largest percentage of cattle were removed in the eleventh lactation month. The second-highest percentage of cattle were removed in the first month of lactation.

Table 36. The Average Lactation Specific Culling Rate For Midwestern and Northeastern Dairy Farms

Lactation Number	Average Annual Lactation Specific Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	22.31	3.33	3.84	3.39	4.17	4.97	0.60	2.01
2	33.12	3.21	5.59	5.21	7.11	7.46	1.18	3.36
3	37.78	2.57	5.57	6.77	7.67	9.59	1.12	4.49
4	42.34	2.22	5.73	8.12	8.22	11.70	1.04	5.31
5	46.09	2.05	5.79	9.08	8.79	13.32	1.00	6.06
6	49.58	2.04	6.11	9.84	9.66	14.80	0.84	6.29
7	52.95	1.99	6.54	10.28	10.16	16.62	0.82	6.54
8	55.48	1.85	7.19	10.20	11.21	17.68	6.54	6.58
9	58.55	1.94	6.95	9.95	11.94	20.25	0.58	6.94
10	58.57	1.93	8.39	9.63	9.15	21.38	0.62	7.47

Table 37. The Within Lactation Removal Schedule for Cattle Culled due to Non- Death Health Culls Used for the BEA Estimation of a Health Cull Reduction

Lactation Month	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
1	8.39	7.93	10.30	11.59	12.38	12.60	12.14	12.39	12.28	10.67
2	7.59	5.07	5.72	5.99	5.88	6.04	6.28	6.05	6.22	5.80
3	6.15	4.85	5.10	5.35	5.58	5.98	5.95	5.94	5.52	6.07
4	5.18	4.90	5.33	5.48	5.88	5.85	6.11	5.82	6.66	6.99
5	4.76	5.20	5.47	5.69	5.96	6.19	6.16	5.65	6.69	7.93
6	4.64	5.58	5.86	5.99	6.18	6.23	6.29	6.82	5.68	6.55
7	4.77	6.08	6.20	6.38	6.47	6.45	6.72	6.56	7.55	5.89
8	4.84	6.73	6.76	6.66	6.79	6.66	6.88	7.29	6.59	7.53
9	5.66	7.33	7.54	7.59	7.16	7.17	7.09	7.10	6.96	6.46
10	7.56	9.08	8.59	8.17	7.80	7.66	7.70	7.33	7.18	8.85
11	40.49	36.77	33.11	30.93	29.91	29.18	28.67	29.05	28.68	27.27
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 38. The Within Lactation Removal Schedule for Deaths Used for the BEA Estimation of a Health Cull Reduction

Lactation Month	Lactation 1	Lactation 2	Lactation 3	Lactation 4	Lactation 5	Lactation 6	Lactation 7	Lactation 8	Lactation 9	Lactation 10
1	23.11	28.04	36.82	41.23	43.84	45.90	46.07	45.40	43.63	43.36
2	9.00	7.70	8.42	7.89	7.69	7.33	6.80	6.67	7.17	6.76
3	6.11	5.43	5.14	5.02	5.02	4.50	5.67	4.89	5.57	7.00
4	4.67	4.44	4.30	4.15	3.96	4.02	3.97	3.46	5.32	4.99
5	4.11	4.15	3.88	3.27	3.42	3.39	3.64	4.14	3.04	3.78
6	4.00	3.95	3.20	3.03	2.97	2.60	2.51	3.12	3.29	2.01
7	3.78	3.75	3.20	2.87	2.89	2.60	2.43	3.29	2.36	3.54
8	4.11	4.05	3.29	2.95	2.82	2.84	2.27	2.45	3.21	2.98
9	4.67	5.13	3.88	3.51	3.42	3.08	3.56	3.46	3.88	3.54
10	7.22	7.40	5.81	5.10	4.73	4.50	4.94	4.97	3.88	3.54
11	29.22	25.67	22.07	20.97	19.25	19.32	18.14	18.57	18.65	18.58
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

With the exception of the eleventh month (it was assumed in the estimation that no health culls would occur during the dry period months, lactation months 12 and 13), these removals are based on the typical removal schedule for Midwestern and Northeastern DHIA dairy farms.

There was a different distribution for cattle deaths. With the exception of the first lactation, the majority of cattle that died during a lactation were removed during the first lactation month (Table 33). The second-highest amount of deaths occurred during the last lactation month. It was assumed that no deaths would occur during the dry period months. Otherwise, the within lactation removal schedule for cattle deaths were based upon the typical removal schedule for Midwestern and Northeastern DHIA dairy farms.

Table 34 displays the other critical production and financial factors used in the BEA estimation for the typical Midwestern and Northwestern dairy farm estimation. It was assumed that debt capital could be obtained for 7.50 percent. The opportunity cost of equity capital was set at 10 percent. The debt to asset ratio was set at 50 percent for all of the example farms in this category. In order to estimate the BEA on a before tax basis, the marginal tax rate was set at zero percent. Thus, the weighted average cost of capital was calculated to be 8.75 percent for all farms.

A replacement heifer price of $1,350 and a cull cow price of $350 were used in the estimation. The cull cow price was adjusted for age and whether the animal was culled due to lameness or injury. These adjustments were explained in Chapter 5. A milk price of $13.50 per hundredweight was assigned. Heifer calves were valued at

$200 per head and bull calves were valued at $75 per head. A death loss of 6 percent was assumed for each.

Table 39. Other Critical Production and Financial Factors for the Typical Midwestern and Northeastern DHIA Dairy Farm Estimation

Item	Value
Interest Rate (%)	7.50
Percent of Cattle Funded by Debt (%)	50.00
Cost of Equity Capital (%)	10.00
Percent of Capital Funded by Equity (%)	50.00
Marginal Tax Rate (%)	0.00
Capital Gains Tax Rate (%)	0.00
Weighted Average Cost of Capital (%)	8.75
Replacement Heifer Price ($/cow)	1,350.00
Typical Cull Cow Price ($/cow)	350.00
Average Milk Price ($/cwt)	13.50
Somatic Cell Count Premium ($/100 lbs)	0.00063
Average Heifer Calf Price ($/cow)	200.00
Heifer Calf Mortality (%)	6.00
Average Bull Calf Price ($/cow)	75.00
Bull Calf Mortality (%)	6.00
Average Feed Cost ($/cow)	982.00
Average Labor Cost ($/cow)	646.00
Average Other Direct Cost ($/cow)	853.00
Average Cost Per Dry Cow Month ($/cow)	45.00
Typical Treatment Cost per Udder and Mastitis Health Problem Episode ($/cow)	133.00
Typical Treatment Cost per Reproduction Health Problem Episode ($/cow)	192.00
Typical Treatment Cost per Lameness and Injury Episode ($/cow)	9.00
Typical Treatment Cost per Disease Episode ($/cow)	112.00
Milk Production Genetic Improvement Rate (% per generation)	1.00
Feed Expense Adjustment to Support the Additional Revenues Associated with the Milk Production Genetic Improvement Rate (% of Milk Revenue Increase)	0.90
Labor Expense Annual Increase (%)	0.00
Other Expense Annual Increase (%)	0.00

An average feed cost of $982 per cow was assigned. The labor expense assigned to each cow was $646. Both feed and labor costs were adjusted to an individual cow's production on a per hundredweight basis. Other direct expenses were valued at $853 per cow. A dry period cost charge of $45 per month was also assigned.

Treatment costs were also charged to culled cattle. For animals that were culled due to udder and mastitis problems, a treatment cost of $133 was assigned. For reproduction culls, a treatment cost of $192 was assigned. Lameness and injury culls were assigned a charge of $9, and disease culls and deaths were assigned a treatment expense of $112. These values were adapted from the work of Weigler et al (1990).

A milk production genetic improvement rate of 1.0 per generation was used in the estimations. It was assumed that a new generation of heifers would begin milking every 13 months. A feed expense adjustment of 0.9 was assigned to cover the increase in feed costs necessary to capture the milk production increase from the genetic improvement rate. Thus, if milk revenues increased by $1 from genetic improvement, feed costs increased by $0.90.

Lactation expenses were adjusted by lactation according to the values expressed in Table 9. The values were adapted from the work of Bauer, Mumey and Lohr (1993).

Table 40. Lactation Expense Adjustment

Lactation	Value
1	0.9627
2	1.0000
3	1.0218
4	1.0572
5	1.0745
6	1.1118
7	1.1136
8	1.1163
9	1.1191
10	1.1245

BEA Estimate Results for Midwestern and Northeastern DHIA Herds

For the example farm with a lactation specific health culling rate that was 50 percent higher than the Midwest and Northeast DHIA sample average (Table 36: *"50% Above"* row), a producer would be willing to pay $213 per month for the health cull reduction. Thus, if the manager was looking at a health cull reduction investment that would cost $213 or less per month for the 130 cow herd, the manager should make the investment. This would reduce the projected average annual total culling rate for this example farm from 41 percent to 39.2 percent. The marginal BEA for the 10 example farms decreased through the remaining farms. For the farm with the sample average lactation specific culling rates, the BEA for a 10 percent health cull reduction was $204 per month. Herds with 40 percent lower lactation specific culling rates could afford to pay $172 for a 10 percent health cull reduction based on a 130 cow herd size.

Table 41. **The Estimated BEA for Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 130 Cow Midwestern or Northeastern DHIA Dairy Farm[1]**

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	41.0	39.2	30.6 – 39.8	24,156	213
40 % Above	39.2	37.5	29.0 – 38.1	24,099	213
30% Above	37.5	35.7	27.4 – 36.4	23,978	212
20% Above	35.7	33.9	25.7 – 34.8	23,775	210
10% Above	33.9	32.0	24.1 – 33.2	23,471	207
Sample Average	32.0	30.1	22.4 – 31.7	23,041	204
10% Below	30.1	28.2	20.8 – 30.3	22,459	198
20% Below	28.2	26.3	19.1 – 29.1	21,690	192
30% Below	26.3	24.3	17.5 – 28.2	20,697	183
40% Below	24.3	22.4	15.8 – 28.0	19,436	172

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

Table 37 shows how much a 130 cow DHIA dairy farm with the Midwestern and Northeastern sample average lactation specific health culling rate would be willing to pay for a 10 percent reduction in specific health culls. The highest estimated BEA was associated with lameness and injury culls. A farm of this type would be willing to pay $62 per month to have a ten percent reduction in lameness and injury culls. The second highest estimated BEA for herds in this category was to

Table 42. The BEA of a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 130 Cow Herd with the Midwestern and Northeastern DHIA Sample Average Health Culling Rate[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	32.0	31.6	23.7 – 32.8	6,031	53
Reproduction	32.0	31.5	23.6 – 32.8	7,303	65
Lameness and Injury	32.0	31.4	23.6 – 32.7	8,682	77
Disease	32.0	31.9	24.0 – 33.1	1,079	10
Death	32.0	31.7	23.8 – 32.9	4,812	43

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

spend $53 per month to reduce reproduction culls be ten percent. A producer in this category would have an estimated BEA of $43 per month to reduce udder and SCC culls by ten percent. Reducing deaths by ten percent would be worth an additional $39 per month. A ten percent reduction in disease culls would benefit the manager the least. The BEA for a ten percent disease cull reduction was $8 per month. Nevertheless, this estimate should be tempered by the fact that the disease health culling rate incidence for the Holstein breed average was very low. Herds with chronic disease problems whereby many animals are culled, such as in the case of Johne's Disease, could probably pay more to reduce the disease health culling rate.

IV. The Estimated BEA for a Health Culling Rate Reduction for Holstein, Jersey and Guernsey Farms

In Section III, the maximum monthly BEA was calculated for the Midwestern and Northeastern DHIA farms. However, no distinction was made between farms. Of course, not all farms are the same. In this section, the monthly BEA for a ten percent health cull reduction is determined for farms with three different breeds of dairy cattle – Holstein, Jersey, and Guernsey – to see how the monthly BEA might vary for farms with different cattle breeds.

The Holstein breed was chosen as it is the major dairy cattle breed in the United States. The Jersey breed was chosen because of its reputation for being a long-lived breed. In Chapter III, it was shown that Jersey cattle are less likely to be culled than Holstein cattle. Guernsey cattle have the opposite reputation. In Chapter III, Guernsey cattle were thirteen percent more likely to be culled in the Eastern region of this analysis than Holstein cattle. Besides how the breeds vary in culling rates, the breeds also vary in size, resulting in lower cull cow prices, milk price, and milk production. As such, the maximum BEA for a ten percent reduction in health culls should differ between the three breeds.

Breed- based Production and Financial Parameters

For the breed-based analysis, it was once again assumed that the dairy herd would consist of 130 milking and dry cows with a thirteen month calving interval. There were initially ten first lactation cows in each of the eleven lactation months and ten cows in each of two dry period months. The cattle in the two dry period months were waiting for their second lactation to begin.

The production parameters used in this analysis can be seen in Table 38. Holstein cattle tend to produce more pounds of fluid milk whereas Jersey and Guernsey cattle tend to produce less milk volume with higher milk component yields. The milk production level of first lactation Holstein cattle was set at 20,000 pounds of milk. The milk production level of first lactation Jersey and Guernsey cattle were set at 14,000 pounds of milk. The lactation-based somatic cell count (SCC) levels were

Table 43. The Expected Rolling Herd Average (RHA) Per Lactation and Somatic Cell Count Levels Per Lactation Used for the BEA Estimation of a Health Cull Reduction for All Scenarios

Lactation	Milk Production per Lactation (lbs)		Somatic Cell Count per Lactation
	Holstein	Jersey and Guernsey	Holstein, Jersey and Guernsey
1	20,000	14,000	200,000
2	22,308	15,616	254,840
3	23,000	16,100	285,900
4	23,136	16,195	308,700
5	22,950	16,065	326,460
6	22,482	15,737	346,280
7	21,790	15,253	356,460
8	21,158	14,811	358,480
9	20,378	14,265	363,560
10	19,736	13,815	362,060

held constant across all three breeds. First lactation cows were assigned a SCC level of 200,000. The culling related production effects used in the breed based estimates were the same as those listed in Table 30 of Section III.

Tables 39 – 41 show the lactation specific culling rates for the three dairy cattle breeds. The lactation specific culling rates for Holstein cattle ranged from 22.26 percent in lactation 1 to 62.88 percent in lactation 10 (Table 39). The most common

Table 44. The Average Lactation Specific Culling Rate For Holstein Cattle

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	22.26	3.09	3.82	3.45	4.17	5.05	0.62	2.06
2	33.65	2.93	5.62	5.36	7.32	7.71	1.23	3.48
3	38.64	2.33	5.68	6.96	7.91	9.99	1.16	4.61
4	43.44	1.99	5.84	8.39	8.49	12.22	1.07	5.44
5	47.39	1.79	5.91	8.49	9.09	13.97	1.04	6.22
6	51.20	1.79	6.30	10.23	10.02	15.55	0.86	6.45
7	54.75	1.64	6.73	10.78	10.47	17.48	0.86	6.79
8	57.23	1.51	7.49	10.57	11.59	18.37	0.78	6.92
9	60.37	1.66	7.38	10.20	18.37	21.06	0.58	7.30
10	62.88	1.73	8.75	10.13	0.78	21.86	0.68	8.35

Table 45. The Average Lactation Specific Culling Rate For Jersey Cattle

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	20.35	6.33	3.28	2.86	2.82	3.52	0.36	1.18
2	25.55	6.09	4.51	3.79	4.29	4.25	0.72	1.90
3	27.92	4.83	4.07	5.24	4.68	5.18	0.70	3.22
4	31.67	4.06	4.44	6.27	5.30	6.77	0.75	4.08
5	35.01	3.77	4.72	7.20	5.69	8.07	0.61	4.95
6	38.79	3.52	5.07	7.91	6.83	9.70	0.65	5.11
7	42.03	3.58	5.99	8.30	7.21	11.58	0.44	4.93
8	46.90	2.97	6.29	8.85	9.07	14.23	0.69	4.80
9	50.62	2.67	5.62	9.00	10.05	17.66	0.52	5.10
10	50.20	2.51	7.52	7.21	7.31	20.84	0.30	4.51

Table 46. The Average Lactation Specific Culling Rate For Guernsey Cattle

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	30.81	3.59	8.40	2.65	4.99	7.83	0.51	2.84
2	38.00	3.05	8.97	3.58	7.37	10.56	0.81	3.66
3	42.69	2.54	7.65	4.84	8.94	12.89	0.72	5.11
4	45.57	2.79	7.48	6.05	8.62	13.68	0.96	5.99
5	49.03	3.02	7.81	7.36	10.19	14.07	0.55	6.03
6	51.54	1.63	7.76	7.68	10.54	16.50	0.65	6.78
7	55.95	2.41	7.69	5.28	12.52	19.61	0.45	7.99
8	55.95	2.98	8.94	8.94	9.27	18.54	0.99	6.29
9	59.99	3.33	11.33	7.33	12.00	17.33	2.00	6.67
10	61.56	0.00	12.31	7.70	10.77	23.08	0.00	7.70

reason for a Holstein cow to be culled during lactations 1 and 2 was *"lameness and injury"* with 5.05 percent of the first lactation Holstein cattle and 7.71 percent of the second lactation Holstein cattle succumbing to lameness and injury problems. As shown in Table 40, Jersey cattle exhibited the lowest lactation specific culling rates, ranging from 20.34 percent in lactation 1 to 50.62 percent in lactation 9. The most common culling reason for Jersey cattle in lactations 1 and 2 was *"sold for dairy purposes."* In Table 41, the lactation specific culling rates for Guernsey cattle ranged from 30.81 percent in lactation 1 to 61.56 percent in lactation 10. The most common reason for first and second lactation Guernsey cattle to be culled was *"lameness and injury"* followed closely by *"production.."* The within lactation removal schedules for cattle culled due to non- death health culls and deaths were set equal to the schedules shown in Tables 32 and 33.

Tables 42 shows the other production and cost parameters used in the breed-based analysis. All Holstein, Jersey and Guernsey replacement heifers were valued at $1,350 per cow. The typical cull price assigned to Holsteins was $350. The typical value for a Jersey cull cow was set at $265 per cow. Guernsey cattle cull cow values were set at $310 per cow. All cull cow values were adjusted for age and cull type as discussed in Chapter 5.

Holstein milk was assigned a value of $13.50 per hundredweight. Jersey and Guernsey milk was assigned a value of $15.50 per hundredweight. A SCC premium/discount of $0.00063/cwt was assigned based upon the formula discussed in Chapter 5. All heifer calves were assigned a value of $200 per calf regardless of

Table 47. Other Critical Production and Production Expense Factors for the Breed Based BEA Estimations

Item	Value
Interest Rate (%)	7.50
Percent of Cattle Funded by Debt (%)	50.00
Cost of Equity Capital (%)	10.00
Percent of Capital Funded by Equity (%)	50.00
Marginal Tax Rate (%)	0.00
Capital gains Tax Rate (%)	0.00
Weighted Average Cost of Capital (%)	8.75
Holstein, Jersey and Guernsey Replacement Heifer Price ($/cow)	1,350.00
Typical Holstein Cull Cow Price ($/cow)	350.00
Typical Jersey Cull Cow Price ($/cow)	265.00
Typical Guernsey Cull Cow Price ($/cow)	310.00
Average Holstein Milk Price ($/cwt)	13.50
Average Jersey and Guernsey Milk price ($/cwt)	15.50
Somatic Cell Count Premium ($/100 lbs)	0.00063
Average Heifer Calf Price ($/cow)	200.00
Heifer Calf Mortality (%)	6.00
Average Holstein Bull Calf Price ($/cow)	75.00
Average Jersey Bull Calf Price ($/cow)	55.00
Average Guernsey Bull Calf Price ($/cow)	65.00
Bull Calf Mortality (%)	6.00
Average Holstein Feed Cost ($/cow)	982.00
Average Jersey and Guernsey Feed Cost ($/cow)	683.00
Average Holstein Labor Cost ($/cow)	646.00
Average Jersey and Guernsey Labor Cost ($/cow)	455.00
Average Holstein Other Direct Cost ($/cow)	853.00
Average Jersey and Guernsey Other Direct Cost ($/cow)	595.00
Average Cost Per Dry Cow Month ($/cow)	45.00
Typical Treatment Cost per Udder and Mastitis Health Problem Episode ($/cow)	133.00
Typical Treatment Cost per Reproduction Health Problem Episode ($/cow)	192.00
Typical Treatment Cost per Lameness and Injury Episode ($/cow)	9.00
Typical Treatment Cost per Disease Episode ($/cow)	112.00
Milk Production Genetic Improvement Rate (% per generation)	1.00
Feed Expense Adjustment to Support the Additional Revenues Associated with the Milk Production Genetic Improvement Rate (% of Milk Revenue Increase)	0.90
Labor Expense Annual Increase (%)	0.00
Other Expense Annual Increase (%)	0.00

breed. Holstein, Jersey and Guernsey bull calves were valued at $75, $55 and $65 per calf respectively.

Feed, labor and other direct costs were adjusted for the differences in milk production between the three breeds. Holsteins were assigned a feed cost of $982 per cow while Jersey and Guernsey cattle were assigned a feed cost of $683 per cow. A labor charge of $670 was assigned to Holstein cattle, and a charge of $646 per cow was assigned to Jersey and Guernsey cattle. A charge of $853 and $595 per cow was assigned to Holstein cattle and Jersey and Guernsey cattle respectively to cover other direct expenses. Treatment expenses, the milk production genetic growth rate, and lactation expense adjustments were set equal to those used in the Midwestern and Northeastern farm estimations.

BEA Estimate Results for Holstein, Jersey and Guernsey Cattle

For the farm with Holstein cattle and a fifty percent higher lactation specific health culling rates than the average Holstein herd (production and sold for dairy purpose culls were held constant at the Holstein breed average), the monthly BEA associated for reducing the health culling rate by 10 percent was $218 per month (Table 43). This means that the manager of such a herd could afford to pay up to $218 dollars per month for the ten percent reduction in health culls. Reducing the health culling rates by ten percent would decrease the average annual total culling rate from 41.5 percent to 39.7 percent for this farm. The marginal BEA for a ten percent reduction in health culling rates for the *"Breed Average"* example farm was $210 per month. The marginal BEA continued to diminish through the remaining example farms. The lowest returns, although still positive, were associated with a ten percent lactation specific health culling rate reduction for herds with health culling rates that were forty percent lower than the Holstein breed average. Managers with herds in this category should be willing to pay up to $178 on a monthly basis in order to achieve the reduction. A ten percent decrease in health culling rates for herds in this category would cause the average annual total culling rate to decrease from 24.5 percent to 22.4 percent.

Table 48. The BEA Associated with Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 130 Cow Holstein Herd[1]

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	41.5	39.7	30.9 – 40.3	24,716	218
40 % Above	39.7	38.0	29.2 – 38.5	24,687	218
30% Above	38.0	36.1	27.5 – 36.8	24,594	217
20% Above	36.1	34.3	25.9 – 35.1	24,420	216
10% Above	34.3	32.4	24.2 – 33.5	24,143	213
Breed Average	32.4	30.5	22.5 – 31.9	23,738	210
10% Below	30.5	28.5	20.8 – 30.4	23,174	205
20% Below	28.5	26.5	19.2 – 29.2	22,415	198
30% Below	26.5	24.5	17.5 – 28.2	21,419	189
40% Below	24.5	22.4	15.8 – 27.9	20,137	178

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

A ten percent reduction in the incidence of lameness and injury culls generated the highest BEA for Holstein herds with the breed average lactation specific health culling rates (Table 44). A farmer in this category would be willing to pay up to $64 per month to reduce lameness and injury culls by ten percent. He or she would be willing to pay $54, $44, and $40 per month to reduce reproduction culls udder and SCC culls, and mortalities respectively. Reducing the incidence of disease culls generated the lowest NPV of maximum potential returns. A farmer that experiences the Holstein breed average lactation specific culling rate would be willing to pay $8 per month to reduce the disease culling incidence by ten percent.

Table 49. The BEA of a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 130 Cow Holstein Herd with the Breed Average Health Culling Rates[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	32.4	32.0	23.8 – 33.1	5,028	44
Reproduction	32.4	31.9	23.7 – 33.0	6,115	54
Lameness and Injury	32.4	31.8	23.7 – 32.9	7,277	64
Disease	32.4	32.3	24.1 – 33.4	925	8
Death	32.4	32.1	23.9 – 33.2	4,569	40

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

The estimates for the example farms with Holstein cattle did not vary tremendously from those determined in the estimates for the typical Midwestern and Northeastern DHIA farms. This is not too surprising as the vast majority of dairy cattle are Holstein. There was a big difference in the amount a manager with Jersey cattle would be willing to pay, however (Table 45). Jersey cattle exhibited decreasing marginal returns throughout the example farms. The example farm represented in the *"50% Above"* row of Table 45 exhibited the highest BEA for a ten percent reduction

Table 50. The BEA Associated with Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 130 Cow Jersey Herd[1]

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Culling Rate[2] (%)	New Average Annual Culling Rate (%)	New Annual Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	33.4	32.2	25.2 – 33.3	17,264	153
40 % Above	32.2	30.9	24.1 – 32.2	17,170	152
30% Above	30.9	29.6	22.9 – 31.2	17,042	151
20% Above	29.6	28.3	21.8 – 30.2	16,874	149
10% Above	28.3	27.0	20.7 – 29.4	16,659	147
Breed Average	27.0	25.6	19.6 – 28.7	16,388	145
10% Below	25.6	24.2	18.5 – 28.2	16,051	142
20% Below	24.2	22.9	17.4 – 28.0	15,638	138
30% Below	22.9	21.5	16.2 – 28.2	15,136	134
40% Below	21.5	20.0	15.1 – 28.9	14,530	128

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

in overall health culling rates. This example farm would be willing to pay up to $153 per month to achieve this reduction, which would lower the average annual total culling rate from 33.4 to 32.2 percent. The manager of the *"40% Below"* example farm would be willing to pay up to $128 per month in order to reduce their health culling rates by ten percent and their average annual total culling rate from 21.5 to 20.0 percent.

Table 51. The BEA for a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 130 Cow Jersey Herd with the Breed Average Health Culling Rates[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	27.0	26.6	20.4 – 29.2	4,202	37
Reproduction	27.0	26.6	20.4 – 29.2	4,101	36
Lameness and Injury	27.0	26.6	20.4 – 29.2	4,674	41
Disease	27.0	26.9	20.7 – 29.4	591	5
Death	27.0	26.7	20.6 – 29.3	2,930	26

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

Managers of Jersey herds exhibiting the breed average health culling rate would be willing to pay the most, $41 per month, for a ten percent reduction in lameness and injury culls. Unlike Holstein cattle, udder and SCC culls were more costly than reproduction culls. Jersey dairy farm managers with the breed average lactation specific health culling rates should be willing to pay $37 per month for a ten percent reduction in udder and SCC culls. They should be willing to pay $36 per month to reduce reproduction culls by ten percent. Jersey dairy farms would be willing to pay $26 per month for ten percent reductions death and $5 per month for disease reductions.

Farm managers with Guernsey cattle would be willing to pay more for a ten percent reduction in health culls than managers with Jersey and Holstein cattle. Reductions in the health culling rate showed increasing marginal returns from the

Table 52. The BEA Associated with Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 130 Cow Guernsey Herd[1]

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Culling Rate [2] (%)	New Average Annual Culling Rate (%)	New Annual Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	47.0	45.0	38.4 – 45.4	29,882	264
40 % Above	45.0	43.0	36.5 – 43.4	29,985	265
30% Above	43.0	40.9	34.6 – 41.5	30,049	266
20% Above	40.9	38.8	32.7 – 39.5	30,064	266
10% Above	38.8	36.7	30.7 – 37.6	30,013	265
Breed Average	36.7	34.5	28.8 – 35.7	29,877	264
10% Below	34.5	32.3	26.9 – 33.9	29,634	262
20% Below	32.3	30.1	24.9 – 32.3	29,254	259
30% Below	30.1	30.1	23.0 – 30.9	28,705	254
40% Below	27.8	25.5	21.0 – 30.0	27,947	247

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the breed average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

"50% Above" through the *"20% Above"* example farms (Table 47). The manager with the example farm represented in the *"Breed Average"* row would be willing to pay $264 per month to reduce health culling rates by ten percent, which would cause the average annual total culling rates to reduce from 36.7 percent to 34.5 percent. Managers with Guernsey herds in the *"40% Below"* initial lactation specific health culling rate category would be willing to pay up to $247 per month to reduce health culls be ten percent.

Table 53. The BEA for a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 130 Cow Guernsey Herd with the Breed Average Health Culling Rates[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	31.8	31.4	23.6 – 32.6	4,223	37
Reproduction	31.8	31.3	23.5 – 32.6	7,766	69
Lameness and Injury	31.8	31.2	23.4 – 32.5	11,529	102
Disease	31.8	31.8	23.9 – 32.9	756	7
Death	31.8	31.5	23.7 – 32.8	5,663	50

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 0 – 150 cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

For Guernsey herd managers with the *"Breed Average"* lactation specific health culling rates, the managers should be willing to pay up to $102 per month for a ten percent reduction in lameness and injury culls (Table 48). They would be willing to pay \$69, \$50, and \$37 per month for ten percent reductions in reproduction culls, deaths, and udder and SCC culls respectively. They would be willing to pay \$7 per month to reduce the number of disease culls.

As these results have shown, the estimated BEA for a ten percent reduction in health culls varies based upon breed type. Farms with Jersey cattle, which generally have lower culling rates than farms with Holstein cattle, cannot afford to pay as much as Holstein or Guernsey farms for a ten percent reduction in health culls. Farms with Guernsey cattle, however, can afford to pay more for a ten percent reduction in health culling rates than Holstein dairy farms.

V. The BEA for a Ten Percent Health Culling Rate Reduction for Farms that Vary by Size

In the previous sections, the BEA estimates were made for farms of the same herd size. In this section, the maximum BEA for a ten percent reduction in health culls was estimated for herds of three different sizes: 130 cows, 390 cows and 650 cows. A larger herd with equivalent culling rates as a smaller herd should be able to pay more on an absolute basis for a ten percent reduction in health culls because more cows are being culled. Besides this herd size difference, it was shown in Chapter 3 that herd size and expansion have some effect on the likelihood of a cow being culled. As such, the BEA for a ten percent reduction in health culls may also vary due to different culling characteristics between the three size categories.

Herd Size-based Production and Financial Parameters

With the exception of the herd size, herd inventory and lactation specific culling rate parameters, it was assumed that all other parameters would be the same as those identified for the Midwestern and Northeastern DHIA Farm estimations in

Section III. For the 130 cow herd estimations, it was assumed that the farm would consist of 110 first lactation heifers evenly distributed between eleven lactation months. The remaining twenty cows would be evenly distributed between two dry period months while waiting for their second lactation to begin. The 390 cow herd would consist of 330 first lactation cows evenly distributed between the eleven lactation months. There would also be 60 cows evenly distributed between two dry period months that are waiting to begin their second lactation. The 650 cow herd would consist of 550 first lactation heifers evenly distributed among the eleven lactation months and 100 evenly distributed cows awaiting their second lactation in two dry period months.

For the estimation of a 130 cow herd, the average lactation specific culling rate for herds less than 150 cows were used (Table 49). The average culling rates ranged from 21.91 percent in lactation one up to 59.52 percent in lactation ten. The most common reason for cattle being culled in this size category was lameness and injuries.

For the 390 cow herd size estimation, the lactation specific culling rates for herds with 300 to 450 cows were used (Table 50). The average annual lactation specific culling rates were higher than the previous size category. The average annual lactation culling rate ranged from 22.95 percent in lactation one up to 74.19 percent in lactation ten. This group culled less than the under 150 cow category for low production and sold for dairy purposes and more for each health related reason. The most prevalent culling reason was lameness and injury.

Table 54. The Average Lactation Specific Culling Rate For Herds with Less Than 150 Cows

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	21.91	3.54	3.77	3.38	4.14	4.82	0.51	1.75
2	33.34	3.53	5.60	5.36	7.28	7.48	1.01	3.08
3	37.39	2.78	5.51	6.80	7.86	9.39	0.94	4.11
4	41.67	2.37	5.65	8.03	8.42	11.37	0.90	4.93
5	45.25	2.15	5.70	8.84	9.00	13.01	0.88	5.67
6	49.58	2.04	6.11	9.84	9.66	14.80	0.84	6.29
7	52.95	1.99	6.54	10.28	10.16	16.62	0.82	6.54
8	55.48	1.85	7.19	10.20	11.21	17.68	0.77	6.58
9	58.55	1.94	6.95	9.95	11.94	20.25	0.58	6.94
10	59.52	2.11	8.34	9.30	10.84	21.17	0.59	7.17

Table 55. The Average Lactation Specific Culling Rate For Herds with 300 to 450 Cows

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	22.95	1.82	3.64	3.54	4.39	5.34	1.18	3.04
2	32.24	2.52	5.44	5.14	6.56	6.60	2.07	3.91
3	40.32	2.15	6.22	7.12	7.09	10.09	1.96	5.69
4	47.02	2.19	6.97	9.53	7.53	12.42	1.88	6.50
5	52.12	1.97	7.14	10.66	7.60	14.67	1.34	8.74
6	55.52	1.87	8.03	11.50	8.76	16.19	1.47	7.70
7	59.52	0.95	9.91	12.39	8.08	17.84	1.68	8.67
8	62.76	1.24	12.23	13.65	8.87	16.14	1.06	9.57
9	64.77	0.48	10.48	10.00	13.81	20.00	0.48	9.52
10	74.19	0.00	11.29	8.06	16.13	27.42	1.61	9.68

Table 56. The Average Lactation Specific Culling Rate For Herds with More Than 600 Cows

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	27.79	3.88	5.70	3.92	3.92	4.31	1.13	4.93
2	38.75	2.77	7.27	5.76	6.80	7.48	1.87	6.80
3	41.94	2.94	7.43	6.99	6.26	6.89	2.16	9.27
4	46.21	2.40	7.75	8.58	6.64	7.30	2.51	11.03
5	47.36	3.12	6.25	10.66	6.25	6.88	2.37	11.83
6	51.78	3.01	10.89	11.72	6.09	6.70	2.48	10.89
7	48.42	3.70	8.32	12.39	5.36	5.90	2.40	10.35
8	60.24	2.18	8.73	13.97	8.73	9.60	2.18	14.85
9	62.21	3.39	8.48	15.26	11.86	13.05	1.69	8.48
10	56.00	0.00	0.00	15.00	10.00	11.00	0.00	20.00

The 650 cow herd size estimation used the lactation specific culling rates listed in Table 51 for herds with over 600 cows. Compared to farms with 300 to 450 farms, herds in this category had higher lactation specific culling rates in lactations one through three, but lower lactation specific culling rates in lactations four through ten. The annual lactation specific culling rates ranged from 27.79 in lactation one to 62.21 percent in lactation nine.

BEA Estimate Results for Dairy Farms that Vary by Herd Size

The monthly BEA for a ten percent reduction in health culls did vary by herd size. This occurred on both an absolute basis and on a per cow basis.

For the 130 cow herd size category, the *"50% Above"* example farm could afford to pay up to $208 per month for a ten percent reduction in health culls (Table 52). The average annual total culling rate dropped from 40.6 percent to 38.9 percent. The marginal ability to pay for an additional 10 percent reduction decreased through the remainder of the categories. For the *"40% Below"* example farm, the manager could afford to pay $167 per month for a ten percent reduction in health culling rates. Achieving this reduction would cause their average annual total culling rate to reduce from 24.2 to 22.2 percent. The *"Size Category Average"* example farm could afford to pay up to $198 ($1.52 per cow) per month for a ten percent health cull reduction.

Table 57. The BEA Associated with Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 130 Cow Herd[1]

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Culling Rate[2] (%)	New Average Annual Culling Rate (%)	New Annual Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	40.6	38.9	30.3 – 39.5	23,528	208
40 % Above	38.9	37.2	28.7 – 37.8	23,470	207
30% Above	37.2	35.4	27.1 – 36.2	23,347	206
20% Above	35.4	33.6	25.5 – 34.5	23,144	205
10% Above	33.6	31.8	23.9 – 33.0	22,842	202
Size Category Average	31.8	30.0	22.3 – 31.5	22,417	198
10% Below	30.0	28.1	20.7 – 30.1	21,842	193
20% Below	28.1	26.1	19.1 – 29.0	21,086	186
30% Below	26.1	24.2	17.5 – 28.2	20,110	178
40% Below	24.2	22.2	15.8 – 28.0	18,874	167

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 0 – 150 cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

Farmers with a herd size of 130 cows and the average lactation specific health culling rates for the 0 to 150 cow herd size could afford to pay the most, $61, for a ten percent reduction in lameness and injury culls (Table 53). This was followed by reproduction culls ($53), udder and SCC culls ($43), deaths ($36) and disease ($7).

Table 58. The BEA for a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 130 Cow Herd with the 0 to 150 Cow Herd Size Average Health Culling Rate[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	31.8	31.4	23.6 – 32.6	4,902	43
Reproduction	31.8	31.3	23.5 – 32.6	6,032	53
Lameness and Injury	31.8	31.2	23.4 – 32.5	6,879	61
Disease	31.8	31.8	23.9 – 32.9	756	7
Death	31.8	31.5	23.7 – 32.8	4,026	36

[1] The initial herd inventory distribution was 110 first lactation heifers evenly distributed between 11 lactation months and 20 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 0 – 150 cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

For the example farms with a 390 cow herd size, the marginal estimated BEA for a ten percent decrease in health culling rates decreased through the example farm categories (Table 54). This size category average farm could pay up to $676 per month or $1.73 per cow per month for the health cull reduction, which would reduce its total annual average culling rate from 33.1 percent to 31.2 percent. The *"40% Below"* example farm could afford to pay $585 for the reduction, which would lower the projected average annual total culling rate from 25.1 percent to 23.0 percent.

Table 59. **The BEA Associated with Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 390 Cow Herd[1]**

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Culling Rate[2] (%)	New Average Annual Culling Rate (%)	New Annual Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	42.5	40.7	31.4 – 41.2	79,290	701
40 % Above	40.7	38.8	29.6 – 39.4	79,194	700
30% Above	38.8	37.0	27.8 – 37.6	78,932	698
20% Above	37.0	35.1	26.1 – 35.8	78,448	693
10% Above	35.1	33.1	24.3 – 34.1	77,680	686
Size Category Average	33.1	31.2	22.5 – 32.4	76,550	676
10% Below	31.2	29.2	20.7 – 30.7	74,963	662
20% Below	29.2	27.2	18.9 – 29.3	72,807	643
30% Below	27.2	25.1	17.1 – 28.1	69,945	618
40% Below	25.1	23.0	15.3 – 27.4	66,218	585

[1] The initial herd inventory distribution was 330 first lactation heifers evenly distributed between 11 lactation months and 60 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 300 – 450 cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

A 390 cow herd with the 300 – 450 cow herd size average health culling rate could afford to pay the most, $191 per month, for a ten percent reduction in lameness and injury culls (Table 55). This was followed by ten percent decreases in reproduction culls ($154 per month), deaths ($154 per month) udder and SCC culls ($138 per month), and disease culls ($43 per month).

Table 60. The BEA for a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 130 Cow Herd with the 300 to 450 Cow Herd Size Average Health Culling Rate[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	33.1	32.7	23.9 – 33.7	15,586	138
Reproduction	33.1	32.7	23.8 – 33.7	17,477	154
Lameness and Injury	33.1	32.6	23.7 – 33.5	21,613	191
Disease	33.1	33.0	24.1 - 34.0	4,907	43
Death	33.1	32.8	23.9 – 33.7	17,462	154

[1] The initial herd inventory distribution was 330 first lactation heifers evenly distributed between 11 lactation months and 60 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 300 – 450 cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

For the 650 cow estimation (Table 56) there was a decreasing ability to pay for a ten percent health culling rate reduction throughout the ten example farms. The manager of the *"50% Above"* example farm could afford to pay $1,815 per month for a ten percent reduction in health culls. This would reduce the average annual total culling rate from 49.5 percent to 46.7 percent for this example farm. The manager of the *"40% Below"* example farm could afford to pay up to $1,113 per month for a ten percent health cull reduction. The average annual total culling rate would decrease from 26.0 to 23.7 percent for the 240 month period for this farm. The "Size Category Average" example farm could afford to pay up to $1,499 ($2.72 per cow) per month to reduce their health culling rate by ten percent.

Table 61. **The BEA Associated with Successive 10 Percent Health Cull Reductions for a 240 Month Period for a 650 Cow Herd**[1]

Example Farm (Described by the % Above or Below the Sample Average Health Cull Rates)	Previous Average Annual Culling Rate [2] (%)	New Average Annual Culling Rate (%)	New Annual Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
50% Above	49.5	46.7	39.5 – 47.0	205,339	1,815
40 % Above	46.7	43.9	36.8 – 44.3	199,608	1,764
30% Above	43.9	41.2	34.2 – 41.7	193,250	1,708
20% Above	41.2	38.5	31.7 – 39.2	186,189	1,645
10% Above	38.5	35.9	29.3 – 36.8	178,354	1,576
Size Category Average	35.9	33.3	26.9 – 34.6	169,679	1,499
10% Below	33.3	30.8	24.6 – 32.6	160,114	1,415
20% Below	30.8	28.4	22.4 – 31.0	149,629	1,322
30% Below	28.4	26.0	20.2 – 29.8	138,222	1,221
40% Below	26.0	23.7	18.2 – 29.3	125,927	1,113

[1] The initial herd inventory distribution was 550 first lactation heifers evenly distributed between 11 lactation months and 100 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 600 plus cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

Unlike the previous estimations, a 650 cow farm that exhibits the typical lactation specific health culling rate for the 600 plus herd size could afford to pay the most ($435 per month) for a ten percent reduction in deaths (Table 57). Reducing lameness and injury culls by ten percent would save a manager $274 per month. A manager of a 650 cow herd could afford to pay up to $252, $250, and $76 per month to reduce udder and SCC culls, reproduction culls, and disease culls respectively.

Table 62. The BEA for a 10 Percent Reduction in Specific Health Culls for a 240 Month Period for a 650 Cow Herd with the 600 or More Cow Herd Size Average Health Culling Rate[1]

Specific Health Cull Reduced by 10 Percent	Previous Average Annual Total Culling Rate [2] (%)	New Average Annual Total Culling Rate (%)	New Annual Total Culling Rate Range (%)	NPV of the Health Cull Reduction ($)	Estimated Monthly BEA for a 10% Health Cull Reduction[3] ($)
Udder and SCC	35.9	35.4	28.9 – 36.4	28,496	252
Reproduction	35.9	35.5	28.8 – 36.4	28,313	250
Lameness and Injury	35.9	35.4	28.8 – 36.4	31,029	274
Disease	35.9	35.8	29.1 – 36.7	8,566	76
Death	35.9	35.3	28.7 – 36.3	49,253	435

[1] The initial herd inventory distribution was 330 first lactation heifers evenly distributed between 11 lactation months and 60 dry cows awaiting their second lactation evenly distributed between their first and second dry cow months.
[2] Lactation specific production and sold for dairy purposes culling rates were held constant at the 300 – 450 cow herd size average.
[3] The monthly BEA is the equivalent annuity of the NPV expressed as a monthly value.

VI. Using the DSS to Estimate the Profitability of Rubberized Alleyway Surfaces

In the previous sections, the DSS has been used to determine the BEA for a general reduction in health culls. Farms participating in the NAHMS Dairy '96 Survey that had their cows walk primarily on soft surfaces experienced a 17.5 percent decrease in lameness and injury culls in Chapter 4[1]. Although they didn't look at the effect on culling rates per se, Bray, Giesey, and Bucklin examined the effect of

[1](Lameness and Culling Rate Reduction / Lameness and Culling Rate Mean Response)* 100 % = (0.528/3.025)*100% = 17.454 percent.

having rubberized floors on lameness episodes on Florida cattle (2002). The researchers had two 130 cow groups, a 130 cow control group on concrete and a 130 experimental cow group on rubberized flooring. The experiment lasted one year. The control group experienced 37 percent fewer lameness episodes. With an average treatment expense of $300 per episode, the experimental group experienced $6,600 lower treatment costs than the control group in that one year period. In this section, the DSS will be used to estimate the profitability of installing a rubberized freestall alleyway floor.

It was assumed that the hypothetical herd for this estimation would take on the characteristics used in the estimation for the 130 cow Holstein herd used in the Holstein breed estimation in Section IV with one exception, the lameness and treatment episodes were increased to $300 per episode. It was assumed that the barn would be a three row variety with 4,775 square feet of alleyways to surface. Purchase and installation costs were set at $4 per square foot (Hadley, 2002). Prior to installation of the rubberized floors, the breed average lactation specific culling rates were used. After the installation, it was assumed that the lameness and injury culling rate would reduce by 17.5 percent for all lactations. A marginal tax rate of 35 percent and a capital gains tax rate of 15 percent were used in this analysis. The rubberized floor was depreciated using the 5 year Half Year Convention MACRS schedule.

The present value of the 240 months of cash flows without the rubberized floor was $1,450,086. The present value of the 240 months of cash flows with the rubberized floors was $1,459,554. The present value of the technology cash flows was -$32,448. Thus, the NPV of the investment in rubberized floors was:

$1,459,554 – $1,450,086 – $32,448 = -$22,980.

Because the NPV of the rubberized floor was negative, it indicates that the floor should not be adopted on the basis of reduced lameness and injury culls alone. When converted to a monthly equivalent basis, the rubberized floor is $161 per month less profitable than not having a rubberized floor from a culling perspective.

This value does not, however, include the total reductions in lameness episodes. According to the research of Bray, Giesey, and Bucklin – the lameness episodes decreased by 37 percent which saved $6,600 per year in treatment costs for the 130 cow experimental group (2002). When converting the $6,600 to a monthly equivalent basis, the savings in treatment expenses was equivalent to $528 per month[2]. If the rubberized floor profitability analysis is adjusted to not include the $300 in lameness and injury treatment expenses, the monthly equivalent value is -$162 per month instead of -$161. Thus, from an overall herd health and culling expense reduction, adopting the technology will result in $528 - $161 = $367 more income per month and should be adopted.

VII. Using the DSS to Estimate the Profitability of Gonadotropin Releasing Hormones

Nagategize examined the profitability of using GNRH and human chronic gonadotropin (HCG) to treat cystic ovaries in cattle, which generally renders cattle infertile (1988). Left untreated, 30 percent of the animals with cystic ovaries will recover. Those that do not recover are generally culled. Cattle with cystic ovaries that are treated with GNRH are 76 percent likely to recover. Those that fail to recover after the initial treatment are also 76 percent likely to recover with a follow up

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[2] Annual Amount/ (Future Value of an $\text{Annuity}_{k=8.724,\, n=12}$) = $6,600/[((1.00727)^{12} – 1)/.00727] = $528.

treatment of GNRH. Cattle treated with HCG are 68 percent likely to recover after the first and second treatments with HCG. Ngategize found that it was more profitable to treat cattle with GNRH and HCG twice prior to culling than to not treat the animals and that GNRH is more profitable to use than HCG.

In this section, the financial feasibility of using GNRH to reduce the number of cattle culled due to cystic ovaries is determined using the DSS. Currently, HCG, which is less effective than GNRH, costs the same as GNRH and is generally not used for cystic ovary treatments (Bauman, 2003). Thus, only the financial feasibility of GNRH is examined in this section.

Production and Financial Parameters

Based upon a study conducted in Michigan, it was assumed that the incidence of cystic ovaries was 12.8 percent (Ngategize, 1988). For a 130 cow herd, that means that 16.64 cows would develop cystic ovaries in a given year. Assuming that 30 percent would recover naturally means that 11.65 of these cows would be culled without treatment. Using GNRH for at the most two treatments would mean that only 0.96 cows would be culled. The cost of these treatments would be $82.52 (Bauman, 2003).

For this analysis, it was assumed that the farm would assume the characteristics of the farm used in the rubberized alleyway floor example with two exceptions. The farm's current and desired lactation specific culling rates would be set according to Tables 58 and 59 respectively. These distribution were chosen to permit a reproduction culling rate that would permit the cystic ovary incidence rate describe by Ngategize (1988). For the current lactation specific culling rate, 19 cows

Table 63. The Current Lactation Specific Culling Rates for The GNRH Financial Feasibility Estimation

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	31.77	3.09	3.82	4.43	10.51	6.48	0.80	2.64
2	49.62	2.93	5.62	6.88	18.44	9.89	1.59	4.47
3	57.11	2.33	5.68	8.93	19.94	12.82	1.49	5.92
4	64.03	1.99	5.84	10.76	21.41	15.68	1.38	6.97
5	69.87	1.79	5.91	12.02	22.92	17.92	1.33	7.98
6	75.78	1.79	6.30	13.13	25.24	19.95	1.10	8.27
7	80.81	1.64	6.73	13.82	26.39	22.42	1.10	8.71
8	85.21	1.51	7.49	13.56	29.22	23.56	1.00	8.87
9	89.96	1.66	7.38	13.08	30.73	27.00	0.74	9.37
10	91.78	1.73	8.75	13.00	28.68	28.03	0.87	10.72

Table 64. The Desired Lactation Specific Culling Rates For the GNRH Financial Feasibility Estimation

Lactation Number	Average Annual Culling Rate (%)	Sold for Dairy Purposes (%)	Production Culling Rate (%)	Udder and SCC Culling Rate (%)	Reproduction Culling Rate (%)	Lameness and Injury Culling Rate (%)	Disease Culling Rate (%)	Death Rate (%)
1	31.77	3.09	3.82	4.43	6.35	6.48	0.80	2.64
2	49.62	2.93	5.62	6.88	11.15	9.89	1.59	4.47
3	57.11	2.33	5.68	8.93	12.05	12.82	1.49	5.92
4	64.03	1.99	5.84	10.76	12.94	15.68	1.38	6.97
5	69.87	1.79	5.91	12.02	13.86	17.92	1.33	7.98
6	75.78	1.79	6.30	13.13	19.95	19.95	1.10	8.27
7	80.81	1.64	6.73	13.82	22.42	22.42	1.10	8.71
8	85.21	1.51	7.49	13.56	23.56	23.56	1.00	8.87
9	89.96	1.66	7.38	13.08	27.00	27.00	0.74	9.37
10	91.78	1.73	8.75	13.00	28.03	28.03	0.87	10.72

of which 11.65 are culled due to cystic ovaries, are culled for reproduction reasons. For the desired lactation specific culling rates, 8.43 cattle are culled due to reproductive failure. The difference between the two distributions are caused by the successful use of the GNRH treatments.

Financial Feasibility Results for the Use of GNRH

The use of GNRH generated a net present value of $66,233 for the twenty year period or $463 per month. Thus, a farmer with the characteristics of the one used in this analysis would be $463 per month more profitable with the GNRH treatments than without the treatments. The use of GNRH in this estimation resulted in the average total culling rate decreasing from 43.40 percent to 36.59 percent.

VIII. Summary and Conclusions

The BEA for a health culling rate reduction can vary based on farm characteristics. In the estimation results described in this chapter, the BEA varied by health cull incidence. For some very high health cull instances, the BEA actually increased for each successive ten percent health cull reduction. Over most of the lactation specific health cull ranges, the marginal BEA diminished with each successive ten percent health cull reduction. Thus, managers and advisors should not think it likely that they can afford to pay the same amount for successive reductions in their health culling rate, and the DSS should be used to estimate the BEA after each successful health cull rate reduction.

The BEA differed based upon breed and herd size. In general, a Guernsey herd could pay the most for a ten percent health culling rate reduction. Although the BEA was still positive for a Jersey herd, Jersey farm managers could afford to pay the least for a ten percent health cull reduction. As herd size increased, the BEA increased with herd size on both an absolute and per cow basis. The relative importance of reducing cattle mortalities increased with herd size. For the 650 cow herd, a ten percent reduction generated the highest BEA. For the 130 cow herd estimate, reducing deaths was the fourth highest BEA behind lameness and injury, reproduction, and udder and SCC culls.

It was determined that it was financially infeasible to adopt rubberized cattle alleyway floors from a culling reduction perspective. Nevertheless, if the reduction in non-culling lameness episode treatments are included, the technology is profitable to adopt.

GNRH proved to be a very profitable technology to use to reduce the incidence of culling due to cystic ovaries. Treating cattle up to two times generated positive returns of $487 per month over and above the treatment costs.

CHAPTER 7.

SUMMARY

In Chapter 1, it was stated that the ultimate goal of this research was to develop a Decision Support System (DSS) to aid producers and advisors in deciding the most profitable methods to reduce their health culling rate. In order to develop such a DSS, it was important to understand how culling affects production, how many cattle are culled, why cattle are culled and how management programs affect culling rates.

In Chapter 2, DHIA records for ten Midwestern and Northeastern states were examined to determine how culling, on average, affects production, the percentage of cattle culled each year, why cattle are culled, and when cattle are culled within a lactation. It appears as though there are both production incentives and disincentives to reducing culling rates and increasing herd culling rates. Cattle generally increase in milk, milk fat, and milk protein production throughout the fifth lactation. Nevertheless, somatic cell counts also rise with age and should be accounted for when determining whether to decrease culling rates. Cattle that were culled for health reasons produced less milk than their healthy herd mates. The majority of cattle were culled for health reasons. Midwestern farms tended to have higher culling rates than the Northeastern farms. The majority of cattle culled for health reasons other than death were culled at the end of a lactation. Most mortalities, however, occurred at the beginning of a lactation.

In Chapter 3, a probit model was used to determine how individual cow and herd level characteristics contributed to the likelihood that a cow would be culled. Data for this model was taken from individual cow and herd level DHIA data for five Midwestern and five Northeastern states for the period of 1995 – 1999. Because of the difference in culling rates between the two regions, the probit model was applied to each region separately. The probit model was able to predict culling and non-culling events at an eighty and eighty six percent accuracy rate for the Midwestern and Northeastern estimations respectively.

Cattle that calved during Winter were more likely to be culled than cattle that calved in Spring in both regions. Summer calving Midwestern cattle were less likely to be culled than their Spring calving counterparts. Cattle calving in Fall were less likely to be culled than their Spring calving counterparts, but, in the Northeastern region, the opposite was true. The likelihood of a cull increased with each successive lactation. The difference between a cow and her herd mate's milk, milk protein, and her production persistency was negatively correlated with the likelihood of a cull. The difference between a cow and her herd mate's somatic cell count and the previous lactation's services per conception was positively correlated with the likelihood of a cull. Cattle with higher or lower genetic potential to produce milk, milk fat, and milk protein did not have a significantly different likelihood than those with average genetic ability. In the Northeast, however, cattle that had lower genetic ability to produce fat were less likely to be culled. Jersey cattle were less likely to be culled and Guernsey cattle more likely to be culled in both regions. Cattle in Midwestern registered herds were less likely to be culled, but cattle on registered Northeastern herds were more likely to be culled. State of origin also had a significant effect on culling. Illinois, Iowa, and Wisconsin had significantly lower culling likelihoods than Indiana. In the Northeast, only Pennsylvania had a significantly lower culling likelihood than Vermont. Herd size had a small but significant negative effect on the probability of a cull in the Midwest, but a positive effect in the

Northeast. There were mixed effects associated with expansion and heifer ratio variables. The milk feed price and cull cow to replacement heifer price ratio of certain months had a significant effect on the likelihood of a cull.

Four ordinary least squares were developed to determine the effect that select management factors had on reducing the udder and mastitis, lameness and injury, disease, and reproduction culling rates. Only a few of the management factors significantly contributed to the udder and mastitis, lameness and injury, disease and reproduction culling rates at a p-value of 0.1000 or less. Only two management factors significantly affected udder and mastitis culling rates, having an employee handbook and using composted manure for bedding. Three factors were positively correlated with the lameness and injury culling rate, the presence of hairy heel warts, the number of veterinary visits – indicating that managers may primarily use veterinarians for treatment rather than prevention – and rolling herd average. Farms with multiple animal facilities and farms with soft cattle surfaces had significantly lower lameness and injury culling rates. There were only two management programs that significantly affected disease culling rates. Managers who prevented their youngstock from nose-to-nose contact with other species had lower disease culling rates than managers who did not. Farms that had animals that tested positive for Johne's Disease exhibited higher disease culling rates. Employee handbooks were also effective at reducing the reproduction culling rate but only when combined with incentives. Herd size was also negatively correlated with reproduction culling rates, possibly indicating that larger farms are more apt to hire specialized labor and to adopt reproduction technologies. Using herd bulls was also an effective method of reducing reproduction culling rates. Rolling herd average was positively correlated with reproduction culling rates.

In Chapter 6, the DSS was used to show that the maximum potential returns for a reduction in health culls varied by breed and herd size. Farms with Guernsey cattle were estimated to be able to pay the most for a ten percent health cull reduction followed by Holstein farms and Jersey farms. In general, producers could pay more for lameness and injury culls. The potential returns associated with health cull reductions decreased with each ten percent health cull reduction. Managers with larger herds were able to pay more per cow per month for health cull reductions than managers of smaller herds. Lameness and injury cull reductions had the highest potential returns for 100 and 400 cow herds, but decreasing mortalities created the highest potential returns for herds of 600 or more cows.

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