THE EFFECT OF INTERMITTENT VACCINATION OF THE BEEF COW HERD ON HERD PRODUCTION

by

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ABSTRACT

Annual vaccination of the beef cow herd is a common management tool for most beef herd operations. However, no studies have established the minimal vaccination frequency needed to attain an acceptable herd production output with minimal financial inputs. The hypothesis of this study stated that the production output and profitability of the cow herd would not be decreased by vaccinating the cow herd at intervals of greater than one year.

An animal's immune response to a vaccine or a direct challenge by a pathogen requires it to partition nutritional resources from other functioning biological systems within the body such as reproduction and lactation. According to the concept of diminishing returns, there is a point at which the cost of inputs (labor costs, vaccine costs and frequency of vaccination) does not result in corresponding levels of production output (measured by calf weaning weight, cow pregnancy rate and calf survivability). Thus, the objective of this thesis was to evaluate the effect of varying the interval of vaccination on cow reproductive productivity, calf productivity at weaning and herd profitability. It is important to note that this research study does not question the premises of vaccinating a cow herd or the effectiveness of the vaccines, but only investigates the time interval between vaccinations.

This study consisted of approximately1000 head of beef cattle divided between two ranch locations in south central South Dakota. Permanent and yearly production records were collected for each individual cow and calf for three production years 1998, 1999 and 2000. At each location cows were randomly assigned into four treatment groups:1) Group V0 – control or non-vaccinated, 2) Group V1 – vaccinated in 2000, 3) Group V2 – vaccinated in 1999 and 2000 and 4) Group V3 – vaccinated in 1998, 1999 and 2000.

At the conclusion of this four year study, varying the interval of vaccinations did not decrease the production and the profitability of the treatment groups compared to the control group in the weaning weight and calf mortality models. However, in the pregnancy model conception rates were significantly reduced in 2 of the 3 treatment groups.

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CHAPTER I: INTRODUCTION

1.1 Introduction

In 1961 Wiltbank et al. stated that failure for a beef cow to conceive a pregnancy and early embryonic death accounted for the largest loss in calf crop potential in the cow-calf industry. Dickerson reported in 1970 that reproduction was the main factor limiting production efficiency in beef cattle. Following this study, in 1994, Bellows and Short stated that the greatest production loss in the cow-calf segment of the beef industry results from cows not being pregnant at the end of the breeding season (Geary). One routinely accepted management method to maintain or increase reproductive efficiency in the beef cow herd is yearly immunizations of breeding animals to prevent reproductive diseases. In 2002 Dunn reported that of the average $430 production cost per cow in the Northern Great Plains, $19.00 was attributed to the category of veterinary medicine which includes all veterinary medicine and supplies. Individual beef cow vaccinations in this study herd ranged from $1.00 to $2.00 per head, with the total vaccine costs per cow-calf pair per year under $10.00. This is less than 2.5% of total production costs per cow depending on the number and frequency of vaccinations.

There is a large variety of bovine vaccines currently marketed in the United States, most of which are very effective in preventing the disease against which they are directed. Ideally, vaccination programs are specifically designed by a veterinarian for each individual client, ranch and herd of cattle. With the seemingly affordable and unlimited supply of available vaccines, it has been common practice to follow FDA labeled instructions for administering vaccines with specific route of administration, location of injection, dosage and frequency of vaccination. From the viewpoint of a practicing veterinarian, vaccines are considered a form of risk management similar to a yearly insurance policy. They cost a little each year but protect owners from large financial losses that can occur in cases of large disease outbreaks. Dunn (2002) reported that there were no statistical relationships between profitability and cow-calf production measures including pregnancy rates and weaning weights as measures of inputs in the Northern Great Plains. He also explains that reducing cost of production is desirable if production is not impacted beyond a certain threshold and identifies the concept of points of diminishing returns as an important point in a production system. Additional inputs do not necessarily result in corresponding levels of output and these thresholds may not be readily visible in a complex system like beef cattle production. Do the inputs required for the yearly vaccination of the breeding cow herd result in corresponding levels of output measured in production parameters? At what point do we reach the point of diminishing returns in a complex biological system?

1.2 Objective

The objective of this thesis was to determine the effect of varying the interval of vaccination on cow reproductive productivity, calf productivity at weaning and herd profitability.

1.3 Hypothesis

Production output and profitability of the cow herd will not be decreased by vaccinating the cow herd at intervals of greater than one year.

1.4 Study Design

This study herd consists of approximately 1000 head of commercial cows, bred heifers and bulls. The herd was separated into two locations about 50 miles apart in south central South Dakota with approximately +/- 380 cows in the northern herd at Gann Valley (GV) and +/- 400 cows in the southern herd described as West River (WR). The cows remained on native pasture for the entire 12 months of the year with a normal summer grazing period of May to November. Fall, spring and winter grazing of native grass was available with additional forage supplements provided during the winter months when determined necessary by management. Salt, mineral and water were provided ad libitum year round. All cows were individually identified using double ear tags and a numbered metal tag. All individual cow and calf information was collected and entered into a cow-calf record keeping program for management purposes and future production analysis. Individual cow-calf production records collected for this herd included but were not limited to: age, pregnancy status, calving ability, maternal ability and culling classifications of the cow and calf birth date, birth weight, vigor, morbidity, mortality and weaning weight.

The health program for this herd prior to entering the study consisted of yearly administration of vaccines, according to manufacturer's directions, to all breeding animals prior to calving and pre-breeding. Bulls were all purchased from outside sources and fertility tested based on the standards of the Society of Theriogenology (www.therio.org). All animals in the herd had been vaccinated, wormed and poured according to a comprehensive herd health program including the use of modified live reproductive vaccines pre-breeding. All mature females had been calf-hood vaccinated for *Brucella* *abortus* prior to entering the breeding herd. Pregnant females received vaccinations for *E. coli* and *Clostridium perfringens* types CD prior to calving to help prevent neonatal diarrhea in newborn calves.

In late spring all breeding age animals were poured and wormed, immunized with Anthrax and the following reproductive vaccines at branding prior to bull turnout: Modified live BVD1 and PI3, killed bacterins *Campylobacter Fetus*, *Leptospira* strains *Canicola*, *Grippotyphosa*, *Hardjo*, *Icterohaemorrhagiae* and *Pomona*. Bulls were pulled at approximately 60 days after turn out and during the fall of the year the cows were pregnancy checked by a licensed veterinarian via rectal palpation/ultrasound and treated for ecto/endo parasites. All open (non-pregnant cows) and culls (bulls or cows unfit for future beef production) were removed from the herd at this time.

This study started in the spring of 1998 (pre-breeding) and ended in the fall of 2001 following calf weaning and pregnancy testing of the cow herd. The test animal is described as a healthy 3 to 10+ year old commercial beef breeding female (*Bos taurus*) weighing from 1100 to 1400 pounds. Cows were randomly assigned into four treatment groups: 1) Group V0, non-vaccinated or control, 2) Group V1, vaccinated in 2000, 3) Group V2 vaccinated in 1999 and 2000 and 4) Group V3 vaccinated in 1998, 1999 and 2000. This study is based on a production cycle of this cow herd which is approximately 14-15 months in duration. Year one production cycle includes the June 1998 pre-breeding vaccinations, fall 1998 pregnancy diagnosis, February 1999 pre-calving vaccinations and the 1999 fall calf weaning weights. Production years 1999 and 2000 follow accordingly with the study ending with the 2001 calf weaning weights and cow pregnancy rates. The calves were vaccinated at spring branding and boostered pre-weaning with modified live IBR, BVD1, PI3 and BRSV, Clostridium 7-way, Hemophilus somnus and Pastuerella hemolytica.

Blood samples for serum titer evaluation of BVD1, BVD2, PI3 and BRSV were collected from cows using the caudal venipuncture method and sent to the Veterinary Diagnostic Lab at South Dakota State University for antibody assay. In the first year of the study, spring of 1998, the first 35 vaccinated animals in the chute were sampled and the next 65 non-vaccinated animals through the chute were bled at each location. In the spring of 1999 and 2000 the cows were sampled based on a randomly assigned bleeding list for all four treatment groups. Also, by design, all cows that were culled from the herd had blood samples collected by described protocol and analyzed at the SDSU diagnostic lab.

CHAPTER II: LITERATURE REVIEW

2.1 Annual Cowherd Vaccinations

Since Jenners introduction of the practice of inoculation approximately 200 years ago the greatest benefit to come from the science of immunology has been the development of safe and effective vaccines against a variety of infectious agents in the human and animal populations (Kimball). The time from the first dose of vaccine to initial protection, range from 3 to 21 days in most bovine vaccines. Over this time period antibodies to the initial vaccine are produced and are detectable in the serum and then steadily decline until they are no longer found in the blood stream. Subsequently most livestock are challenged by the agent a second time in form of a booster vaccine or the live pathogenic organism itself. In either case, a secondary immune response is triggered and specific antibodies to the agent are produced in a period of hours, not days immediately protecting the animals in the herd. Many vaccines incorporate adjuvant agents like aluminum hydroxide that enhance the immunogenicity of the product by increasing antibodies produced by the antigen (Kimball). Most commercially available livestock vaccines are labeled to have an initial immunization followed by a second dose in 2 to 4 weeks and followed by yearly boosters to enhance the secondary immune response.

Beef cow herd vaccination programs are determined based on many variables; age and sex of the herd, disease history of the geographical location inhabited by the herd, disease history of the herd, previous vaccination history of the cattle, intended use of the livestock, nutritional status of the herd and management philosophy. Animals in poor or declining nutritional status and deficient in protein and/or energy are unable to develop an acceptable immune response to a pathogenic challenge simply because most aspects of the immune system, such as antibodies, require specific types of proteins to function. Vaccinations that are highly recommended for use in all adult beef herds include: Brucellosis, Infectious Bovine Rhinotracheitis Virus (IBRV), Bovine Viral Diarrhea Virus (BVDV), Leptospira and Campylobacteria bacterins. Vaccines that may be useful in specific herds and specific geographical locations include: Trichomonas and Clostridium bacterins and Anthrax modified encapsulated spore vaccine (Hjerpe).

2.1.1 Viral Vaccines

The two most highly recommended reproductive viral vaccines in a beef cattle herd health program are Bovine Viral Diarrhea Virus (BVDV) and Infectious Bovine Rhinotracheitis Virus (IBRV). Both viruses can be involved in multiple organ systems and cause disease in both the reproductive and respiratory systems. The duration of immunity is considered life long following the initial dose with modified live BVDV and IBRV vaccines, although vaccine manufacturers recommend yearly boosters.

Infectious Bovine Rhinotracheits Virus, is well recognized as a pathogen that infects the respiratory and reproductive tracts and also infects the fetus, potentially leading to abortion in susceptible pregnant females with as many as 25% to 60% of the cows in the herd aborting (Kelling). The respiratory form of the disease can be subclinical in immune animals and severe in immunologically naïve cattle with morbidity rates approaching 100% and mortality rates reaching 10%. Primary infection often occurs following transport to and acclimation in feedlot environments. Although the vaccine does not prevent infection, beef cattle are routinely vaccinated for IBRV in many parts of the world contributing to significantly reduced incidence of the disease (Fenner).

Bovine viral diarrhea virus (BVDV) is one of the most economically important and commonly found cattle diseases in North America. It is also one of the most complex diseases in cattle and causes both acute and chronic diseases involving the reproductive, gastrointestinal and immunological systems. Infection of the reproductive system can lead to early embryonic or fetal death, abortion, stillborn calves and/or weak calves at birth. Mucosal disease is a chronic wasting disease of the gastrointestinal system that is associated with high mortality rates. The immune system of an unborn fetus can be persistently infected (PI) if the fetus has a PI dam or if the pregnant dam is infected during the early stages of pregnancy (Fenner). There are two genetic genotypes of bovine viral diarrhea, BVDV types 1 and 2. Most BVDV vaccines have some antigenic cross reactivity and for vaccines to be effective they must provide cross protective immunity against both genetic types (Kelling). At the time of this study, BVDV type 1 was the only serotype available in bovine vaccines, in recent years almost all vaccine manufacturers now include BVD virus types 1 and 2 in their products.

2.1.2 Bacterial Vaccines

Multiple *Leptospira* species and *Campylobacter fetus* are the primary bacterial pathogens that cause reproductive diseases in beef cattle. Vaccination for these two diseases is highly recommended in bovine herd health management. Leptospirosis is associated with a broad spectrum of disease caused by multiple serovars of the organism. This disease in cattle is associated primarily with abortion from 4 months to term and birth of weak calves. Abortion rates may be as high as 50% in non protected herds. Immunization with a killed bacterin is recommended at 6 to 12 month intervals and more frequently in areas with heavy exposure. Campylobacter fetus is primarily associated with infertility due to early embryonic loss in beef cattle with sporadic abortions occurring from the fourth to the eight month of gestation. Campylobacteriosis is controlled by use of a killed adjuvanted bacterin administered at yearly intervals and more frequently if needed (Youngquist).

2.1.3 Beef Cowherd Production Benchmarks

Being competitive in the current cow-calf segment of the beef industry requires that producers are capable of collecting relevant herd production and financial data that can be analyzed to evaluate herd productivity and profitability and be utilized to affect future management decisions (Ringwall). Table 2.1 is a compilation of cow-calf production records collected in the Northern Great Plains by the North Dakota State University Extension Service, Cow Herd Appraisal of Performance Software (CHAPS) and North Dakota's Intergrated Resource Management (IRM) program. The herd performance calculations in this table were obtained from 74,421 cow records from production years 2002 to 2006 (NDSU). These measures can be used as benchmarks for evaluation of the results of the research models and discussion in this study.

Table 2.1 IRM-SPA Cow-Calf Enterprise Reproduction and Production Measures

Benchmark Data Years	**2002-06**
Exposed Cows in CHAPS Herds	74,421
Reproduction Performance	**Mean %**
Pregnancy Percentage	93.67
Pregnancy Loss Percentage	0.73
Calving Percentage	92.99
Calf Death Loss/calves weaned	3.08
Calf Weaning Percentage	90.85
Female Replacement Rate	14.71
Calf Death Loss/calves born	3.22
Calves Born First 21 Days	64.1
Calves Born First 42 Days	89
Calves Born First 63 Days	95.6
Calves Born After 63 Days	4.4
Production Performance	
Average Age at Weaning	189
Actual Weaning Weight Steers	566
Actual Weaning Weight Heifers	546
Actual Weaning Weight Bulls	621
Average Weaning Weight	561
Weight Weaned per Exposed Female	502

Source: NDSU, Integrated Resource Management Program

Pregnancy percentage is the number of cows that are diagnosed pregnant divided by the number of cows exposed to a bull in the same year. Pregnancy loss percentage is the difference between the number of cows diagnosed pregnant in the fall minus the number of cows that did not calf in the following spring due to fetal loss, abortion or error in pregnancy diagnosis. Calf death loss born is the number of newborn calves that die during the neonatal calving period (first 10 days of life) and calf death loss weaned is the number of calves that survive the neonatal period but die prior to weaning.

CHAPTER III: METHODS

3.1 Analysis Methods

In 1997 a study design and hypothesis was developed for this project. The data for this study were collected beginning in the spring of 1998 and completed in the fall of 2001. A literature review was conducted but no information was found that dealt with determining the effect of varying the time intervals of beef cow herd health vaccinations on production. The empirical models were chosen based on variables and functional form. Next the sign of the coefficients was hypothesized and the equations were estimated, evaluated and documented as described in the following paragraphs.

To accomplish the objectives of the project required development of several statistical models to test specific hypotheses regarding cow productivity measures with different vaccination treatment programs. Of particular interest is the impact of the vaccination program on 1) cow pregnancy, 2) pregnancy loss - whether a live birth occurred in the spring given a cow was diagnosed as pregnant the previous fall, 3) calf mortality - whether a calf was weaned given a live calf was born, and 4) calf weaning weight. The first three variables of interest are binary in nature. For example, either a cow is pregnant or she is open. Explaining factors determining whether a cow is pregnant or not requires using a statistical methodology designed for analyzing binary data such as a logit model. The calf weaning weight is a continuous variable for which Ordinary Least Squares regression analysis is appropriate. This chapter presents the general statistical methodology used first for the binary dependent variable models and summarizes the specific models estimated using that method. Next, the statistical procedure used for continuous variables is presented followed by the specific model estimated using that method.

3.2 Binomial Logit Regression Models

The first model that is used to test hypotheses for the first three dependent variables noted above is of a binomial logit framework. The binomial logit is an estimation technique used for equations with dummy dependent variables that are in the form of the binary digits 1 or 0. The binomial logit is an estimation technique that reports the maximum likelihood or concordance of a model and is especially useful for equations that are nonlinear in the coefficients.

The conceptual form of the binomial logit regression models can be represented by the following equation;

$$\mathbf{Di = B0 + B1X1i + B2X2i + \ldots\ldots + BnXni + ei} \qquad (3.1)$$

where **Di** is the dependent binomial dummy variable to be estimated by the equation. **Bo…Bn** are the estimated regression coefficients, **Xi** represents the independent variables and **ei** is the error term (Studenmund). The dependent variables include binary cowherd productivity measures collected during this study (cow pregnancy status, pregnancy loss, and calf mortality) and dummy independent variables that represent different locations, treatment groups and production years (1998, 1999 and 2000). Continuous independent variables included into the model were cow age, and cow age squared. For each logit model the independent variables are the same but differ in the dependent variables cowherd pregnancy, cowherd pregnancy loss, and calf mortality. Because a binary logit model is predicting an odds ratio, the estimated coefficients from the model are difficult to interpret. The signs of the coefficients indicate direction of impact but the marginal impacts (for continuous explanatory variables) or changes in probability (for binary explanatory variables) that can be calculated directly from the model estimates and are of the most interest.

3.2.1 Pregnancy Model

Whether a cow is pregnant or not represents whether the cow was diagnosed pregnant in the fall. To determine how pregnancy was affected by the different variables in the treatment groups the following binomial logit regression equation was estimated.

$$PPi = a0 + a1LOCi + a2V3i + a3V2i + a4V1i + a5DAMAGEi + a6DAMAGE2i + a7DUM1999i + a8DUM2000i + ei \qquad (3.2)$$

PP, pregnancy probability is the dummy dependent variable where (1) indicates a pregnant cow and (0) a non-pregnant cow. The independent variables are: LOC is the dummy variable for location with (1) indicating Gann Valley and (0) for West River, V3 is a dummy variable equal to (0) if unvaccinated and (1) if the cow received immunizations all three years of the study (1998, 1999, and 2000), V2 is a dummy variable equal to (1) if the cow received immunizations two of the three years of the study (1999 and 2000) and (0) during the year the cow was treated the same as the unvaccinated control group, V1 is a dummy variable equal to (1) if the cow received immunizations one of the three years of the study and (0) during the years the cow was treated the same as the unvaccinated control group. A control group of cows (V0) was not vaccinated any of the three years and is the default treatment variable not included in the model. DAMAGE is the age of the cow in years and DAMAGE2 is the age of the cow in years squared. DUM1999 is a dummy variable equal to (1) for the production year 1999, DUM2000 is a dummy variable equal to (1) for the production year 2000 and 1998 is the dummy default variable for production year. The error term is represented by **e** and **i** the individual cow-calf records.

The expected signs for the coefficients of the pregnancy percentage model are:

a1 =? The sign for the coefficient of location is difficult to predict, the biological variation in pregnancy rates will vary due to numerous factors.

a2 > 0 It would be expected that cattle on a regular reproductive vaccination schedule would experience higher pregnancy rates.

a3 > 0 Again, the expected sign should be positive due to the fact that the cows were vaccinated two of the three years.

a4 > 0 This sign should be positive considering that this group was vaccinated at least once as opposed to the control group that received no vaccinations during the study.

a5 > 0 Pregnancy rates generally increase in young to middle aged cows as they mature so I expect this sign to be positive.

a6 > 0 The coefficient for this sign should be positive in young cows, however, it could also be negative if older cows begin to lose fertility.

a7 =? The coefficient of the year variables is difficult to determine because of the many factors influencing production from year to year.

a8=? The coefficient of the year variables is difficult to determine because of the many factors influencing production from year to year

3.2.2 Pregnancy Loss Model

The pregnancy loss model estimates factors affecting a cow that was diagnosed pregnant in the fall and did not calf in the following spring. Pregnancy loss is the result of early embryonic death, abortions or misdiagnosis of pregnancy. To determine how pregnancy loss probability was affected by the different variables in the treatment groups the following binomial logit regression equation was estimated.

$$PLi = b0 + b1LOCi + b2V3i + b3V2i + b4V1i + b5DAMAGEi + b6DAMAGE2i + b7DUM1999i + b8DUM2000i + ei \quad (3.3)$$

PL, pregnancy loss is the dummy dependent variable where (1) indicates a loss in pregnancy and a (0) indicates that a live calf was born. The independent variables are the same as presented in equation 3.2

The expected signs for the coefficients of the pregnancy loss percentage model are:

b1 =? The sign for the coefficient of location is difficult to predict, the biological variation in pregnancy loss rates are not usually influenced by location alone.

b2 < 0 It would be expected that cattle on a regular reproductive vaccination schedule would experience minimum pregnancy loss.

b3 < 0 Again, this sign should be negative due to the fact that the cows were vaccinated two of the three years.

b4 < 0 This sign should be negative considering that this group was vaccinated at least once as opposed to the control group that received no vaccinations during the study.

b5 =? 0 Pregnancy loss rates are influenced by many factors other than age and this would be difficult to determine.

b6 =? 0 The coefficient for this sign would also be difficult to determine.

b7 =? The coefficient of the year variables is difficult to determine because of the many factors influencing production from year to year.

b8=? The coefficient of the year variables is difficult to determine because of the many factors influencing production from year to year

3.2.3 Calf Mortality Model

The calf mortality model predicts the probability that a calf born alive in the spring will die prior to weaning in the fall. To determine how calf mortality was affected by the different variables in the treatment groups the following binomial logit regression equation was estimated.

$$CM_i = c_0 + c_1LOC_i + c_2V3_i + c_3V2_i + c_4V1_i + c_5DAMAGE_i + c_6DAMAGE2_i + c_7DUM1999_i + c_8DUM2000_i + e_i \quad (3.4)$$

CM, calf mortality is the dummy dependent variable where (1) indicates a calf that died in the herd and (0) indicates a calf that survived to weaning. The independent variables are the same as in equation 3.2

The expected signs for the coefficients of the calf mortality model are:

c1 >0 The sign for the coefficient of location should be positive because this ranch location was farther north and did not have as much natural protection for newborn calves

c2 < 0 It would be expected that cattle on a regular reproductive vaccination schedule would experience lower calf mortality rates.

c3 < 0 Again, this sign should be negative due to the fact that the cows were vaccinated two of the three years.

c4 < 0 This sign should still be negative considering that this group was vaccinated at least once as opposed to the control group that received no vaccinations during the study.

c5 < 0 Calf mortality rates should decrease as a cow gets older due to better mothering ability of the dam.

c6 =? 0 The coefficient for this sign would be difficult to determine.

c7 =? The coefficient of the year variables is difficult to determine because of the many factors such as weather influencing production from year to year.

c8=? The coefficient of the year variables is difficult to determine because of the many factors such as weather influencing production from year to year

3.3. Ordinary Least Squares Regression Model

The empirical model for evaluation of weaning weight, a continuous dependent variable, in this study takes the form of a multivariate regression model:

$$\mathbf{Yi = do + d1Xi + d2Xi + \ldots\ldots + dnXi + ei} \qquad (3.5)$$

Yi is the dependent variable to be estimated, **do….dn** are the estimated regression coefficients, **Xi** are the independent variables and **ei** is the error estimate. The independent variables in this regression include cowherd production parameters and dummy variables similar to the previous models but the estimated coefficients have a direct negative or positive impact on the dependent variable. For each unit of change of an independent variable the dependent variable changes by its estimated coefficient.

3.3.1 Calf Weaning Weight Model

The calf weaning weight model is a measure of the actual weaning weights of the calves in the study herd. To determine how weaning weight was affected by different independent variables in the treatment groups the following regression equation was developed:

WW = d0 + d1LOCi + d2CALFSEXi + d3CALFAGE*1999i + d4CALFAGE*2000i + d5CALFAGE*V3i + d6CALFAGE*V2i + d7CALFAGE*V1i + d8DAMAGEi + d9DAMAGE2i + d101999i + d112000i + ei (3.6)

WW is a calf's weaning weight and the dependent variable in this equation. The independent variables are as follows: LOC is a dummy variable describing location with (1) representing GV and (0) WR, CALFSEX is a dummy variable with (1) indicating a heifer and (0) a steer. Because of the management decision to implement early weaning, several interaction terms are included in the model to evaluate the average daily gain of the calf (i.e., the coefficient of calf age {CALFAGE} in days multiplied by production year and treatment group). This calf age adjustment is similar to adjusting the actual weaning weight of a calf to the industry standard 205 day age adjusted weaning weight measurement but in this case each variable was adjusted by each individual calf age in days. CALFAGE*1999 is an interaction variable between the dummy variable for production year 1999 multiplied by calf age, CALFAGE*2000 is a dummy variable for production year 2000 multiplied by calf age, CALFAGE*V3 is a dummy variable for the treatment group V3 multiplied by calf age, CALFAGE*V2 is a dummy variable for the treatment group V2 multiplied by calf age, CALFAGE*V1 is a dummy variable for the treatment group V1 multiplied calf age. DAMAGE is the age of the cow in years and DAMAGE2 is the age of the cow squared. The production year 1998 is the default dummy variable for year, 1999 represents the production year 1999 and 2000 represents the production year 2000. The expected signs for the calf weaning weight model are:

$d1 < 0$ The sign of the coefficient for location is expected to b negative due to more inclimate weather and poorer protection on the ranch.

$d2 < 0$ The binary digit 1 represents a heifer calf and the sign for this coefficient should be negative because they are generally lighter than steer calves.

d3 =? The production year was adjusted by calf age to account for earlier weaning in 1999 than 1998 but I am uncertain how to determine a sign for the production year due to the many variables involved in a production year such as environment.

d4 =? The production year was adjusted by calf age to account for earlier weaning in 2000 than 1998 but I am uncertain how to determine a sign for the production year due to the many variables involved in a production year such as environment.

d5 > 0 The calves that had dams belonging to the treatment group vaccinated all three years should produce heavier calves as a result of improved health compared to the control group.

d6 > 0 Calves from the treatment group that was vaccinated two of three years should wean heavier calves as a result of improved health compared to the control group.

d7 > 0 Calves from the treatment group that was vaccinated one year should wean calves heavier than the control as a result of improved health compared to the control group.

d8 > 0 The sign for this coefficient should be positive because as cows approach maturity they should wean heavier calves.

d9 < 0 The sign of this coefficient should be negative indicating that the calf weight increases at a declining rate (that is, if d8>0, then expect d9<0).

d10 =? It would be difficult to determine the sign of the coefficient of a production year due to the many factors that would affect it such as environment.

d11 =? It would be difficult to determine the sign of the coefficient of a production year due to the many factors that would affect it such as environment.

The cow age for maximum weaning weight can be calculated by using the following formula from Mansfield Chapter 2 Optimization Techniques:

$$WW = d8DAMAGE + d9DAMAGE2$$

Taking its first derivative

$$dWW/dDAMAGE = d8 + 2\ d9DAMAGE = 0 \qquad (3.7)$$

$$DAMAGE = (-d8 / 2d9)$$

CHAPTER IV: DATA DESCRIPTION

Individual cow-calf production records were collected on central South Dakota ranch operations from the spring of 1998 through the fall of 2001. Permanent and yearly production records were collected for each individual cow and calf and entered into a commercially available cow-calf record keeping system. The performance measure data collected for this study includes: individual cow and calf identification, cow age, cow pregnancy rate, calf birth date, calf birth weight, calf death loss, calf weaning weight and calf weaning date. There were 2693 individual cow records collected during this time period, 54 of the records were incomplete and not used for analysis. The study group consisted of 2639 usable records with the control group (V0) containing 1105 records, the treatment group vaccinated 3 years (V3) having 663 records, the treatment group vaccinated 2 years (V2) with 352 records and the treatment group vaccinated 1 year (V1) with 496 records. The average cow age in this herd over the three years was 5.9 years with a range of 2.0 to 13.8 years. Average pregnancy rate for production year 1998 was 88.78%, for 1999 was 92.73% and for 2000 was 90.76%. Pregnancy loss rate, the difference between cows diagnosed pregnant in the fall and not having a calf in the following spring averaged 1.76% over the three years. Calf death loss rate, calf mortality from birth to weaning was 2.79% and calf weaning rate during the study was 86.12%. The average age of the calves at weaning were 161.6 days and the average herd weaning weight was 443.5 lbs. per calf. The average weight per day of age in this herd for the three production years was 2.74 lbs. Table 4.1 provides the summary statistics for the data collected for the study herd for production years 1998, 1999 and 2000.

Table 4.1 Herd Study Summary Statistics

Research Study Years 1998 to 2000

	Total	%
Cows Records in Study Herd	2639	
V0 - Non-vaccinated Control Group	1105	42.24%
V3 - Treatment Group Vaccinated 3 years	663	25.34%
V2 - Treatment Group Vaccinated 2 years	352	13.46%
V1 - Treatment Group Vaccinated 1 year	496	18.96%

Production Performance

	Mean	Median	Min	Max	StdDev
Calf Age at Weaning	161.6	164.5	88.0	241.0	26.9
Weaning Weight - Steers	457.0	462.0	183.0	670.0	77.7
Weaning Weight - Heifers	429.4	430.0	200.0	606.0	66.5
Total Calf Weaning Weight	443.5	444.0	183.0	670.0	73.6
Calf Birth Weight	82.6	83.0	41.0	128.0	10.7
Cow Age	5.9	5.8	2.0	13.8	2.9

Production Performance	%
Pregnant Rate	90.67%
Pregnancy Loss Rate	1.76%
Calving Rate	88.91%
Calf Death Loss Rate	2.79%
Calf Weaning Rate	86.12%

Table 4.2 contains the correlation of variables used in the regression models. Correlation numbers range from r = +1, a perfectly positively correlated pair to r = –1 a perfectly negatively correlated pair. If r = 0 then the two variables are totally uncorrelated (Studenmund). The pair-wise correlations are generally less than 0.50 in absolute values with a few exceptions such as year and calf age. Year and calf age have correlations that are relatively large in absolute values because calves were weaned at different ages each year. Overall, the correlation matrix reveals that at least pair-wise colinearity (high x-variable correlation) is not likely to be a substantial problem in the models estimated in this study. High levels of pair-wise correlation can make otherwise statistically significant independent variables insignificant (i.e., standard errors can be inflated with high correlations among the x-variables) and lack of pair-wise colinearity concerns does not necessarily preclude multivariate colinearity.

Table 4.2 Pair-wise Correlations of Variables Used in Regression Models

	Wnwt	*Location*	*Calf Sex*	*Calf Age*	*V3(98-00)*	*V2(99-00)*
Wnwt	1					
Location	-0.231187	1				
Calf Sex	-0.187342	-0.044139	1			
Calf Age	0.308415	0.012553	0.063953	1		
V3(98-00)	-0.003761	0.054162	-0.019518	-0.042658	1	
V2(99-00)	-0.081374	0.091452	0.023284	-0.033992	-0.199209	1
V1(2000)	0.012302	-0.119197	-0.002377	-0.231566	-0.188161	-0.105825
V0(Cont)	0.017816	-0.024562	0.020006	0.071575	-0.513041	-0.288544
Dam Age	-0.052587	0.299743	-0.032045	-0.236314	0.283355	-0.330494
Dam Age2	-0.112163	0.326387	-0.026807	-0.211762	0.236759	-0.269136
1998	0.007815	0.06566	0.016879	0.485231	0.094067	-0.244372
1999	0.068279	-0.032488	-0.011572	0.16885	-0.035046	0.134734
2000	-0.076106	-0.034211	-0.005579	-0.661126	-0.060492	0.113529

	V1(2000)	*V0(Cont)*	*Dam Age*	*Dam Age2*	*1998*	*1999*
Wnwt						
Location						
Calf Sex						
Calf Age						
V3(98-00)						
V2(99-00)						
V1(2000)	1					
V0(Cont)	-0.272542	1				
Dam Age	-0.106656	0.060839	1			
Dam Age2	-0.071258	0.043145	0.973569	1		
1998	-0.23082	0.102071	-0.055663	-0.073636	1	
1999	-0.219463	0.007067	-0.020433	-0.02047	-0.506785	1
2000	0.453417	-0.110664	0.076903	0.095183	-0.509068	-0.484021

CHAPTER V: RESULTS

To evaluate the effects that the vaccination treatment groups have on the probability of a cow being pregnant, on the probability of a pregnancy loss and the probability of calf mortality the independent variables in each of the first three binomial logit regressions were identical. While developing and analyzing the regression models it was determined that including cow age squared (DAMAGE2) could improve the overall fit of the models. This indicates nonlinear impacts of cow age on these variables of interest. Of course marginal impacts of individual x-variables in logit models are inherently non-linear and the addition of quadratic terms on continuous variables that are expected to have diminishing marginal returns can improve model fit.

5.1 Pregnancy Probability Model Results

A binomial logit regression model was developed to determine the effects of the independent variables, primarily the four vaccination treatment groups, on the probability that a cow will become pregnant (1) or be open (0). The dummy independent variables include location (GV and WR), treatment groups (V0, V1, V2 and V3) and production years 1998, 1999 and 2000. The dummy default variables include location WR, treatment group V0 and production year 1998. The independent continuous variables included in this model are cow age and cow age squared. The pregnancy probability model had 2616 recorded observations and correctly predicted whether or not a cow was pregnant 58.6% of the time, percent concordant. It incorrectly predicted the outcome 38.2% of the time, percent discordant. The R-squared value, which is typically low in binomial logit regression models, has a value of 0.0118. The dependent variable mean is 0.907 which indicates the proportion of cows that are pregnant in this data set. Parameter estimates from this model are presented in table 5.1.

Table 5.1 Logit Regression Results for Pregnancy Probability Model (Dependent Variable Pregnant = 1, Open = 0)

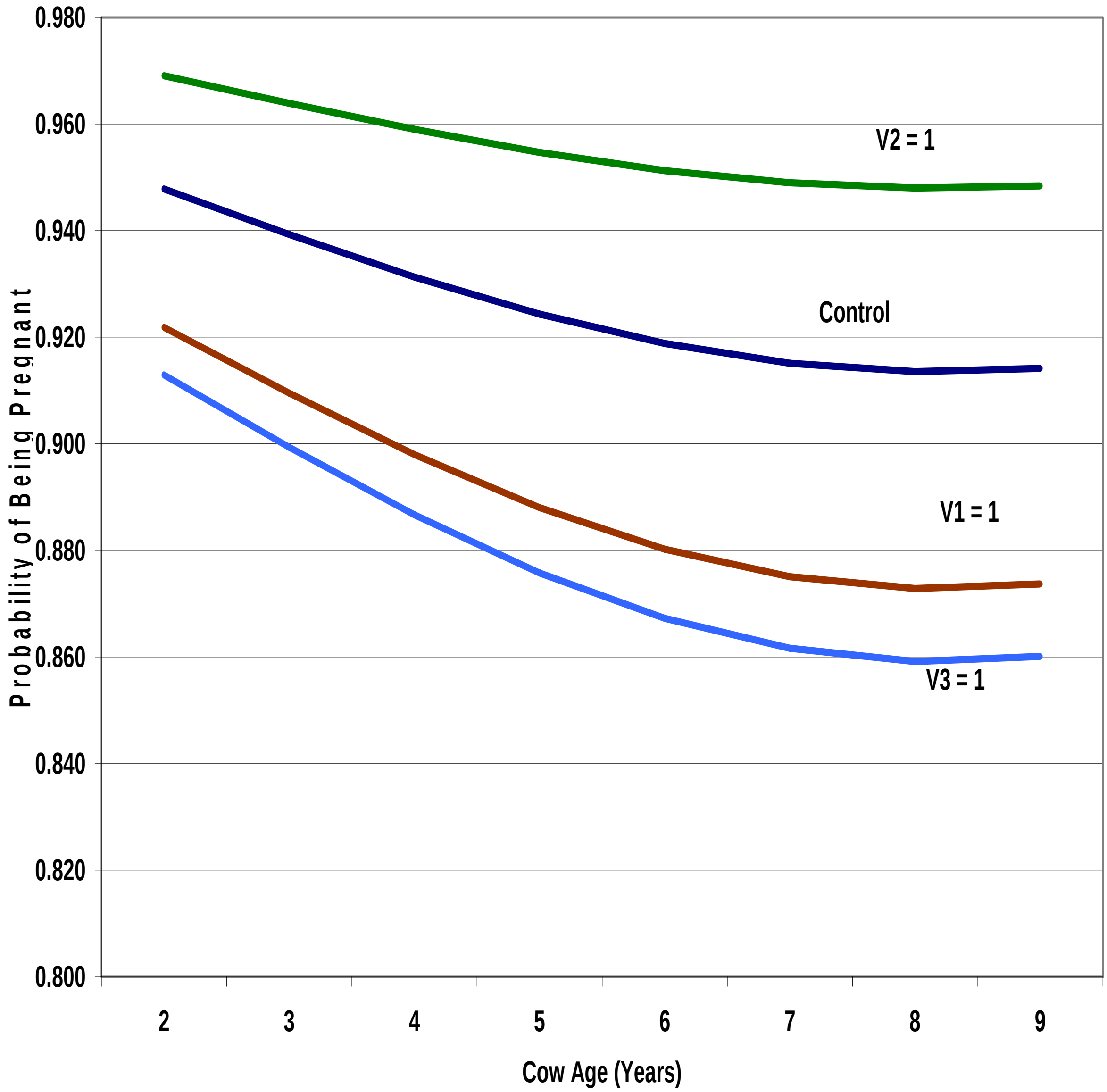
Variable	Estimate	Std Error	ChiSq	p-Value
Intercept	3.1348	0.3998	61.4661	<.0001
Location	-0.0572	0.1493	0.147	0.7014
v3	-0.4314	0.153	7.9489	0.0048
v2	0.5452	0.368	2.1944	0.1385
v1	-0.5492	0.2668	4.2385	0.0395
DamAge	-0.2302	0.1253	3.3744	0.0662
DamAge2	0.014	0.00907	2.384	0.1226
Dum1999	0.1093	0.1701	0.4128	0.5205
Dum2000	0.1685	0.1917	0.7727	0.3794

R-squared	0.0118
Observations	2616
Dependent Variable Mean	0.907
Percent Concordant	58.6
Precent Discordant	38.2
Precent Tied	3.2

The estimated coefficient of location (GV) was -0.0572 and was not statistically significantly different from zero with P>0.05. A P value greater than 0.05 indicates that the variable tested was not statistically significant at the 95% confidence level and a P value less than or equal to 0.05 indicates that the variable tested was statistically significant. An expected negative sign for location in this model was not predicted because pregnancy rates were not expected to be higher or lower at one ranch relative to the other. The sign of the estimated coefficient of treatment group V3 was incorrectly predicted (cows vaccinated all 3 years) and was expected to be positive but instead is negative at -0.4314 and statistically significant at $P<0.05$. Treatment group V2 (cows vaccinated 2 of 3 years) has a positive estimated coefficient of 0.5492 with a P-value of 0.1385. V1 (cows vaccinated for only 1 of 3 years) has an estimated coefficient of -0.5492 that is statistically significant at $P<0.05$. DAMAGE has a negative estimated coefficient of -0.2302 ($P>0.05$) in this model and DAMAGE2 has a positive estimated coefficient of 0.014 ($P>0.05$) both marginally significant with P-values less than 0.13. The dummy variables 1999 and 2000 are both positive (0.1093 and 0.1685) but insignificant with $P>0.05$.

As noted previously, the estimated coefficient magnitudes in the logit model are difficult to interpret as they indicate the marginal changes in an odds ratio. Therefore, calculation of the marginal effect of the variables of interest facilitate interpretation of the model. Figure 5.1 shows the effect of cow age on the probability of being pregnant for each vaccination treatment group in the production year 2000 calculated using the estimates from table 5.1. Treatment group V2 is the only vaccination group that has a higher pregnancy probability curve than the control, V0, but has an insignificant P-value of 0.1385. Groups V1 and V3 have similar significant ($P<0.05$) probability curves but are below the probability curve of the control group V0. Treatment group V2 has the smallest sample size of 352 records which is 13.46% of the total observations. A larger sample size of this treatment group may be needed to accurately predict the probability of being pregnant in this model. The empirical model 3.2.1 predicted the signs on these three treatment groups to be positive based on the concept that annual vaccination is a beneficial part of a complete herd health program. It would appear that all treatment groups have pregnancy probabilities that are within normal biological variation and decline at an acceptable rate with age of the cow.

Figure 5.1 Effect of Dam Age on Probability of Being Pregnant



5.2 Pregnancy Loss Model Results

The pregnancy loss model is a binomial logit regression sharing the same independent variables as the pregnancy probability model in 5.1, but predicting effects on pregnancy loss (1) due to early embryonic loss, abortions or misdiagnosis of pregnancy. The binary digit (0) stands for a pregnancy that survived to full term gestation. Estimated results from this model are presented in table 5.2

Table 5.2 Logit Regression Results for Pregnancy Loss Model (Dependent Variable Pregnancy loss =1, Calf born=0)

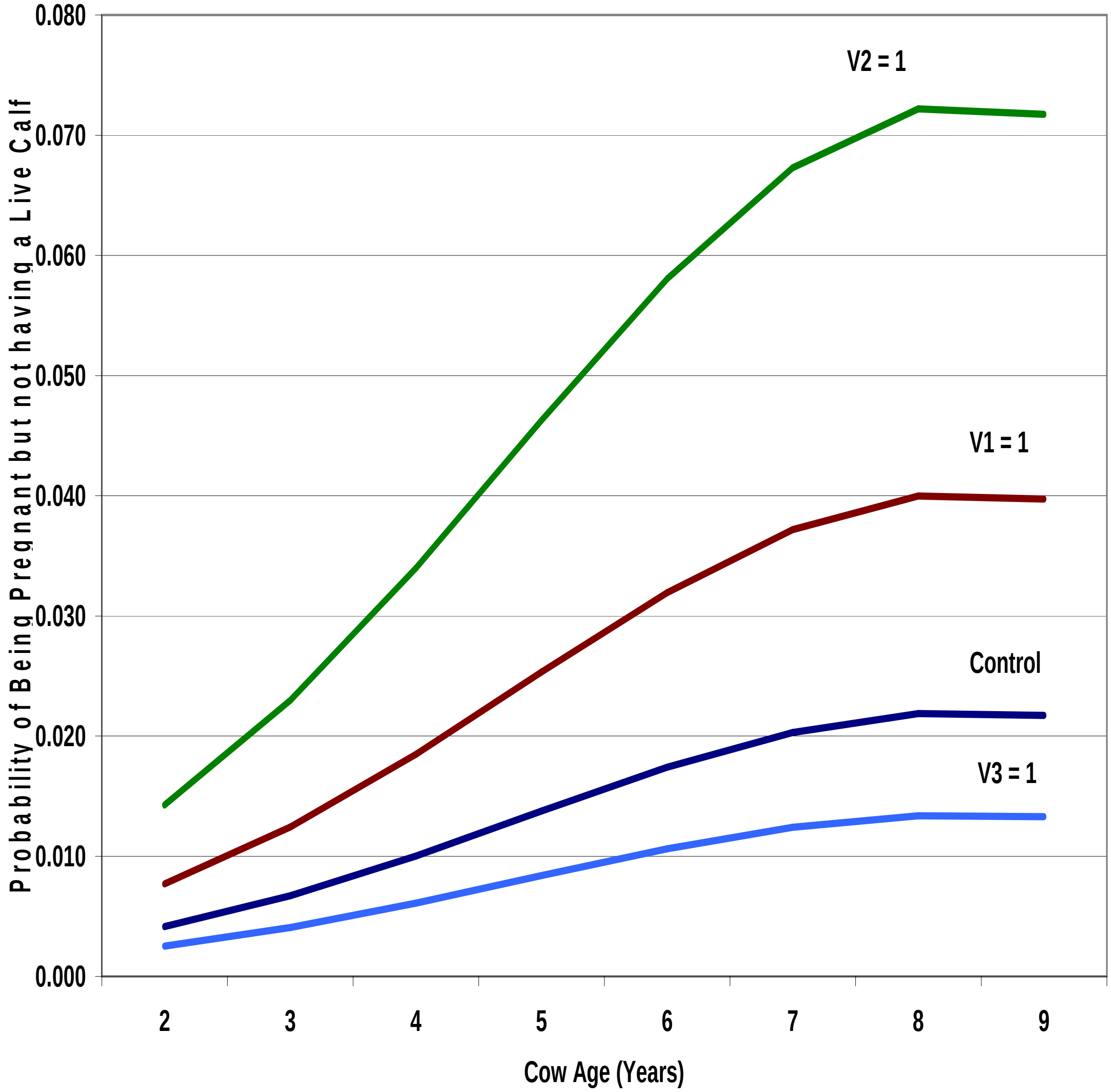
Variable	Estimate	Std Error	ChiSq	p-Value
Intercept	-7.4859	1.0742	48.5638	<.0001
Location	0.3878	0.3188	1.4803	0.2237
v3	-0.5006	0.4167	1.4438	0.2295
v2	1.2473	0.51	5.9814	0.0145
v1	0.6222	0.5407	1.3241	0.2499
DamAge	0.6904	0.2953	5.466	0.0194
DamAge2	-0.041	0.0209	3.8529	0.0497
Dum1999	1.1489	0.476	5.8256	0.0158
Dum2000	0.7858	0.5207	2.2776	0.1313
R-squared		0.0093		
Observations		2616		
Dependent Variable Mean		0.018		
Percent Concordant		66.5		
Precent Discordant		28		
Precent Tied		5.5		

There are a total of 2616 observations in this model with an R-squared value of 0.0093. The pregnancy loss model correctly predicts percent concordance of 66.5% and percent discordance of 28%. A dependent variable mean of 0.018 indicates that 1.8% of the cows in the sample had a pregnancy loss. The location at GV has a + 0.3878 estimated coefficient but is insignificant with a P-value of 0.2237. The estimated coefficient for

DAMAGE has a positive sign and is statistically significant at P = 0.0194 and DAMAGE squared has an estimated coefficient of -0.041 that is significant (P<0.05). The production year 1999 has a positive estimated coefficient of 1.1489 and is significant at P<0.05 while the production year 2000 has a positive estimated coefficient of 0.7858 but is insignificant at P = 0.1313.

Figure 5.2 illustrates how cow age affects the probability of pregnancy loss for each of the four treatment groups in the year 2000 estimated from the results reported in table 5.2. In the model 3.2 the signs of the estimated coefficients of the treatment groups were predicted to be negative following the logic that a herd that is vaccinated annually with the proper reproductive vaccines would experience less pregnancy loss. Treatment group V3 has an estimated coefficient of -0.5006 with a P-value of 0.2295, group V2 has an estimated coefficient of 1.2473 with a significant P <0.05 and group V1 has an estimated coefficient of 0.6222 with a P-value of 0.2499. The total pregnancy loss rate in the study herd from 1998 to 2000 was 1.76% which is within normal pregnancy loss in a beef cow herd (<3.0%). The average pregnancy loss for the NDSU IRM herds is 0.73% (Table 2.1) which is similar to treatment group V2. Because treatment group V2 has the highest probability of being pregnant (Figure 5.1), the results for group V2 in the pregnancy loss model would not be unexpected and are acceptable because they fall within normal biological limits. On the other hand, in each production year, there was an increasing number of pregnancy losses in this herd: 6 in production year 1998, 22 in production year 1999 and 24 in production year 2000.

Figure 5.2 Effect of Dam Age on Pregnancy Loss



5.3 Calf Mortality Model Results

The calf mortality model is the last binomial logit regression model and shares the same independent variables as described in 5.1 and 5.2. The calf mortality model is designed to predict the probability of the death (1) of a calf from birth to weaning in the study herd and (0) designates a calf that has survived to weaning. Results of this model estimation are in table 5.3.

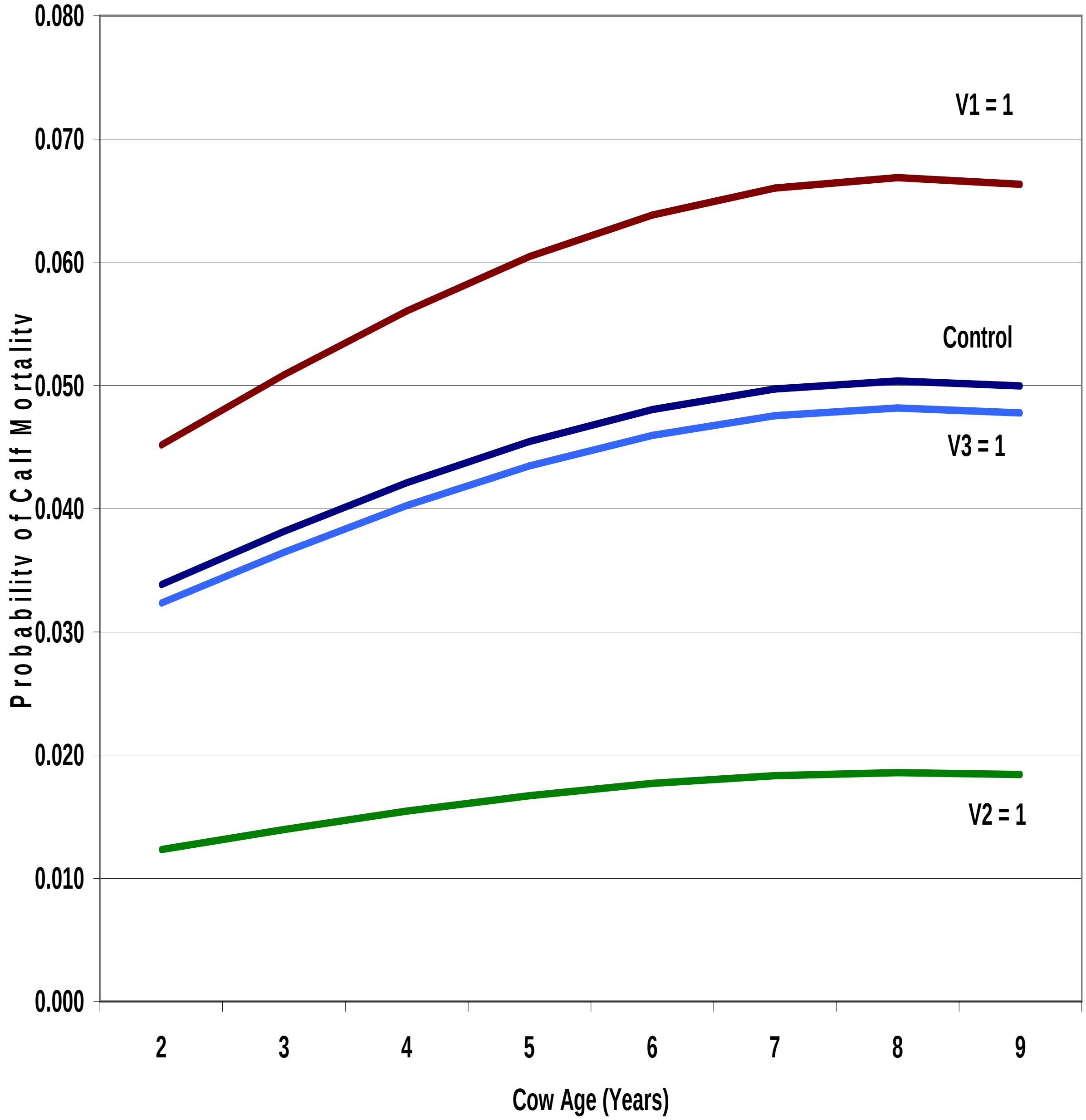
Table 5.3 Logit Regression Results for Calf Mortality Model (Dependent Variable Calf Mortality Prior to Weaning = 1, Live Calf Weaned = 0)

Variable	Estimate	Std Error	ChiSq	p-Value
Intercept	-4.7564	0.7028	45.8078	<.0001
Location	0.1022	0.2712	0.142	0.7063
v3	-0.0469	0.2927	0.0257	0.8727
v2	-1.0299	0.655	2.4728	0.1158
v1	0.3009	0.3769	0.6374	0.4246
DamAge	0.1802	0.2102	0.7344	0.3915
DamAge2	-0.0111	0.015	0.5494	0.4586
Dum1999	0.4376	0.3606	1.4724	0.225
Dum2000	1.0883	0.35	9.6677	0.0019
R-squared		0.0087		
Observations		2616		
Dependent Variable Mean		0.028		
Percent Concordant		62.3		
Precent Discordant		31.6		
Precent Tied		6.2		

The calf mortality model has 2616 observations with an R-squared value of 0.0087. It has a percent concordance of 62.3% correctly predicted and percent discordance of 31.6% incorrectly predicted. A dependent variable mean of 0.028 or 2.8% is well under the total calf death loss of 6.3% (calf death born + calf death weaned) in the NDSU IRM data base (Table 2.1) and is within expected ranges on calf mortality. Location GV, has an estimated coefficient of 0.1022 with a $P>0.05$. DAMAGE has a positive estimated coefficient of 0.1802 and DAMAGE2 has a negative estimated coefficient of -0.0111 both of which are insignificant with $P>0.05$. In 1998 21 calves died from birth to weaning and in 1999 20 calves died from birth to weaning with an estimated coefficient of 0.4376 with a $P = 0.225$ for the 1999 dummy variable. In production year 2000, 52 calves died from birth to weaning and the dummy variable for the year has an estimated coefficient of 1.0883 with a $P<0.05$.

Figure 5.3 illustrates the effect of dam age on the probability of calf mortality for the four treatment groups in year 2000 estimated using the results from the model presented in table 5.3. Again, the calf mortality model in 3.2 predicts the signs of the coefficients of the treatment groups V1, V2 and V3 to be negative, based on the fact that any calves in a vaccinated treatment group should experience a lower death loss than the non-vaccinated control group. Treatment group V1 has a positive estimated coefficient of 0.3009 and treatment groups V2 and V3 have negative estimated coefficients of -1.0299 and -0.0469 respectively. None of the treatment groups had coefficients that were significantly different from zero at $P<0.05$.

Figure 5.3 Effect of Dam Age on Probability of Calf Mortality



5.4 Calf Weaning Weight Model Results

The calf weaning weight model is an Ordinary Least Squares regression model developed to determine the effects of the independent variables described in 3.3.1 on the dependent variable Weaning Weight.

In the original weaning weight model that was developed there a large difference between coefficients of the treatment groups that was at first difficult to explain. From Table 4.1 Herd Study Summary Statistics, the average cow in this study was 5.9 years old and weaned a calf that was 161.6 days old weighing 443.5 pounds. Table 2.1 from the North Dakota State University IRM shows that the average cow in their data base was 5.7 years old weaning a 189 day old calf weighing 561 pounds. One of the management tools that was being introduced during this study was early weaning. In this study herd in the production year 1998, the average calf weaning age was 180 days with a weaning weight of 444 lbs. In the 1999 production year, the average calf weaning age decreased to 168 days but increased weaning weight to 450 lbs. In the final production year, 2000, the average calf weaning age was only 134 days with the weaning weight declining to 435 lbs. This association of variables is identified in the pair-wise correlation of variables in table 4.2 where calf age (180 days) has a +0.485 correlation to the production year 1998 and a -0.661 correlation to production year 2000 (134 days). From a management standpoint, by timing the herd calving period with optimal nutrition of the native pastures it is possible to obtain similar weaning weights in 1998 and 2000 (444 lbs vs. 435 lbs) with a calf that is 46 days younger. To correct for the decreasing weaning age in each production year the dummy production year variables and treatment groups were multiplied by the calf age for each record. This would be similar to calculating the adjusted weaning weight in a commercial cow-calf record keeping program but this model is non-linear due to the variable of DAMAGE2.

The regression model for calf weaning weight has an R square of 0.366 (Table 5.4) indicating that the independent variables explain 36.6% of the variation in the dependent variable. There are 2531 observations in this model which has a standard error of 58.68. The estimated coefficients of the independent dummy variables Location (GV) and Calf Sex (Heifer) are -33.028 and -32.91, respectively, and both are highly significant at $P < 0.05$. Likewise the estimated coefficients of Calfage*1999 and Calfage*2000 have estimated coefficients of 0.6896 and 1.181, respectively, and are also both highly significant at $P < 0.05$. When adjusted for calf age, independent dummy variables Calfage*V3 and Calfage*V2 have a negative sign for the estimated coefficient and Calfage*V1 has a positive sign for the estimated coefficient. All three variables have very small coefficients none of which are significant at $P<0.05$. Independent dummy variables for the production year 1999 has an estimated coefficient of -96.082 and production year 2000 has an estimated coefficient of -114.56 both of which are highly significant at $P<0.05$.

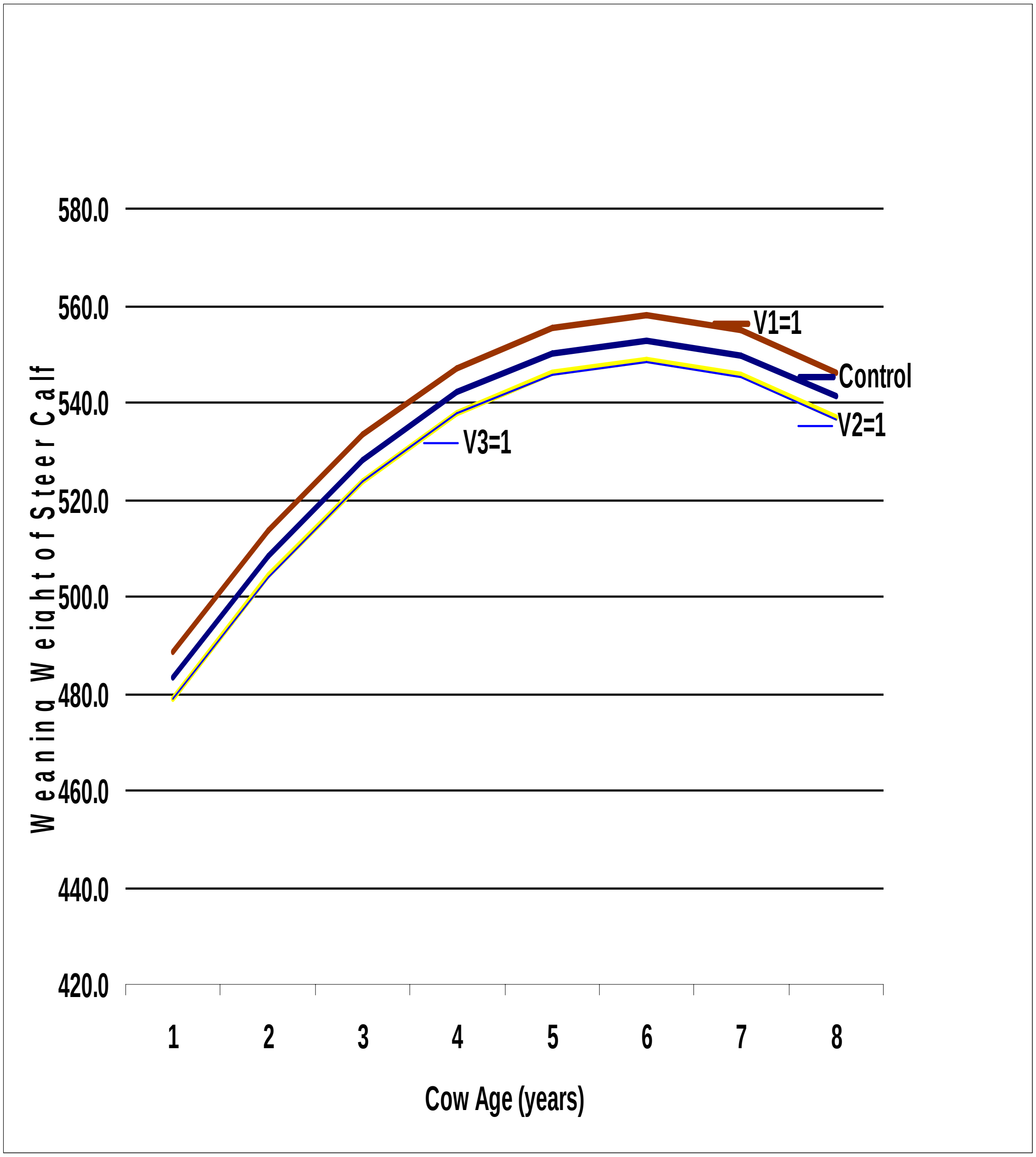
Table 5.4 Ordinary Least Squares Regression Results of Weaning Weight of Calves

Variable	*Coefficients*	*Standard Error*	*P-value*
Intercept	160.4940	18.3729	4.34449E-18
Location GV	-33.0282	2.6312	4.23893E-35
Calf Sex - Heifer	-32.9101	2.3454	4.02278E-43
Calfage*1999	0.6897	0.1286	8.95911E-08
Calfage*2000	1.1814	0.1543	2.74736E-14
Calfage*V3	-0.0275	0.0177	0.120257947
Calfage*V2	-0.0263	0.0296	0.374579549
Calfage*V1	0.0321	0.0362	0.374962738
DAMAGE	39.4128	2.0405	1.26134E-77
DAMAGE2	-2.8314	0.1508	9.91788E-74
Calf Age	1.1298	0.0903	7.00384E-35
1999	-96.0817	22.3803	1.82839E-05
2000	-114.5567	23.1152	7.67732E-07
Multiple R	0.61		
R Square	0.37		
Adjusted R Square	0.36		
Standard Error	58.68		
Observations	2531		

The continuous variables in this model are DAMAGE, DAMAGE2 and Calf age. Dam Age has a positive sign for its estimated coefficient of 39.412 and Dam Age-squared has a negative sign for its estimated coefficient of -2.831 both significant at $P<0.05$. Calf Age has an estimated coefficient of 1.1298 and is highly significant at $P<0.05$. After introduction into the herd this model predicts that the weaning weight of the calf will increase each year but at a declining rate until the cow is 6.96 years of age (formula 3.7). The nonlinear relationship between cow age and calf weight is shown in figure 5.4.

Figure 5.4 shows the effect of Dam Age on the weaning weights of the four vaccination treatment groups V1, V2, V3 and V0 (control group).

Figure 5.4 Effect of Dam Age on Weaning Weight of Calves



CHAPTER VI: CONCLUSIONS AND FURTHER RESEARCH

In this study 4 regression models were developed to analyze the records collected from a beef cowherd from 1998 to 2001. The objective of this thesis was to determine the effect of varying the interval of vaccination of the beef cowherd on calf productivity at weaning, cow reproductive productivity and herd profitability.

The weaning weight and the calf mortality models were designed to evaluate the effect of the vaccination treatment groups on calf productivity at weaning (calf weaning weight). None of the three treatment groups (V1, V2 or V3) were significantly different from the control group in either the weaning weight or calf mortality model indicating that varying the frequency of vaccination in the beef cow herd had no impact on calf weaning weights or calf mortality in this study.

The pregnancy loss and the pregnancy probability models were designed to evaluate effect of the vaccination treatment groups on cow reproductive productivity in this herd. The total pregnancy loss for this herd in the production years 1998-2000 was 1.76% (Table 4.1) as compared to .73% (Table 2.1) for the cows in the NDSU IRM data base. In the pregnancy loss model vaccination treatment group V2 was the only treatment group that was statistically different from the control group V0. Although treatment group V2 has a pregnancy loss larger than the control group V0 it is still considered within normal biological limits. Pregnancy losses due to early embryonic death and abortions are considered within normal biological limits if they are less than 3.0% in the beef cow herd.

Treatment groups V1 (vaccinated in production year 2000) and V3 (vaccinated in production years 1998, 1999 and 2000) were both significantly lower than the control group V0 in the pregnancy probability model. Figure 5.1 shows the predicted pregnancy probabilities in the four treatment groups ranged from the low of 86% for treatment group V3 to the high of approximately 95% for treatment group V2. Although all four treatment groups are within the normal biological variation that could naturally occur between different production years in a beef cow herd, two of the three vaccination treatment groups, with the largest number of observations, were statistically lower than the control group. This finding indicates that yearly modified live reproductive vaccine boosters may be detrimental to herd pregnancy rates.

In conclusion, the results of this study support the Hypothesis that production output and profitability of the beef cow herd was not decreased by vaccinating the cow herd at intervals of greater than one year. Because this data was collected in a normal ranch situation, the results were impacted by: 1) implementing new management practices such as early weaning, 2) normal herd dynamics of adding and culling breeding females and 3) seasonal variations in production years due to changing environmental conditions.

The scope of this thesis was limited to analyzing only the production parameters of this cow herd. As previously stated in the Study Design 1.4, blood samples were randomly collected and analyzed from individual cows in the study herd but this data was not included in this thesis and should be examined in further research. Also, this study should be repeated for a longer time period to determine if the results are similar.

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