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Prepared by: Penelope McGown, Beef Cattle Veterinarian,
Keith Entwistle, Veterinary Consultant,
Peter O'Rourke Statistical Consultant,
Nigel Perkins, Ausvet Animal Health Services

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Economic Impact of Bovine Ephemeral Fever Virus in Extensive Northern Beef Herds.

Phase 1 & Phase 2

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Abstract

Bovine Ephemeral Fever (BEF) is a familiar disease to Northern Australian cattle producers. Economic losses are experienced through rapid loss of body weight, slow recovery, temporary infertility in bulls, temporary to permanent cessation of lactation in cows, low levels of mortalities and delayed station mustering.

The virus is transmitted by biting insects (vectors), which are more prevalent after seasonal rain. Overwintering of the virus has allowed the evolution of seasonal epidemics and sporadic outbreaks with occasional severe widespread epidemics. There is little to no ability to predict the timing or severity of outbreaks.

Vaccination for ephemeral fever has been available in Australia since 1986. The viral strain used in the vaccine is efficacious in conditions of experimental challenge and has shown a sixfold reduction in the number of serologically confirmed ephemeral fever cases in commercial trials.

In this study, undertaken over the period 2003 to 2009, vaccination of animals in a number of extensive northern herds was tested; growth, carcass and reproductive variables were measured and compared with control counterparts. The project was carried out under normal extensive cattle station management and regular cattle finishing and slaughter regimes. During these years no significant differences were found between vaccinated and control animals for the variables measured. Confounding factors include unknown prior immunity of recruited weaners, inability to measure mortalities, efficacy of vaccine against wild viral strains and unknown exposure levels of control animals throughout the project.

The occurrence of sporadic BEF outbreaks was recorded anecdotally during the trial. However, these years would be regarded as low incidence years for BEF in terms of sentinel herd seroprevalence information.

Economic modelling using the data set as a source of herd production indices was undertaken. Break even cost to vaccinate, using the current commercial vaccine and a hypothesised next generation single dose vaccine, was calculated as the most industry appropriate outcome. For both vaccines, a break even situation was achieved if steer sale prices increased by 5.5%.

Executive Summary

In a study completed in 2001, undertaken by members of the Northern Pastoral Group of Companies; modelling of economic losses resulting from **Bovine Ephemeral Fever** (BEF) showed potential annual losses ranging from $5.5 to $110 million, in best and worst case disease years across the northern cattle herd of approximately 11 million head. A more recent study (Holmes and Sackett, 2006) estimated losses due to BEF to be about $83 million per annum for northern herds, and concluded that BEF was the third most important economic disease in northern cattle herds.

Due to the sporadic nature and seasonality of BEF in extensive northern herds, it is difficult to determine its impact by surveys and serological confirmation. Other methods were required to assess the true impact of the disease or conversely to trial the existing vaccine in order to quantify any decrease in the economic impact of the disease resulting from vaccination.

The project was conducted across a number of commercial breeding, grower, backgrounding and feedlot properties in various geographical areas across northern Australia. Cattle originated from breeder properties in the Barkly Tableland, Gulf Savannah and North West Downs regions with the objective of attempting to encompass sporadic regional outbreaks of disease. Grower properties were located in the Channel Country or Gulf Savannah, backgrounding properties in Central Queensland and feedlots in Central or South East Queensland.

A total of 6,500 male and female predominantly Bos Indicus weaners were enrolled, with a randomly selected half of each group given the commercially available Fort Dodge two dose BEF (Living) vaccine. Females were given an annual booster vaccination, while the males did not receive any further boosters after the initial regime. Fresh year cohorts of weaners were inducted annually for 4 consecutive years. Data were collected from females once annually until they were 4.5 years old and from males until they were slaughtered, at between one and three years of age.

The project was carried out over six years, 2003-2009, attempting to cover worst and best case disease year situations. Female cattle remained on the breeder property and male cattle were followed through various supply chains used for the major markets of beef cattle. The project was carried out under normal extensive cattle station management and under regular cattle finishing and slaughter regimes. The data underwent rigorous validation and complete statistical analysis. Data was evaluated for growth performance of males from weaning to slaughter and reproductive performance of females from two or three matings.

For growth from weaning to first joining in females, average daily gain (0.38kg/d) was not significantly different between controls and vaccinates. Inter-conception intervals were recorded for the first two gestations, derived from foetal ageing estimates at pregnancy test. The inter-conception intervals were not impacted by vaccination. Pregnancy rates resulting from three consecutive matings were calculated, and while there was a difference between control and vaccinates of 2.4%, there was no significant impact of vaccination. Also, there was no difference in the proportion of each group mustered in three consecutive years. A rollcall taken at the consecutive annual muster showed a difference of 0%, 0.5%, and 0.8%, between controls and vaccinates.

The total number of calves reared per trial female was calculated using two models for vaccinates and controls. Using the intention to treat model, 10.9% of controls and 11.2% of vaccinates raised 3 or 4 calves while 16% of controls and 14% of vaccinates raised no calves. Using only data from

the scheduled mating periods a maximum of 2 calves could be raised. There was a mean difference between controls and vaccinates of 1.9% raising no calves and 0.8% raising two calves. Vaccination had no significant effect on number of calves raised. Culls were removed from the paddock at each muster, as defined by normal station management. Cull rates for control and vaccinated groups varied by 1.7% after the first mating period, 0.4%, after the second mating period and 1.1%, after the third mating period. The first cull rate was in favour of the controls and the second and third rates were in favour of the vaccinated group.

On one property, progeny from two cohorts of project females were evaluated for growth from birth to weaning for four consecutive progeny groups. There were no significant differences between control and vaccinates for days from mating start date to birth date (0.38 days, 2.5 days, 2.9 days, and 0.22 days, for years 1-4 respectively. Average daily gains calculated from birth to weaning of progeny from control and vaccinated dams were similar at 0.93kg/d; 0.88kg/d, 1.06kg/d and 0.94kg/d respectively, indicating no impact of vaccination. Recorded birth dates of the progeny were used to calculate the inter-calving interval for control and vaccinated groups. Measured in days there was a marginally shorter inter-calving interval for vaccinates (average of 0.9 days), however this was not statistically significant.

Average daily gains for steers from the control and vaccinated groups were calculated. There was no significant effect of vaccination on mean average daily gain (0.45kg/d) for all steers at the grower location. Background steer growth was not impacted by vaccination with mean average daily gain of 0.50kg/d, whilst performance of feedlot steers (mean average daily gain 1.9kg/d) again showing no significant effect of vaccination. Carcass weights were recorded from animals finished in the feedlot using Ausmeat feedback. There was no significant effect of vaccination on Hot Standard Carcass Weight (control 315kg; 316kg vaccinates), whilst carcass values also showed no impact of vaccination (controls $1143; vaccinates $1146)

Wastage, measured as absent from musters was evaluated within the scope of the design. The female wastage rates from induction to first mating were similar with control 4.3% and vaccinates 4.1% The cumulative wastage for the period of the trial was 48.1% for both groups.. Wastage in males from induction to exit from grower location was 29.7% for controls and 28.1% for vaccinates. After the grower stage, steers were grouped according to subsequent supply chain. Steers that went on to backgrounding experienced cumulative wastage rates of 28.6% in controls and 25.9% in vaccinates. Feedlot steers suffered similar wastage rates. This type of data must group all reasons for wastage together, and it is not appropriate to infer mortalities and calf losses due to mis-mustering or mis-mothering, nor can it infer mortalities or illness due to BEF.

Combined means for production parameters from the analyses were used in a broad economic analysis to evaluate the break even cost of whole herd vaccination. The *sensitivity analyses* for gross margins on a herd basis indicated that, unless there is a scenario of increased steer sale prices in the order of 5.5%, there was no <u>single</u> response parameter where a break-even situation could be achieved. A number of scenarios where combined theoretical incremental responses to vaccination (eg.fertility, steer prices, and survivability) were also modelled. Several of these enabled achievement of a break even cost for vaccination.

In addition, further modelling and analyses of the value of a next generation one dose vaccine showed a reduced breakeven cost to five incremental scenarios averaging $1.77 break-even cost/AE, given there is no requirement for a second muster. The *sensitivity analyses* for gross margins in a feedlot environment indicated there was an increase of $130 per head in vaccinated animals in the longer fed, heavier animals. The comparable figure for shorter fed animals was significantly lower at about $11. For those feedlots in BEF endemic areas, for the heavier weight animals this is equivalent to about $13/hd/yr risk protection, and for lighter animals about $8/hd/yr risk protection. However industry opinion suggests the importance of BEF in the feedlot environment is low, outbreaks uncommon and the value of these estimates is questionable. Some cattle being paddock backgrounded prior to feedlot entry could occasionally be affected, incubating the disease and subsequently showing symptoms after feedlot entry. Vaccination during the backgrounding process would have economic benefit in situations where cattle could be at risk of exposure prior to feedlot entry.

Whilst there were no significant differences between control and vaccinated groups for any of the parameters measured, there is a question as to the level of disease activity during the years of the project. There were many variables that were able to be controlled during this project while there were also many that were not, owing to the scope and financial resources of the project.

Vaccine cold chain integrity was controlled, as was vaccine reconstitution and administration technique, including needle length, location of administration and hygiene. The vaccinates and controls in each location were managed within the same mob in the same manner, hence were given equal opportunity for exposure to disease, nutrition, water availability, mismustering, mismothering and mortality. Again, these factors were not able to be recorded individually and they are combined effects making up the wastage component of the analysis. Variables unable to be controlled in this project were numerous, however the most important included the prevailing climatic conditions and presence or otherwise of BEF virus, a complete knowledge of the vector(s), influences on their lifecycles and geographic distribution, genetic drift and antigenicity of wild strains of BEF compared with that of the vaccine, level of prior immunity in weaners and the level of cumulative natural immunity in the control groups as they aged. Prevalence of vectors or seroconversion rates in naive cattle were unable to be measured accurately within the scope of the project, but data supporting seroconversion rates was derived from the National Arbovirus Monitoring Program. Small scale sampling conducted as part of the project demonstrated a prior antigenic BEF exposure level of 25% to 40% in two year old females.

The project has shown that in the years of the study, there was no impact of vaccination, using the currently available vaccine, on female reproduction rates and on male growth rates and carcass characteristics. The results suggest there is little economic benefit in whole herd vaccination every year in extensive northern beef herds with the current commercially available vaccine where successive years of BEF disease activity are low. It is possible, that triggers including weather events, local prevalence of disease, prevalence of *at risk* animals such as bulls, heavy bullocks and pregnant heifers may stimulate the use of the vaccine in these target animals or in the whole herds in target areas. Further studies would be required to demonstrate the effectiveness of this approach. Confirmation of the current vaccine strain effectiveness against circulating wild viral strains is important as is assessing vaccine efficacy in all classes of cattle. Generally, a greater understanding of natural viral exposure and herd immunity dynamics, temporal and spatial distribution of the disease, vector identification and their population dynamics and the influence of non-pathological but similar viruses will assist in simplifying the question of vaccination in the future.

One ancillary outcome of this project is a comprehensive database of herd production indices for a number of northern breeder herds and considerable data on male cattle production performance and carcass traits. There is potential benefit to be gained from more detailed analyses of this database, to provide further information on herd performance in the extensive northern beef cattle industry. Such analyses may also assist related projects currently funded by MLA in Northern Australia on a range of animal health and production aspects in tropical beef cattle.

Contents

1 Background

1.1 Epidemiology of Bovine Ephemeral Disease

Bovine ephemeral fever (BEF) is a viral disease of cattle, spread by biting insects, and which occurs at frequent intervals in beef cattle herds in northern Australia. Exposure to the virus is variable, resulting in years with little to no exposure, followed by severe epidemics resulting in significant losses in naïve or unvaccinated animals. Outbreaks have historically started in late winter and spring in the top end of the Northern Territory, spreading south and east, reaching northern Queensland by January and then progressing to reach the northern rivers of NSW by around March. In the case of major outbreaks, spread may occur as far south as Victoria. Over recent decades there appears to be a changing pattern from north south epidemics to mainly sporadic outbreaks with occasional large and widespread outbreaks[1]. The disease is now occurring in successive years with high and low prevalence years. Even in relatively low incidence years there is a seroconversion rate of 16-20% in sentinel herds[2]. Spread of disease is largely independent of cattle movements and is more dependent on insect vector populations and general weather patterns. Prevailing wind direction appears to influence the direction of movement of epidemics.

The disease was first experienced in the Northern Territory in February 1936. A major epidemic followed, sweeping eastern Australia and reaching northern Victoria [6]. There were five more similar major epidemics until 1975. Since then, the pattern of disease has evolved, becoming more seasonally endemic, emerging as localised sporadic outbreaks with occasional epidemics. The northern two-thirds of Australia appear to have become seasonally endemic [2]. Natural infection is generally regarded as conferring long term immunity and cattle do not become carriers of the virus[3, 7], however some reports indicate varying lifetime immunity [2]. It appears many cattle in endemic areas are escaping infection in the years of low prevalence, providing a susceptible reservoir for future major outbreaks[2, 3]. The longer the period between epidemics, the higher the proportion of older and subsequently more severely affected animals there will be in the population when next exposed. As an example of low levels of natural herd immunity in endemic areas, cattle tested in sentinel herds for serum neutralising antibody between 1983 and 1985 in North West Queensland revealed a seroprevalence of 15%, 14% and 15% of approximately 150 head tested in the respective years [2].

Emergence of the disease in association with recent rain is reported frequently. The major epidemics prior to 1975 began in the tropical north after the monsoonal wet season. More recently however, BEF has been reported appearing within 4 weeks of unseasonal winter rain in more southern parts of Queensland. In this area it is rare to experience an outbreak of BEF during winter. Outbreaks of this nature are due in part to a viral overwintering mechanism that is poorly understood[3]. The disease may also follow swollen river systems and hence vector populations into arid parts of Australia, however wind patterns determine the duration and distance of movements into such areas [2].

Our understanding of the epidemiology of BEF is constrained by factors including identifying every vector, understanding the mechanisms which control the persistence of BEF virus between epidemics, the effect of other arboviruses on herd immunity and disease transfer, and identification of the site of replication of the virus in the bovine. Identification of all the major vectors is incomplete. Biting insects including *Culicoides spp* midges, *Culicine spp* mosquitos and *Anopheles bancrofti* are regarded as the major vectors. It is clear they can support BEF virus growth. The limits of spread of ephemeral fever well exceed the combined limits of distribution of these insects, indicating BEF virus will likely be isolated from additional arthropod species in the future [4].

There are many arboviruses that take advantage of the bovine – *Culicoides brevitarsis* biological cycle and there is evidence that some may interfere with the transmission of the BEF virus. For example, exposure to Kimberley virus is subclinical. Although it prompts the production of low levels of neutralising antibodies to BEF virus, it will not confer immunity to the bovine[4]. Conversely, serology may indicate prior seroconversion to BEF virus, however it may have been exposure to another antigenically related virus such as Kimberley, Berrimah or Adelaide river virus, all of which infect cattle. A prior infection with Kimberley virus will sensitise the cows' immune system, leading to a secondary antibody response occurring on initial encounter with BEF virus [4]. The effect of these virus-antibody interactions make the understanding of herd immunity more complicated.

The extent and severity of morbidity and mortalities can vary between outbreaks. These differences are likely to be due to variation in virulence of the viral agent and possibly associated with some variation in antigenic strain, or in the vector population. As herd immunity varies between different strains of the virus and cross immunity is limited, there will always be some susceptible cattle in a herd.

1.2 Biological Importance

Morbidity rates in outbreaks are historically about 30-35%, except when the cattle population is highly susceptible and environmental conditions favour spread of the disease the morbidity rate may approach 100%. Severe epidemics have occurred in Australia in 1936-37, 1955-56 and 1966-68 [2], with outbreaks of varying severity occurring at frequent intervals over the past 2-3 decades. Mortalities, expressed as a percentage of the population at risk, underestimate the actual loss due to Bovine Ephemeral Fever. Mortalities are generally around 0.25% in beef cattle, however almost all this loss occurs in the most productive animals in the herd, namely mature cows, bulls or older steers. Recent anecdotal evidence from producers also suggests that mortality rates may be higher than previously recorded (B. Hill pers comm. 2010).

There is a severe temporary loss of weight caused by dehydration; however there remains a milder permanent weight loss presumably occurring in muscle and fat loss. Milk production temporarily decreases, reducing availability to the suckling calf for a period, however the cow will not recover full milk production and lactation can cease altogether, resulting in decreased calf performance. Late term abortion is also common during outbreaks [4]. Other losses, difficult to quantify include temporary or in some cases permanent loss of fertility in bulls due to general hyperexia with consequent derangement of testicular thermoregulation. As well, effects on delayed trading and dispatch of market cattle, impacts on carcass characteristics and perhaps meat quality, and delays and/or abandoning musters are reported.

1.3 Economic Importance

Economic impacts in commercial beef herds are variable from season to season and therefore difficult to forecast. The impact is variable, depending on environmental factors influencing vector density and the level of herd immunity, which is dependent on previous frequency and extent of exposure. A QDPI exercise[12] modelled the possible costs of BEF on the productivity of Queensland beef herds. Impacts considered, included branding percentages, mortality rates, growth rates and carcass quality. The models examined impacts in several regions across Australia, but of interest were impacts modelled on herds in Central and North West Queensland.

The modelling for these two environmental areas, typical of larger pastoral company holdings and private operators, indicated losses of $0.31/hd/yr in the North West, and $7.00/hd/yr for large central Queensland herds. Another model done for an Atherton Tableland breeding herd suggested the impact of BEF to be as high as $10/hd/yr. The value of the impacts considered was an average of the high and low disease years. The models for NW Qld and the Atherton Tableland did not consider possible impacts of BEF on meat quality and the opportunity costs of lost sales. Whilst such losses are difficult to quantify, they no doubt occur.

In 2002, Stanbroke Pastoral Company undertook an internal review of the impact of BEF on their 530,000 head herd, using input data similar to those generated from the DPI economic modelling exercise as well as the practical experience of long term Stanbroke property managers. Using best case and worst case scenarios, estimated losses across all company properties from the combined effects of mortalities, reduced reproductive performance, growth rates and carcass quality ranged from $1-7million/yr. If these scenarios were extrapolated across the northern Australian herd of approximately 11 million head, production losses and economic impact could conceivably range from $20-$140 million/year under BEF outbreaks of variable severity.

A further exercise by technical staff of the Northern Pastoral Group (Henderson, pers.com. 2000), in conjunction with QDPI, suggested that effects of BEF could result in losses equivalent to about $20,000/yr for a 3,000 head herd, equating to a break even cost to vaccinate of about $7.00 per head. On the basis of the estimates from this latter exercise, BEF outbreaks could result in production losses up to about $75 million per year across the entire northern herd, a figure about midpoint on the extrapolated estimates from the Stanbroke Pastoral Company review.

A more recent MLA commissioned study has modelled economic losses from BEF including reduced income from convalescing animals and mortalities as well as the cost of vaccination. This exercise resulted in losses calculated at $83 million per annum for Northern herds [1]. Of interest, this study concluded that BEF was the third most important economic disease affecting northern herds.

1.4 BEF Vaccine

There have been a number of vaccines developed, both killed and live attenuated, of varying use in commercial situations. The most useful vaccines are those attenuated through successive tissue cultures and mixed with an adjuvant shortly before administration [4].

In Australia a commercial vaccine of this type has been continuously available since 1986. It is based on the BB2271-919 strain, isolated in 1978. The vaccine is given in two doses at an interval of approximately 1 month [10]. An annual booster is then required to maintain immunity. In Australia, vaccination has not been significantly adopted or sufficiently widespread to have influenced the epidemiological pattern of the disease. There is now uncertainty about the effectiveness of the vaccine against all circulating strains of BEF virus and its performance in the face of a major epidemic is untested. However, there is clear evidence that the costs of BEF to the cattle industry could be effectively contained by an appropriate vaccination regime [6], though the need for a costly follow-up muster to administer the second vaccination remains a constraint to widespread use of the existing two dose vaccine.

1.5 Development of Control Programs for the Northern Pastoral Industry

Numerous models have indicated similar costs of BEF when extrapolated across the northern beef herd of around $100 million; however there remains a large variation in the cost of BEF in low and high impact years. Without further information and research, it is difficult to progress the development of recommendations for control programs in extensive northern herds and to encourage vaccine manufacturers to invest in new vaccine technology.

Future information technology and epidemiological techniques may be of value in forecasting the likelihood of different types of BEF outbreaks in advance. However, such information is not likely to be of great value in extensive herds, since the logistics of handling cattle late in the dry season for vaccination pending a possible outbreak may not be feasible.

Future improvements in cattle production efficiency and enhanced economic prospects for the industry may indicate prevention of outbreaks via vaccination of susceptible animals is a more important management scenario. In turn increased market demand for an improved BEF vaccine, particularly a single dose product, may provide the impetus for commercial vaccine manufacturers to invest in such technology.

Whilst reliable protection can be obtained by vaccination[2,10], currently available vaccines require reconstitution and have a short shelf life once reconstituted. They require two administrations at a short time interval plus annual boosters, a strategy that may be largely impractical in extensive herds.

There are a large number of factors interacting in a complex relationship that influence animal health and productivity in extensive pastoral regions. Small scale controlled experimental trials can be used to demonstrate vaccine efficacy but there are often difficulties in extrapolating findings to the enormously variable situations that exist on extensive beef properties in the northern regions of Australia. An alternative approach to assess vaccine efficacy is through a large scale field trial involving animals being assigned to vaccinated and unvaccinated groups across multiple properties in different regions of the country. In such trials other factors such as property management decisions, climate, pasture availability and quality, genetics, concurrent disease apply equally to vaccinated and control groups and are all allowed to operate without interference. This approach ensures that all of the complex web of biological factors that may influence the outcomes of interest will be present in both groups. A measurable and positive impact of vaccination under these circumstances provides strong support for the use of vaccination in commercial herds. The major benefit of this approach is a valid test of efficacy under real world conditions.

2 Project Objectives

To measure the impact of BEF infections on fertility of susceptible cattle in northern herds by comparison of the reproductive performance of vaccinated and unvaccinated heifers;

To measure the protection conferred by a two dose weaner vaccination on subsequent growth and carcass performance of castrate male progeny, either retained on property of origin, transferred to grow-out/fattening areas elsewhere, or transferred after grow-out to feedlot environments;

To undertake these studies over a six year period in order to cover a likely range of low and high impact years for BEF virus infection, and to obtain reproductive data from at least three age cohorts of breeders and from four age cohorts of steers.

To examine regional differences across northern Australia on the severity of BEF outbreaks from different areas across an east-west axis.

To undertake a comprehensive economic analysis of the impact of protection via vaccination on reproducing, growing and finishing cattle in an endemic BEF area, in terms of measurable production traits and costs of vaccine protection

To present to vaccine manufacturers the biological and economic data obtained with a view to undertaking additional research on a suitable single dose BEF vaccine which would provide immunity for at least 12 months or longer.

To see how reliable epidemiological data is in predicting BEF outbreaks and whether it can be used in combination with vaccination and other techniques to prevent or reduce BEF outbreaks

3 Methodology

3.1 Experimental Design

The project involved replication of treatments over both space (location of origin and subsequent dispersal) and time (total six years) to cover the possibility that outbreaks of BEF may not occur annually and may be of differing severity between years.

Groups of weaner heifers and weaner steers were identified on seven breeding properties across northern Australia, stretching from the Barkly Tableland in the west to the Eastern fringe of the Gulf and including the North West Downs.

In order to detect the relatively small differences expected in reproductive performance, recruitment of 2700 females and 2400 males was required. Expectations were for 8% difference in branding rates at the annual muster between controls and vaccinates. Calves were not mothered up at branding therefore unique rates to the treatment and control groups were impossible, for this reason lactation rates were used as a proxy for branding rates at the annual muster. Expectations of losses of animals from the trial by way of mustering inefficiency, loss of identification, unreported transfers and accidental out of season matings, prompted recruitment of an additional 15-20% more weaners as an allowance for such losses.

3.1.1 Females

Annual cohorts of heifer weaners, allocated to vaccinated and unvaccinated groups were monitored through to third mating and reproductive data obtained at one muster annually. All pregnancy testing and foetal ageing was carried out by experienced veterinarians, members of the National Cattle Pregnancy Diagnosis Scheme (NCPD) managed by the Australian Cattle Veterinarians.

Pregnancy testing by rectal palpation was carried out at Pregnancy Test 1 (PT1) to confirm maiden status and identify pre joining conceptions and at subsequent Pregnancy Tests (PT2-4) to detect pregnancy or otherwise. Likewise lactation status at PT1 was to confirm dry status or pre joining conceptions, and that at PT2-4 to estimate if a calf had been reared. Ovarian activity was checked by rectal palpation to determine presence or absence of a corpus luteum as an index of puberty at PT1. Average daily gain (ADG) was calculated for each heifer from induction to PT1. Conception date was calculated from estimates of foetal age using the date of pregnancy testing and 15 December as the assumed mating start date. Likewise inter-conception interval was estimated as the difference between conception dates for two consecutive pregnancies. Other data collected at the annual muster included weight and Body Condition Score (Appendix 10.1).

Individual data for progeny were only available for North West Downs 1 property 2003 and North West Downs 1 property 2005 cohorts. Average daily gain was calculated from birth to weaning and inter-calving interval as the difference between two consecutive birth dates.

Culling of females in the trial was a decision made by property management in line with the broader breeder management for the property.

3.1.2 Males

Annual cohorts of weaner steers were allocated to either vaccinated or unvaccinated groups for four successive years and their growth to slaughter/disposal monitored. After weaning, all steers were transferred to a Grower station, determined by the supply chain logistics of the owners of the steers. A variable called *destination class* was used to distinguish the way the steers were managed and included the broad phases of management they experienced. The classes included:

- Grower to Background to Feedlot: animals managed in a grower phase and then sent to backgrounding and finally to feedlot. “Grow_BG_FL”
- Grower to Feedlot: animals grown out at one location and then sent direct to feedlot without any separate backgrounding. “Grow_FL”
- Grower to External Sale: animals sold off the property. “Grow_ES”
- Grower to Slaughter: animals grown out for a more extended period or grass finished and then transported direct to slaughter. “Grow_Slaught”
- Unspecified: no details on what steps the animals went through. “Unspecified”

Curfew weights measured at the time of transfer were used to calculate the ADG (kg/d) over time the animal spent at that location. Variations in the time at each location were accounted for by analyzing each location by different classes. Grower station ADG was analyzed by Destination Class. Background property ADG was already restricted by pathway to destination (minimum sixty days). Feedlot ADG was analyzed by destination class and days on feed class. Days on feed were split three ways, a) up to 90 days, b) between 90 and 120, c) more than 120.

(The curfew was defined as overnight (minimum 8 hours) off feed, but allowed access to water. Feedlot exit weights were not curfew weight)

3.1.2.1 Carcass Characteristics

Where steers were sold through the grid system, carcass data was collected. Carcass weight (HSCW), carcass value and any discounts subtracted from the grid premium were analysed, comparing controls and vaccinates.

3.1.3 BEF Outbreaks

Establishing the presence of an outbreak in areas where trial cohorts were located was attempted, using references to sentinel herds and regular surveys of property managers. Blood sampling of trial animals was undertaken only on females on two occasions to establish the seroconversion rate within vaccinates and controls.

3.2 Analysis and Modelling

3.2.1 Females

The analyses were based on intention-to-treat principles, so heifers still in the herd that missed a scheduled vaccination and those conceiving out of season were **retained** in the data set. Denominators for pregnancy and lactation rates were based on presence at the same muster rather than the more correct number of heifers returned at the previous muster. Mustering inconsistencies appeared to be higher than mortalities making the calculation of the correct denominator unreliable. Under this model data was analysed as per the initial randomisation and made no allowance for whether the heifer received each vaccination or not. In one sense this approximates the real world where the intention is to vaccinate annually but to accept that some animals will miss some scheduled vaccinations.

An alternative form of analysis was also conducted on a per protocol basis. All heifers who missed a muster and hence a vaccination, and all who were pregnant out of the scheduled period were excluded from the data set. Isolated data of suspicious quality was also deleted. As this set of analyses gave the same interpretation as the intention-to-treat set, only the latter are presented here.

Statistical analysis compared vaccinated versus control using analysis of variance for continuous variables and logistic regression for rates. Heifer data were adjusted for cohort, and progeny data for cohort and sex. Cohort was the seven properties by year combinations rather than region, year and property within region factors. The main purpose of including cohort was to remove any possible bias from the comparison of control versus vaccinated rather than specific interest in its effect *per se*. It was expected that cohort would reflect management and environmental differences. Stratified analyses were also completed to compare vaccinated versus control for each cohort separately. Interactions with the vaccination variable were fitted but none were significant, so final models did not include interaction terms

A wastage analysis was conducted to follow the disposition of all inducted heifers. Failure to muster is the ratio of the number of heifers not present at each muster divided by the number returned to the paddock at the previous muster. Cumulative wastage is the ratio of the number of heifers known to be no longer in the paddock divided by the number originally inducted. This allows for heifers present at subsequent musters, except in the case of PT4 which was the final muster. Culling rate is the ratio of the number culled at a muster to the number present and assessed for culling.

3.2.2 Males

Multivariable statistical models were used to analyse the various outcomes. All models incorporated a random effect coding for property to account for lack of independence for cattle from the same property. Each model included three explanatory variables: GROUP (control, vacc), ORIGIN (Barkly, Gulf, NW Downs) and YEAR (2003, 2004, 2005, 2006). These variables are independent of the Cohort variable used in female analysis as there were multiple properties within a region for steer origin in comparison to single property per region in the female analysis. Some steer analysis models included additional variables coding for DESTINATION (Grow_BG_FL, Grow_ES, Grow_FL, Grow_Slaught, and Unspecified) and DAYS ON FEED (Up to 90, betw90-120, More than 120).

Different models were used to analyse three ADG outcomes (grower period, backgrounding period and feedlot period). Similar models were then used to analyse carcass weight (HSCW), carcass value and discount from the grid premium.

Simple counts and proportions of missing data at different time periods were compared between control and vaccinated animals to look for any evidence of an association between “missingness” and treatment as a proxy for mortality risk.

Interactions between GROUP and the other two explanatory factors were considered in each model and were only retained in the model if they were significant. Estimated marginal means for each outcome were then generated from the mixed model (adjusted to account for other factors in the multivariable model) and follow-up tests used to compare means between levels for each outcome.

All analyses were performed in STATA version 11.0, using alpha=0.05.

3.2.3 Economic analyses

At the completion of data collection, a summary of sample sizes, data means and standard errors by group (vaccinates and non vaccinates) was used in an economic analysis to calculate outcomes. The well established and widely accepted Breedcow and Dynama economic models, developed by Mr Bill Holmes of QDPI for use in northern beef herds was the model of choice for this project.

Economic comparisons between vaccinated and control groups were undertaken together with calculation of break even responses required to cover vaccination and handling costs. Further, using information from sources other than the trial, modelling was undertaken of the likelihood of these responses arising from an episode or a series of episodes of BEF. The purpose in calculating these responses was to determine the incremental values for impacts such as steer prices, mortality rates, weaning rates so that “realistic“ responses comprising a combination of impacts could be valued, and thus compared with the cost (vaccination and handling) of achieving those responses relative to an unprotected herd. Vaccine costs were calculated at $2.40 per vaccination (total $4.80) with an additional handling cost for the second weaner vaccination of $4.20 per head for both females and males (total $9.00). Annual female vaccinations ($2.40/hd) coinciding with other husbandry events e.g pregnancy diagnosis or weaning, meant that no additional breeder handling costs were factored in.

The specific model was based on the Breedcow Representative Herd Templates for Northern Australia, with a herd size of 1000 breeders mated, with property carrying capacity fixed at approximately 1850 adult equivalents. Adult equivalents were calculated from an inbuilt file in the model, while values for age and sex classes based on weights and price per kg were also determined from an inbuilt file in the model, with some adjustments relative to the BEF project agreed to for these parameters. Estimates of input costs for weaner induction and maintenance (NLIS tags; Botulism vaccination; HGP treatment of males; costs of first dry season supplementation prior to dispatch), bull vaccination (vibrio) and bull replacement costs and annual BEF vaccination and breeder dry season supplementation costs were also built into the model.

A *sensitivity model* developed for feedlots Bullocks program, a component program of the Breedcow and Dynama set was used to determine break-even costs for male cattle either vaccinated or not vaccinated at weaning before being finished in the feedlot. In this model, two scenarios were tested, one based on a 100 day feeding regime to produce a heavier export type carcass, the second on a 70 day feeding regime commonly used for production of a carcass suitable for the domestic market. Parameters in the model included: animals on feed for either 70 or 100 days; average ADG of 1.9kg; feed costs of $300/tonne fed; feed conversion efficiency of 8:1; a 15% incidence rate of BEF infection occurring once every 5 years with a mortality rate of 0.5%, and a management regime where animals experiencing significant weight loss and reduced ADG following a BEF episode would be pulled and sold rather than be continued on feed.

A second breeder herd analysis examined a situation using a hypothesised next generation single dose vaccine. The vaccine, costing an estimated $3.20 was used for all weaners, (with a single weaner vaccination for males and annual vaccination for breeding females). In this scenario the need for a second weaner handling was eliminated, thus reducing the initial vaccination costs to $3.20. Theoretical differences in production parameters between vaccinates and controls were factored into the models, which were essentially *sensitivity models* to determine break-even costs.

4 Results and Discussion

Situations arose during the trial that required minor adjustments to the experimental design in order to maintain the goal of achieving the given objectives. The trial was broken down into Phase 1 (2003 – 2004) and Phase 2 (2004 – 2010), due to the withdrawal from the project of one of the major contributing pastoral companies. Essentially the experimental design did not change between phases and there were many cattle that were carried over from one phase to the next. Owing to changing ownership of some participating stations and consequent “loss” of cattle from the trial, it was necessary to recruit a number of trial cattle on new stations after the project had begun, effectively broadening the geographic scope however limiting the years in some locations.

The first weaners were inducted in 2003. The total numbers recruited, with useable data for the trial, were 3100 females and 3450 males. The last weaners were recruited in 2006.

4.1 2003 – 2009 BEF Incidence and Outbreaks

Serology was conducted on the North West Downs 2003 Female cohort (controls only) prior to first mating as part of the National Arbovirus Monitoring Program (NAMP). In the first instance the prevalence of antibodies to BEF in these heifers as 2 year olds was 23%. The re-testing was conducted 10 months later with 0% seroconversion rate in at risk animals. The timing of this study was over the 2004/2005 wet season, indicating there was little to no disease activity in this mob over this period.

Further serological studies were performed on the Barkly 2006 Female cohort prior to first mating. In the control animals there was a 39% seroprevalence at 2 years old. This study suggests there was a period of activity prior to this date causing this level of seroprevalence. There was no further blood sampling done on these females. By contrast, there was a 95% seroprevalence rate in the vaccinates, indicating the vaccine was efficiently prompting an immune response. The latter part of this study was conducted to qualify the vaccination procedure and subsequent immunity in the vaccinated trial animals (see Appendix 10.2 for comprehensive results).

Data from National Arbovirus Monitoring Program (NAMP) sentinel herds were compiled to investigate patterns in annual seroconversion of BEF. There were no definitive patterns of disease over the period of the trial from 2003 to 2009. There were no widespread epidemics where all areas in the Northern Territory and Queensland, or whole regions within these states, representative of this project, have been simultaneously affected during the time of this project. There were three incidences when every sentinel herd in a region recorded seroconversions, that is, in Central Eastern Queensland in 2002 and 2008 and Central Western Queensland in 2006. A feedlot used for steers from Gulf 3 and Barkly 3 properties is located in Central eastern Queensland. A total of 61 trial steers would have been in the feedlot for the duration of the 2008 outbreak, which appears to have been present from January to March. However there were no significant differences in ADG, carcass weight, meat yield or other carcass traits between vaccinates and controls. North West Downs 1 property and growout properties for Barkly 2, Barkly 4 and Gulf 4 steers is located within Central Western Queensland. There were approximately 700 trial females and 872 trial steers on the properties in this region during the outbreak. Data from this area is more difficult to predict timing of outbreaks accurately due to the extensive nature of the properties in this area. However it is likely the outbreak began in summer and may have extended through to winter after unseasonal and above average rain in April 2006.

For the remainder of the regions in northern Australia, there were isolated incidences in all years, except central eastern Northern Territory where seroconversions were recorded only once during six years. In conclusion, the period of the project would be regarded as low prevalence years for BEF. The only exceptions on a regional basis would be 2006 and 2008 as previously described with sporadic outbreaks.

A log of anecdotal reports from property managers was collated over the duration of the trial. There were occasional reports of severe morbidity without mortalities, however most were isolated reports of low morbidity and occasional mortality. The incidence of reports was highest in 2005 and 2006, where properties within the Central Western Queensland, North West Queensland and North Eastern Northern Territory regions were affected. These reports detailed outbreaks between February and April with one property report from July in 2005. Reports from property managers were not consistent with NAMP data in 2005, however the generalised 2006 outbreak in Central western Queensland was consistent with managers' reports of morbidity and mortalities in February, March and April of 2006.

4.2 Females

4.2.1 Production and Fertility Analysis

Data were available for all cohorts (property by year combinations) for Induction, and the annual musters at PT1, PT2, PT3 and PT4. Weights were obtained at all musters and body condition score (BCS) at each of the PT musters. Trial mobs were identified by geographical location and a number representing a participating property

Table 1: Muster dates for Female Cohorts by year and region from induction to 4.5 years of age

Date	NW Downs-1 03	NW Downs-1 04	Gulf-1 04	NW Downs-1 05	Gulf-1 05	Gulf-3 05	Barkly-3 05
Induction	21/06/03	12/10/04	15/10/04	10/10/05	20/09/05	17/05/05	19/05/05
PT1	26/10/04	15/10/05	14/10/05	02/06/06	19/09/06	15/08/06	25/10/06
PT2	18/07/05	12/06/06	07/09/06	08/05/07	16/06/07	15/05/07	18/07/07
PT3	02/06/06	08/05/07	14/06/07	19/05/08	25/05/08	26/05/08	13/04/08
PT4	08/05/07	22/05/08	21/05/08	19/05/09	25/05/09		12/05/09

The overall analyses for heifers are set out in Table 2 and the separate stratified analyses for each cohort are given in Appendix 10.3, (Tables 2a-2g). There were no meaningful significant differences between vaccinated and control females. The only significant overall difference was an average later conception date of 5 days for the vaccinated group at PT2. Likewise for the stratified analyses there were several non-meaningful differences which were significant but there were no consistent patterns. All differences were small and of no biological importance. While there were in excess of 1300 heifers in each group at induction, there were still over 800 at PT4. Hence there was adequate power to detect meaningful differences if they were present.

The summary of data separating each cohort is shown in Appendix 10.4. Differences here are not meaningful as they relate to seasonal, environmental and management decisions. Data were not available for weight at PT2-4 for Gulf-3 05; for BCS at PT1 for NW Downs-1 05 and at PT4 for Gulf-3 05; and for all reproductive parameters at PT4 at Gulf-3 05. The cohort means reflect an assumed date of 15 December for mating start date.

Progeny data from the NW Downs property analyses are summarised in Table 3. Differences between vaccinated and control are small and not significant. Data from NW Downs-1 05 were only available for the first two sets of progeny. Further summary of the two available progeny cohorts separated is shown in Appendix 10.5.

The cumulative number of calves reared for heifers over PT1-4 and PT3-4 are set out for vaccinated and control groups in Table 4 and stratified by cohort in Appendix 10.6, (Tables 4a-4f). The data for Gulf-3 2005 were incomplete so this cohort has not been included here. Overall, 2396 heifers were analysed, 60% of all recruited heifers reared two or more calves and 44% did so over the expected periods for PT3 and PT4. There were no significant differences between vaccinated and control groups. The same data are summarised by cohort in Appendix 10.7. Again differences here are reflective of seasonal, environmental and management decisions.

Table 2: Comparison of weight, body condition score and reproductive parameters of vaccine and control groups for females across seven cohorts in northern Australia in 2003-09

		VACCINE			CONTROL			
		N	**mean**	**SE**	**n**	**mean**	**SE**	**p**
Weight (kg)	Induction	1377	209.92	0.77	1373	211.13	0.77	0.26
	PT1	1365	358.13	1.05	1359	358.55	1.05	0.78
	PT2	1008	445.43	1.90	1030	445.13	1.87	0.91
	PT3	929	467.53	1.98	929	468.27	1.98	0.78
	PT4	830	492.69	2.15	838	493.23	2.14	0.85
ADG (kg/d)	Induction-PT1	1365	0.382	0.002	1359	0.379	0.002	0.44
BCS (Scale 1-5)	PT1	1228	3.55	0.01	1215	3.55	0.01	0.98
	PT2	1258	3.83	0.01	1266	3.84	0.01	0.51
	PT3	1017	3.90	0.01	1026	3.89	0.01	0.46
	PT4	834	3.75	0.02	848	3.73	0.02	0.32
Inter-conception Interval (d)	PT2-3	520	374.39	2.35	554	375.35	2.29	0.72
	PT3-4	497	367.26	2.29	508	365.78	2.28	0.58
Conception Date *	PT2	859	55.34	1.66	902	50.31	1.62	**0.026**
Conception Date*	PT3	698	47.96	1.70	708	47.22	1.67	0.69
Conception Date*	PT4	621	40.52	1.56	634	39.67	1.55	0.67

		VACCINE		CONTROL		
		N	**%**	**n**	**%**	**P**
Corpus Luteum (% present)	PT1	1345	92.8	1341	92.2	0.44
Pregnant (% positive)	PT2	1261	72.0	1279	74.4	0.89
	PT3	1024	72.8	1032	72.9	0.998
	PT4	839	74.1	852	74.9	0.94
Lactating (% wet)	PT3	1022	72.7	1030	73.0	0.93
	PT4	842	85.9	852	86.9	0.94
Rollcall (% present)	PT2	1197	95.2	1199	95.2	0.96
(**NOTE**: Gulf-2	PT3	1113	88.7	1114	88.2	0.64
excluded from roll call analysis)	PT4	1113	75.7	1114	76.5	0.60

* Days from December 15

Table 3: Comparison of birth to weaning performance of progeny of vaccine and control groups for NW Downs-1

			VACCINE			CONTROL		
		N	mean	SE	n	mean	SE	P
progeny 1	Birth Weight (kg)	169	32.24	0.48	179	31.50	0.47	0.27
	Birth Date *	169	286.89	1.76	179	286.51	1.71	0.88
	Weaning Weight (kg)	155	243.34	2.27	164	243.93	2.22	0.85
	ADG (kg/d)	155	0.926	0.009	164	0.926	0.008	0.99
progeny 2	Birth Weight	175	35.25	0.40	196	35.83	0.37	0.29
	Birth Date	175	295.45	1.41	196	292.95	1.33	0.20
	Weaning Weight	168	233.48	2.00	188	236.06	1.89	0.35
	ADG	168	0.883	0.007	188	0.882	0.006	0.93
	Inter-calf Interval	132	373.26	2.33	146	372.19	2.22	0.74
progeny 3	Birth Weight	86	30.64	0.72	86	31.20	0.72	0.58
	Birth Date	86	287.37	1.48	86	284.47	1.48	0.17
	Weaning Weight	84	264.71	2.81	83	267.47	2.82	0.49
	ADG	84	1.058	0.010	83	1.055	0.010	0.81
	Inter-calf Interval	79	355.70	2.39	82	356.06	2.35	0.91
progeny 4	Birth Weight	71	35.81	0.62	73	35.53	0.61	0.76
	Birth Date	71	287.44	2.03	73	287.66	2.01	0.94
	Weaning Weight	71	244.27	3.55	73	241.30	3.52	0.55
	ADG	71	0.947	0.014	73	0.938	0.014	0.66
	Inter-calf Interval	67	365.16	2.65	66	368.59	2.67	0.36

* Days from December 15th joining date. Actual birthdates were recorded

Table 4: Comparison of Vaccine and Control Groups for Calves Reared per cow from all properties for the duration of the project, 2003-2009

		VACCINE %	CONTROL %	p
For pregtests 1-4	N	1197	1199	
	0 calves	14.4	16.3	0.51
	1 calf	26.3	23.8	
	2 calves	48.1	49.0	
	3 calves	10.0	10.0	
	4 calves	1.2	0.9	
For pregtests 3-4	N	1197	1199	
	0 calves	21.3	23.2	0.87
	1 calf	33.2	32.3	
	2 calves	43.7	44.5	

4.2.2 Wastage

Failure to muster, cumulative wastage and culling rates are summarised in Table 5. Although 13 heifers were not present for the second vaccination, these heifers were present at subsequent musters. Of the 3100 expected to be mustered at PT1 155 were missing and 103 of these had no subsequent data. A further 27 had no useful subsequent data and these 130 were deleted from the data file. A further 25 did have subsequent data. There were only 4 recorded deaths prior to PT1, 2 in each of control and vaccinated groups. Hence wastage rates from induction to PT1 were 67/1550 = 4.3% for control and 63/1550 = 4.1% for vaccinated.

At PT2 2970 heifers were expected to be mustered, but 336 were not mustered. These comprised 220 which were not seen subsequently (deleted from the analysis data file) and 116 which were seen subsequently. Only 1 additional death in a vaccinated heifer was recorded. Hence the cumulative wastage up to PT2 was 363/1550 = 23.4% for control and 381/1550 = 24.6% for vaccinated. At PT2 394 heifers were culled, giving rates of 14.1% for control and 15.8% for vaccinated.

At PT3 2356 heifers were expected to be mustered, based on those returned to the paddock after PT2. There were 309 not mustered, 176 not seen subsequently and 133 seen subsequently. A further 2 controls and 3 vaccinated were recorded as dead. Cumulative wastage up to PT3 was 605/1550 = 39.0% for controls and 607/1550 = 39.2% for vaccinates. At PT3 292 heifers were culled, giving rates of 14.5% for control and 14.1% for vaccinated.

At PT4 1888 heifers were expected to be mustered but 195 were not. As this was the final muster it is not known how many of these might still be in the paddock. No deaths were specifically recorded. Considering all of the ‘not mustered’ heifers as lost, cumulative wastage from induction to PT4 was 745/1550 = 48.1% for controls and 746/1550 = 48.1% for vaccinated. At PT4 84 heifers were culled, giving rates of 5.5% for control and 4.4% for vaccinated.

In summary there was no difference in failure to muster, cumulative wastage and culling rates between control and vaccinated heifers. Only 10 deaths were specifically recorded, 4 in control and

6 in vaccinated. Overall wastage was high with almost half of the inducted heifers not in the herd after they were scheduled to wean their second calf.

Table 5: Comparison of wastage patterns for Vaccine and Control Groups.

		VACCINE			CONTROL			
		N	n	%	N	n	%	p
Fail to muster	PT1	1550	75	4.8	1550	80	5.2	0.68
	PT2	1487	169	11.4	1483	167	11.3	0.93
	PT3	1169	152	13.0	1187	157	13.2	0.87
	PT4	943	102	10.8	945	93	9.8	0.49
Cumulative wastage	PT1	1550	63	4.1	1550	67	4.3	0.72
	PT2	1550	381	24.6	1550	363	23.4	0.45
	PT3	1550	607	39.2	1550	605	39.0	0.94
	PT4	1550	746	48.1	1550	745	48.1	0.97
Culling	PT2	1318	208	15.8	1316	186	14.1	0.24
	PT3	1013	143	14.1	1026	149	14.5	0.79
	PT4	836	37	4.4	852	47	5.5	0.30

4.3 Males

4.3.1 Production Analysis

4.3.1.1 Average Daily Gain (kg) for Grower Period

Destination class (described in experimental design) has particular relevance when considering Average Daily Gain (ADG) estimates for a grower period and is best illustrated by showing the ADG for Grower periods for different destinations. Data were available for GROUP (control, vacc), ORIGIN (Barkly, Gulf, NW Downs) and YEAR (2003, 2004, 2005, 2006).

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The Average Daily Gain estimate is calculated with a numerator comprised of the weight change from date of second vaccination to date the animal exited the grower property and the denominator is the number of days between these two dates. Summary statistics for the number of days in the grower phase depending on the destination class are presented in Table 6. Animals sent directly from grower property to slaughter had the longest stay in days on the grower property, being the grass finished steers, followed by animals that were sent to external sale. ADG for animals in the Grow_BG_FL class was significantly lower than the ADG for animals in the Grow_FL class.

Table 6: Summary statistics for grower days for animals managed under different destinations

Grower days	Count	Mean (d)	SD	Min	Max	95% CI Lower	Upper
Grower-Backgrounder-Flot	1367	342	109.6	139	1056	336	348
Grower - External sale	95	462	82.4	267	610	446	479
Grower - Flot	1017	386	107.2	82	791	380	393
Grower - Slaughter	267	1030	134.2	406	1186	1014	1046
All combined	2746	429	227.7	82	1186	421	438

These data indicate reasons for Grower animals to be analysed in their respective destination class. They were managed for different periods of time in the growing phase depending on their intended destination. Analyses for the Grower period were split into different analyses depending on the next destination.

There was no significant effect of vaccination on mean ADG for the grower period (0.003; 95% CI -0.005, 0.012; p=0.4),(Table 7). Other differences between years and regions shown in a mixed effects model (Appendix 10.8) are not meaningful and are reflective of season, environment and management decisions.

Table 7: Estimated ADG marginal means for the steer Grower period

		Mean ADG (kg/d)	se	95% CI Lower	Upper
Group					
	Control	0.454	0.020	0.414	0.494
	Vacc	0.457	0.020	0.417	0.497
Year					
	2003	0.530	0.030	0.472	0.588
	2004	0.459	0.030	0.399	0.519
	2005	0.389	0.021	0.348	0.430
	2006	0.444	0.021	0.403	0.484
Origin					
	Barkly	0.417	0.024	0.369	0.465
	Gulf	0.439	0.022	0.397	0.482
	NW Downs	0.510	0.036	0.440	0.580
Destination					
	Grow_BG_FL	0.473	0.017	0.439	0.507
	Grow_ES	0.496	0.024	0.448	0.543
	Grow_FL	0.529	0.019	0.493	0.566
	Grow_Slaught	0.338	0.022	0.295	0.380
	Unspecified	0.441	0.056	0.332	0.551

Grow_BG_FL= Grower to Background to Feedlot
Grow_ES = Grower to External Sale
Grow_FL= Grower to Feedlot
Grow_Slaught= Grower to Slaughter
Unspecified = missing or no specification on destination

Animals destined for external sale (ES) were excluded from further analyses as they were not grouped for a specific market. These animals became un-marketable in their intended market for many reasons including, dog bite, pulled from feedlot, drought destocking, surplus to market etc, all of which are normal outcomes in steer grow out management.

4.3.1.2 Average Daily Gain (kg) for Backgrounding period

There was no significant effect of vaccination on average daily gain during the backgrounding period (0.000; 95%CI – 0.031, 0.031: p=0.998), (Table 8). Other differences between years and regions are not meaningful differences and are reflective of season, environment and management decisions. The mixed effects model for backrounding period can be found in Appendix 10.8.

Table 8: Estimated marginal means for ADG during backgrounding

		Mean ADG (kg/d)	se	95% CI Lower	Upper
Group					
	Control	0.505	0.016	0.475	0.536
	Vacc	0.505	0.013	0.476	0.534
Year					
	2003	0.710	0.030	0.651	0.770
	2004	0.299	0.026	0.242	0.343
	2005	0.584	0.012	0.561	0.607
	2006	0.434	0.016	0.402	0.465
Origin					
	Barkly	0.370	0.011	0.348	0.392
	Gulf	0.726	0.026	0.675	0.778
	NW Downs	0.420	0.018	0.385	0.454

4.3.1.3 Average Daily Gain for Feedlot period

There was no significant effect of vaccination on average daily gain during the feedlot period (0.023; 95% CI -0.015, 0.061: p=0.23), (Table 9). Other differences between years and regions are not meaningful differences and are reflective of season, environment and management decisions, see Mixed Effects model for feedlot period in Appendix 10.8.

Table 9: Estimated margin means for ADG during feedlot period

		Mean ADG (kg/d)	se	95% CI Lower	Upper
Group					
	Control	1.949	0.190	1.576	2.321
	Vacc	1.972	0.190	1.599	2.344
Year					
	2003	2.098	0.196	1.715	2.481
	2004	1.971	0.199	1.582	2.360
	2005	1.891	0.189	1.521	2.261
	2006	1.880	0.189	1.510	2.250
Origin					
	Barkly	1.859	0.242	1.385	2.332
	Gulf	2.131	0.297	1.549	2.713
	NW Downs	1.890	0.253	1.395	2.386
Destination	**Grow_BG_FL**	1.900	0.188	1.531	2.268
	Grow_FL	2.019	0.191	1.645	2.393
	Unspecified	1.962	0.204	1.561	2.362
Days on feed	**Bet90-120**	2.242	0.200	1.849	2.634
	More than 120	1.772	0.196	1.388	2.157
	UpTo80	1.866	0.196	1.483	2.250

4.3.1.4 Carcass Weight – HSCW (kg)

Carcass weights were recorded only from animals that were finished in the feedlot. There was no significant effect of vaccination on HSCW (0.7; 95%CI -1.7, 3.2; p=0.55), (Table 10). Other differences between years and regions are not meaningful differences and are reflective of season, environment and management decisions, and are shown in the Mixed Effects model for HSCW in Appendix 10.9.

Table 10: Estimated marginal means for HSCW for steers following the feedlot supply chain only

		Mean HSCW (kg)	se	95% CI Lower	Upper
Group					
	Control	314.93	6.63	301.93	327.94
	Vacc	315.67	6.63	302.67	328.67
Year					
	2003	323.22	9.27	305.05	341.39
	2004	298.60	7.47	283.95	313.24
	2005	318.28	6.28	305.98	330.58
	2006	321.11	6.29	308.79	333.43
Origin					
	Barkly	325.91	8.72	308.82	343.00
	Gulf	316.81	10.51	296.21	337.41
	NW Downs	303.18	9.75	284.07	322.30
Days on feed					
	Bet90-120	341.46	8.70	324.41	358.51
	More than 120	342.97	8.13	327.04	358.90
	UpTo80	261.47	8.28	245.25	277.70

4.3.1.5 Carcass Value ($)

Meatworks data reported from steers finished in the feedlot was used to calculate a carcass value. There are limitations in statistical analysis of these estimates as there are external forces causing market prices to move during any period. However it was argued the change in the market over the period the steers were slaughtered (August 2004 to June 2008) would not have affected the outcome of analysis for impact of vaccination as both vaccinates and controls would have equal exposure to market fluctuations. Variation in the market over this period was $3.40 to $3.90 per kg HSCW based on the grid.

There was no significant effect of vaccination on Carcass value (2.38; 95%CI – 7.6, 12.4: p=0.64), (Table 11). Other differences between years and regions are not meaningful differences and are reflective of lifetime seasonal effects, environment and management decisions, and are shown in the Mixed Effects model for carcass value in Appendix 10.9.

Table 11: Estimated marginal means for carcass value of steers slaughtered after feedlot period

		Carcass value	se	95% CI Lower	Upper
Group					
	Control	1143.18	41.55	1061.74	1224.62
	Vacc	1145.56	41.59	1064.05	1227.06
Cohort					
	2003	no data			
	2004	1101.76	84.63	935.89	1267.64
	2005	1168.48	26.98	1115.59	1221.36
	2006	1162.87	27.05	1109.85	1215.88
Origin					
	Barkly	1191.60	35.21	1122.59	1260.60
	Gulf	1145.12	46.13	1054.70	1235.54
	NW Downs	1096.39	82.68	934.34	1258.45
Days on feed					
	Bet90-120	1284.66	41.83	1202.68	1366.64
	More than 120	1251.68	48.77	1156.10	1347.26
	UpTo80	896.76	49.32	800.09	993.44

4.3.1.6 Carcass Discounts

Carcass discounts were analysed as a measure of meat quality that may have been influenced by impacts on performance from an earlier BEF incident. There were 1737 entries for Discount, comprised of 775 rows where the entry was zero and 962 rows where the entry was a negative number (ranging from -0.025 to -0.85), representing a discount in $ per kg from the grid premium. The data for this variable were not normally distributed.

Two approaches were taken to analyse the data.

First, a new variable was coded with the value 0 (no discount) and 1 (any row with a negative value for Discount) and a 2x2 table used to analyse association between Group and Discount.

Discount	Group Control	Vaccinates	Total
no	380	395	775
yes	463 (55%)	499 (56%)	962
Total	843	894	1737

A chi-square analysis was done and there was no evidence of an association (p=0.71).

Secondly the data were transformed as follows:

- Multiplied by -100 to create a new variable representing discount in cents with higher values being worse.
- Then log transformed after adding 1 to every cell

- This new outcome was used in a general linear model using the same approach as for other production outcomes – interpretation was based on the fact that increasing outcome was worse (larger discount)

There was no significant effect of vaccination on discount (-0.005; 95%CI – 0.014, 0.004: p=0.26), (Table 12). Other differences between years and regions are not meaningful differences and are reflective of season, environment and management decisions occurring during the life of the steers, see Mixed Effects model for carcass value in Appendix 10.9.

Table 12: Estimated marginal means for carcass discounts in steers slaughtered after feedlot period

		Carcass Value ($)	se	95% CI Lower	Upper
Group					
	Control	-0.105	0.054	-0.210	0.000
	Vacc	-0.110	0.054	-0.215	-0.004
Year					
	2003	no data			
	2004	-0.170	0.109	-0.384	0.044
	2005	-0.081	0.035	-0.150	-0.012
	2006	-0.071	0.035	-0.140	-0.002
Origin					
	Barkly	-0.088	0.045	-0.176	0.000
	Gulf	-0.044	0.061	-0.163	0.075
	NW Downs	-0.190	0.105	-0.396	0.016
Days on feed					
	Bet90-120	-0.025	0.054	-0.131	0.080
	More than 120	-0.138	0.059	-0.253	-0.022
	UpTo80	-0.159	0.059	-0.275	-0.042

4.3.2 Wastage Analysis

Most of the wastage from the trial occurred as missing data, where animals did not return in the subsequent muster for weight recording. An attempt was made to assess missing data at different weigh points as an indirect measure of mortality. It was recognized that there are many other possible explanations for missing data (mustering inefficiency, loss of ear tags etc). These other causes were assumed likely to occur with equal probability amongst control and vaccinated animals. Assessment of missing data by vaccination status was conducted to see if there was a pattern that may have been consistent with an association between vaccination and “missingness”.

There were 11 animals in the male dataset where mortality had been recorded with an indication of when the mortality occurred.

Table 13: Recorded Deaths in trial steers

Recorded deaths	Control	Vacc
Grower period	2	2
Background period	4	1
Feedlot	2	0
Total	8	3

There were a total of 1918 control steers and 1974 vaccinated steers in the cleaned dataset. Of these, 266 control animals (13.9%) had missing weight data at the second vaccination period, and 268 vaccinated animals (13.6%) had missing weights at the same period. A chi-squared analysis indicated the proportion of missing data was not different (p=0.8).

A subset of animals with valid weights recorded at time of second vaccination (1652 controls and 1706 vaccinates) were then assessed to determine the count and proportion of animals that were missing a value for the next weight record. A total of 491 controls (29.7%) and 480 vaccinates (28.1%) had missing values and the proportion was not statistically different (p=0.3).

After the grower period the cumulative wastage analysis was divided dependent on subsequent destination.
Of those animals classified as being backgrounded (678 controls and 718 vaccinates), a total of 194 controls (28.6%) and 186 vaccinates (25.9%) were missing. This proportion was not significantly different (p=0.26).

Of those animals classified as being prepared for feedlot (either through grower direct to feedlot or through backgrounding), a total of 207 of 972 controls (17.6%) and 208 of 1034 vaccinates (16.8%) were missing. These proportions were not significantly different (p=0.6).

Of those animals that had a valid weight recorded at feedlot entry, a total of 48 of 984 controls (4.9%) and 51 of 1053 vaccinates (4.8%) had no weight recorded at feedlot exit. These proportions were not significantly different (p=0.98).

There was no evidence of any statistically significant association between treatment group and “missingness” at different muster and weigh points through the dataset. Owing to the absence of a major BEF incident during the trial, the effectiveness of vaccination in the face of a major challenge remains inconclusive.

4.4 Economic Analysis

As a first step in this modelling exercise, a base herd structure was developed from the trial data using mean data, pooled across year cohorts for female performance and fertility and weaning rate and weight in mobs with progeny data. These were age at first mating - 2 years; time to conception (1st,2nd,3rd matings, range 26-68d from mating start date), calving interval (range 1.3-1.4 years); weaning rate (range 62-84%, mean 73%); estimated age at weaning (6-8 mths) and weaner weight (range 223-268kg, mean 239kg).

For males, data included weaning weight; age/weight at dispatch, average daily gain (ADG) in the grower and backgrounding environment and in feedlot. ADG was used to calculate final turnoff weights. Turnoff weight, in conjunction with project carcass yield data and carcass value/kg was used to calculate hot carcass weight (HCW) and hence carcass value.

Initial analysis confirmed the lack of statistical difference between vaccinates and controls for economic outcomes, as previously shown in male and female productivity. Economic analysis was then conducted, modelling the break-even cost to vaccinate.

4.4.1 Breeder and male progeny performance and survival using the existing two dose BEF vaccination regime.

The *sensitivity analyses* for gross margins on a herd (and adult equivalent) basis indicated that, other than a scenario of an increase in steer sale prices of 5.5 %, there was no single response parameter where a break-even situation could be achieved. In line with the male and female analyses of the biological impacts of vaccination on animal productivity, the economic analyses reported here were unable to demonstrate any significant economic benefits of a two dose weaner vaccination (with an annual breeder vaccination).

However combined theoretical incremental responses to vaccination for BEF, such as improvements in fertility, together with increases in steer prices, and/or improvements in either male or female survival meant that break-even responses to vaccination could be achieved. The most realistic of these are outlined below

Scenario 1. A 5% increase in conception rates at 1st mating and 3% at 2nd mating together with a 1% increase in survival rates for both females and steers for vaccinates compared to controls (Break-even costs $5.71/AE).

Scenario 2. A 5% increase in conception rates at 1st mating, together with a 1.2% increase in female survival rates and a 1% increase in steer survival rates (Break-even costs $5.81/AE).

Scenario 3. A 5% increase in conception rates at 1st mating, together with a 1% increase in female survival rate, and an increase in steer prices of 1.5% (Break-even costs $5.58/AE).

Scenario 4. A 1% increase in steer prices, together with a 1% increase in male and female survival rates (Break-even costs $5.57/AE).

Scenario 5. A 2% increase in steer prices, together with a 1% increase in female survival rates (Break-even costs $5.49/AE).

Any of the above impact combinations would enable break-even costs of the vaccination and handling regimes to be achieved, thereby justifying the application on a herd basis of a two dose vaccination regime for all weaner cattle, with an annual vaccination for all retained breeders in the herd.

However, given the situation in the present trial, where in the years of observation there were no major BEF incidences, and where there was a lack of any significant biological responses to vaccination on measured female reproductive variables and steer growth rates, the two dose vaccination regime is difficult to justify unless measurable combination responses as in the above scenarios can be quantified. Furthermore, under extensive conditions, the small changes in the sensitive parameters used in the scenarios above may be difficult to measure, thereby making an assessment of the value of a BEF vaccination somewhat problematic.

4.4.2 Breeder and male progeny performance and survival using a next generation, one-shot vaccine

A vaccination regime using an enhanced next generation single dose vaccine (yet to be developed) could have a significant impact on the *sensitivity analyses* outlined above. An estimate of the vaccine costs for a next generation vaccine was $3.20/head but this higher cost is offset through elimination of the need for a second handling cost for weaners, with potential savings of about $5.50-$5.80/weaner.

Under this regime, other than two scenarios of an increase in steer sale prices of about 4%, or an increase of about 1% in female survival rates, there was no single response parameter where a break-even situation could be achieved. However a break-even situation would be achieved when a number of combinations of impacts of vaccination were considered. The most realistic are outlined below.

Scenario 1. A 5% increase in conception rates at 1st mating and 3% at 2nd mating together with a 0.5% increase in survival rates for both females and steers (Break-even costs $3.85/AE).

Scenario 2. A 4% increase in conception rates at 1st mating, together with a 0.8% increase in female and male survival rates. (Break-even costs $4.10/AE).

Scenario 3. A 4% increase in conception rates at 1st mating, together with a 1% increase in female survival rate (Break-even costs $3.88/AE).

Scenario 4. A 1% increase in steer prices, together with a 0.8% increase in female survival rates (Break-even costs $3.76/AE).

Whilst the outcomes from the modelling of a next-generation one dose vaccine are similar, there is a clear cost saving with a lower break-even cost compared with the two shot vaccine. Furthermore, if formulations of new generation vaccines also result in a longer duration of immune protection, further reductions in costs of breeder protection could possibly be achieved.

4.4.3 Backgrounding and feedlot steer performance using the existing two dose vaccination approach

As outlined earlier, two separate models were evaluated, one based on a 100d feeding period to produce heavier carcasses suitable for the export trade, the other based on a shorter 70 d feeding period to produce lighter carcasses suitable for the domestic market.

The *sensitivity analyses* for the feedlot scenario were much more positive. For the longer fed, heavier animals there was an increased gross margin per animal of about $130 in favour of vaccinated animals, whilst the comparable figure for shorter fed animals was much lower at about $11. For those feedlots in BEF endemic areas, for the heavier weight animals this is equivalent to about $13/hd/yr risk protection, and for lighter animals about $8/hd/yr risk protection.

However, opinion within the industry suggests the importance of BEF in the feedlot environment was low with outbreaks uncommon. BEF vaccinations are not routinely undertaken at feedlot induction, but some cattle being paddock backgrounded prior to feedlot entry could occasionally be affected. Thus these analyses are more appropriate to situations where cattle are being backgrounded but may be incubating the disease, and subsequently show some ill effects after feedlot entry.

While BEF vaccination is rarely used in a feedlot environment, the sensitivity analyses indicated that vaccination during the backgrounding process could be economically advantageous in situations where such cattle could be at risk of exposure prior to feedlot entry.

5 Success in Achieving Objectives

This project has involved a dedicated network of company leaders, property managers, advisory and project personnel who have worked for six years to achieve the objectives. Achieving the objectives has not been without constraints given the extensive nature of the properties, the withdrawal of a major cattle contributor and the low level of BEF incidence over the duration of the project.

Whilst the results indicate there is no statistically significant nor biologically or economically important impact of vaccination on female and male productivity and economic outcomes in northern beef herds, the limitations faced by the experimental design of this project need to be recognised. Owing to the large numbers required for statistical power in analysis, it was cost prohibitive to conduct serological studies of prior immunity and monitor serological evidence of outbreaks in the trial groups. The scope of the project for normal management of animals in the extensive environment of pastoral properties did not allow for measurement or diagnosis of mortalities (other than a few opportune events) or more regular data collection. Transfer of steers to other company properties at various stages through their lives left no choice but to vaccinate the males with two doses only at weaning, whilst females received their weaner shots then an annual booster. Data was collected on variables that were accurately measurable within the confines of the project, the budget and property management logistics. There are potentially many other variables that were affected by vaccination; however these were not within the scope of the project (e.g. temporary impacts on lactation, bull fertility, and weight loss).

Despite data on an extremely large number of recruited cattle over the range of northern beef herds and the long duration of the project, there is no doubt there were sporadic outbreaks over the general region that did not affect cattle in the trial. There is also no doubt there would have been a level of prior immunity in many of the control animals, which can only be marginally accounted for by the small amount of serology conducted during the project.

The range of exposure to BEF virus across the regions was varied. During the course of the project, no major BEF episodes were recorded. There were many isolated reports from property managers of disease incidence; however none were severe enough to warrant veterinary or otherwise investigation. The sentinel herd data supports the low disease impact years with no episode of simultaneous activity across the extensive north during the project. Sporadic incidences were recorded in sentinel herds; however this did not extend to causing production or economic impacts on control animals in this project.

Lack of significant biological or economic responses does not signify failure of the project, however it is likely to be a reflection of a lack of significant animal challenges by BEF virus during the period of data collection, a situation impossible to predict, or to manage.

6 Impact on Meat and Livestock Industry – now & in five years time

This project has been unable to demonstrate an impact of BEF vaccination on female reproductive rates, steer growth rates and carcass traits and whole herd economics, within the scope of time, space, class and numbers. However, BEF has been a major problem in the industry in recent years, supported by numerous studies completed in the last decade that model the costs of BEF disease to the industry, all estimating a cost approaching $100 million. The most recent study classes this disease as the third most economically important disease in cattle in Australia. The models used assumptions accounting for disease effects in cows under 4 years, decrease in branding rate of 5% in cows under 5 years, up to 2% mortalities in cattle 0 – 4 years when an epidemic occurred.

Sentinel herd data shows the virus was circulating through the relevant regions during the project. The outcomes of this project cannot support the levels of loss described in the documented studies, for reasons that may include absence of a major outbreak, high natural herd immunity, genetic drift of wild viral strains from vaccine strain, or overestimated assumptions. Further, there was no scope in the project design for measurement of mortalities.

Low levels of reporting from property personnel may not reflect the true underlying incidence of the disease; conversely the project may have begun when natural herd immunity was high showing low rates of affected cattle despite virus circulating. Historically as diseases have become more familiar to those in the industry the level of reporting and investigation has decreased. Changes in epidemiology of this disease, demonstrated through history, indicate data on familiar diseases should be recorded and reported routinely.

The major confounding factors of this project included prevailing climatic conditions and presence or otherwise of BEF virus, unknown immune status prior to vaccination, the level of cumulative natural immunity in the control groups as they aged, lack of recent evidence supporting vaccine efficacy in the face of an outbreak and absence of direct measurement of mortality.
A low incidence of BEF virus in the monitored cattle during the project would result in little to no difference between controls and vaccinates.
High levels of natural herd immunity prior to vaccination would have the effect of silhouetting the impact of the vaccination in the control group, resulting in little to no difference between the control and vaccinated group.
If the vaccine strain is antigenically different from wild pathological strains, there would not be expected to be any impact of vaccination if the vaccinates were exposed to an antigenic variant strain.
Without mortality as a separate measurement, the project cannot offer any understanding of the breakdown of the wastage component which included almost 25% of females and 20% of males and what the levels of mortality are as a percentage in total wastage.

Many variables were controlled by the random odds and evens model where vaccinates and controls in each location were managed within the same mob in the same manner, and hence were given equal opportunity for exposure to virus, nutrition, water, mismustering, mismothering and mortality. Vaccine cold chain integrity was controlled as was vaccine reconstitution and administration.

The absence of a vaccination impact raises the issues of the complexity of this disease and the limited knowledge available defining vector, virus, natural immunity dynamics and temporal-spatial distribution of the disease. Vectors have been identified, however virus has been isolated beyond the geographic distribution of known vectors indicating more vectors, and vector distribution is dictated to a degree by moisture and wind direction and strength. The virus is antigenically close to other non pathogenic viruses isolated in the Northern Territory, allowing some cattle to be partially immune from exposure to non BEF virus. Natural immunity will rise exponentially after an outbreak of disease in a cattle population and then decrease at an unknown and non fixed rate over time as older immune cattle are replaced by naive calves. Suckling calves will gain immunity from their dams, however the rate that circulating anitibody levels decreases as the calf approaches weaning is unknown, and is confounded by the effectiveness of their immune response to virus exposure prior to weaning. There is little known of recent strain variation in the wild and its susceptibility to antibody produced from vaccination. The case for whole herd vaccination must be constructed upon a base of limited understanding of the disease in the current environment where a robust project has demonstrated no significant effect of vaccination.

The absence of biological differences between controls and vaccinates restricted, the scope of the economic analysis of the data from this project.. The modelling indicated that the only single response parameter to provide a break-even situation was an increase in steer price of 5.5%. However a number of other scenarios combining theoretical incremental responses to vaccination (eg.fertility, steer prices, and survivability) could result in a break-even response to vaccination.

However, BEF disease remains one of the cattle industry's biggest costs and therefore this project has been integral in learning more about the complexity of this disease.

The next priority for the industry is to pursue the development of a single dose vaccine, an approach which would have been strongly justified by a positive effect of vaccination in this project. Further the economic modelling in this project showed an average $1.77/AE break even cost reduction from the two dose vaccine in the first instance. There may not be a case at this stage for whole herd vaccination however targeted vaccination programs using a single dose vaccine will no doubt decrease the cost of the disease in Australia.

7 Conclusions and Recommendations

In a large population of about 6,500 mixed sex weaners and adults aged from 6 months to 4.5 years, originating from three northern Australian regions, and monitored over six years, no measurable biological or economic impacts could be demonstrated resulting from vaccination with the currently available Bovine Ephemeral Fever (living) vaccine.

From data from NAMP sentinel herds compiled to investigate patterns of annual seroconversion to BEF, there were no definitive patterns of disease over the period of the trial, 2003 to 2009. The incidence of anecdotal reports from property managers was highest in 2005 and 2006. Reports from property managers were not consistent with NAMP data in 2005; however the generalised 2006 outbreak in Central western Queensland was consistent with managers' reports of morbidity and mortalities during early 2006.

Female reproduction rates, male growth rates and carcass traits were not influenced by vaccination., and .the project was unable to demonstrate a single statistically significant parameter influenced by vaccination. These included, in females; growth from weaning to first joining, inter-conception intervals, pregnancy rates, proportion of vaccinates and controls mustered annually, number of calves raised per dam, cull rate, days to calving, inter-calving interval and progeny growth and weaning weights. In males parameters analysed included growth from weaning to completion of grower phase, backgrounding and feedlot performance, carcass weight and value by market destination, average value of discounts and prevalence of carcass discounts. Wastage, measured as absent from musters was evaluated within the scope of the design. There was no impact of vaccination on wastage in either control or vaccinate group. As this type of data had to group all reasons for wastage together, it is not suitable to infer mortalities and calf losses due to mismustering and mismothering, nor can it infer mortalities or illness due to BEF.

Findings from this project would not support recommendations for whole herd vaccination every year in extensive northern beef herds with the current commercially available vaccine. It is possible there will be years of high viral prevalence in sentinel herds, unseasonably wet conditions, excessive wet season rains or severe outbreaks upstream which may stimulate the use of the vaccine in target animals or in the whole herd in target areas. However, greater understanding of the vector and disease and further research would be required to demonstrate the effectiveness of this approach.

Confirmation of the current vaccinal strain effectiveness against circulating wild viral strains is important as is assessing vaccine efficacy in all classes of animals, particularly older and heavier cattle. However, there are factors affecting vaccine efficacy and economics that are beyond the scope of these recommendations. A greater understanding of natural viral exposure and herd immunity dynamics, temporal and spatial distribution of the disease, vector identification and their population dynamics and the influence of non-pathological but similar viruses will assist in simplifying the question of vaccination in the future.

One ancillary outcome of this project is a comprehensive database of herd production indices for a number of northern breeder herds and considerable data on male cattle production performance and carcass traits. There is potential benefit to be gained from more detailed analyses of this database, to provide further information on herd performance in the extensive northern beef cattle industry. Such analyses may also assist related projects currently funded by MLA in Northern Australia on a range of animal health and production aspects in tropical beef cattle.

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Endurance is patience concentrated *Thomas Carlyle*

10 Appendices

10.1 Body Condition Scoring System

BEEF CATTLE BODY CONDITION SCORING		
BCS 1 to 5 System	**Body Condition**	**Description**
5	Overfat	Heavily covered with fate, lumpy fatness around hindquarter
4.5	Fat	Well covered with muscle and fat but not lumpy
4	Prime	Animal has a smooth rounded appearance
3.5	Forward Store	Frame has muscle over it with little fat. Backbone and ribs are not visible but hip bone can be seen
3	Store	Frame only moderately covered with muscle. Backbone, rear (short) ribs, hips and shoulders clearly seen
2.5	Backward store	Light tissue cover of the skeleton. Backbone, ribs, hips and shoulders clearly defined
2	Poor	Skeleton has little muscle tissue cover and bony frame is readily distinguishable
1.5	Very Poor	Death may occur at this level in lactating cows
1	Emaciated	Eyes sunken and the animal has a lethargic appearance. Death is imminent.

10.2 Northern Territory NAMP Sentinel Herd seroconversion rates in 2006 from project Barkly-3 2005 cohort

2006/1259 Not Vaccinated		2006/1260 Vaccinated	
Animal No.	BEF VNT Titre*	Animal No.	BEF VNT Titre*
1	32	1	32
2	<4	2	8
3	<4	3	128
4	<4	4	>160
5	<4	5	>160
6	<4	6	>160
7	<4	7	24
8	>160	8	8
9	80	9	36
10	<4	10	12
11	<4	11	128
12	64	12	144
13	<4	13	>160
14	<4	14	>160
15	80	15	>160
16	<4	16	20
17	6	17	>160
18	<4	18	9
19	<4	19	144
20	<4	20	>160
21	10	21	40
22	<4	22	32
23	<4	23	64
24	<4	24	>160
25	24	25	10
26	<4	26	>160
27	20	27	12
28	8	28	32
29	<4	29	18
30	64	30	16
31	<4	31	<4
32	40	32	>160
33	40	33	144
34	<4	34	>160
35	36	35	24
36	<4	36	32
37	<4	37	80
38	12	38	<4
		39	48
		40	>160

* BEF VNT Titre: <4 = Negative, >4 = Positive

10.3 Stratified Analysis of Production and Fertility for Each Cohort of Females

Table 2a: Comparison of Vaccine and Control Groups for Females 2003-09 **NW Downs-1 2003 Cohort**

		VACCINE			CONTROL			
		n	mean	SE	n	mean	SE	p
Weight	Induction	134	204.51	1.83	138	212.22	1.67	**0.002**
	PT1	133	321.32	3.70	135	322.00	3.74	0.898
	PT2	124	400.45	6.77	125	395.17	6.03	0.560
	PT3	122	426.76	5.02	130	436.27	4.74	0.169
	PT4	101	461.38	4.96	115	466.97	3.33	0.116
ADG	Induction-PT1	133	0.237	0.007	135	0.223	0.007	0.138
BCS	PT1	134	3.34	0.02	134	3.29	0.03	0.112
	PT2	124	3.97	0.05	124	4.01	0.05	0.540
	PT3	121	3.85	0.04	127	3.84	0.04	0.936
	PT4	101	3.82	0.03	115	3.94	0.03	**0.011**
Inter-conception Interval	PT2-3	78	379.60	3.67	90	380.95	3.64	0.796
	PT3-4	95	343.51	3.54	97	337.19	2.88	0.167
Conception Date	PT2	95	51.03	3.88	100	43.26	2.46	0.089
Conception Date	PT3	107	57.55	2.29	119	59.51	2.54	0.571
Conception Date	PT4	95	32.34	3.04	100	26.50	2.83	0.161

		VACCINE		CONTROL		
		n	%	n	%	p
Corpus Luteum (% present)	PT1	132	84.8	135	87.4	0.545
Pregnant (% positive)	PT2	124	76.6	125	80.0	0.517
	PT3	122	87.7	128	93.0	0.158
	PT4	101	94.1	115	87.0	0.079
Lactating (% wet)	PT3	122	81.1	128	75.8	0.303
	PT4	101	98.0	115	95.7	0.327
Rollcall (% present)	PT2	134	92.5	138	90.6	0.562
	PT3	134	91.0	138	94.2	0.318
	PT4	134	75.4	138	83.3	0.105

Table 2b: Comparison of Vaccine and Control Groups for Females 2003-09 **NW Downs -1 2004 Cohort**

		VACCINE			CONTROL			
		n	**mean**	**SE**	**n**	**mean**	**SE**	**p**
Weight	Induction	182	211.52	1.89	198	209.90	1.96	0.555
	PT1	182	353.43	2.42	197	352.13	2.18	0.689
	PT2	176	399.69	2.66	193	397.31	2.39	0.505
	PT3	132	489.86	4.74	144	485.59	4.75	0.525
	PT4	109	542.15	5.61	111	528.36	5.00	0.068
ADG	Induction-PT1	182	0.357	0.005	197	0.357	0.004	0.993
BCS	PT1	182	3.63	0.02	197	3.70	0.02	**0.011**
	PT2	176	3.22	0.04	189	3.19	0.03	0.607
	PT3	132	4.07	0.03	144	4.08	0.03	0.783
	PT4	109	4.14	0.03	111	4.10	0.03	0.257
Inter-conception Interval	PT2-3	112	337.85	3.60	119	348.08	4.13	0.064
	PT3-4	94	375.81	3.96	97	370.32	4.34	0.352
Conception Date	PT2	152	72.00	2.85	171	71.62	2.83	0.926
Conception Date	PT3	116	37.58	2.93	123	45.92	2.95	**0.046**
Conception Date	PT4	100	50.89	2.26	103	53.27	2.38	0.469

		VACCINE		CONTROL		
		n	**%**	**n**	**%**	**p**
Corpus Luteum (% present)	PT1	182	99.5	197	99.5	0.955
Pregnant (% positive)	PT2	176	86.4	193	88.6	0.516
	PT3	132	87.9	144	85.4	0.549
	PT4	109	92.7	111	92.8	0.970
Lactating (% wet)	PT3	132	91.7	144	89.6	0.554
	PT4	109	93.6	111	97.3	0.185
Rollcall (% present)	PT2	182	96.7	198	97.5	0.654
	PT3	141	93.6	156	92.3	0.660
	PT4	141	77.3	156	71.2	0.227

Table 2c: Comparison of Vaccine and Control Groups for Females 2003-09 **Gulf-1 2004 Cohort**

		VACCINE			CONTROL			
		n	mean	SE	n	mean	SE	p
Weight	Induction	294	209.30	2.02	287	210.12	1.91	0.767
	PT1	291	320.07	2.22	286	322.20	2.17	0.493
	PT2	285	466.50	3.64	277	471.99	3.96	0.307
	PT3	252	437.40	3.54	256	438.53	3.37	0.817
	PT4	232	477.46	4.03	243	477.01	3.68	0.934
ADG	Induction-PT1	291	0.304	0.007	286	0.308	0.007	0.689
BCS	PT1	291	3.61	0.01	285	3.63	0.02	0.444
	PT2	285	4.65	0.04	277	4.66	0.04	0.712
	PT3	253	4.11	0.02	258	4.11	0.02	0.957
	PT4	234	3.99	0.03	246	3.91	0.03	**0.040**
Inter-conception Interval	PT2-3	107	383.08	4.57	130	376.73	4.01	0.296
	PT3-4	118	367.68	3.60	139	376.22	3.58	0.096
Conception Date	PT2	198	65.45	5.08	211	51.96	4.37	**0.044**
Conception Date	PT3	171	42.61	3.38	185	35.64	2.81	0.111
Conception Date	PT4	168	37.63	2.67	181	43.27	2.38	0.115

		VACCINE		CONTROL		
		n	%	n	%	p
Corpus Luteum (% present)	PT1	289	94.8	285	93.3	0.454
Pregnant (% positive)	PT2	287	69.0	284	74.3	0.160
	PT3	259	67.6	259	74.5	0.081
	PT4	234	72.2	246	75.2	0.458
Lactating (% wet)	PT3	257	60.7	259	61.8	0.802
	PT4	235	77.9	246	80.9	0.413
Rollcall (% present)	PT2	294	97.6	287	99.0	0.216
	PT3	275	91.6	276	92.8	0.625
	PT4	275	85.5	276	89.1	0.195

Table 2d: Comparison of Vaccine and Control Groups for Females 2003-09 **NW Downs-1 2005 Cohort**

		VACCINE			CONTROL			
		n	mean	SE	n	mean	SE	p
Weight	Induction	139	236.39	1.83	145	241.97	2.05	**0.044**
	PT1	137	371.31	2.65	142	374.58	2.75	0.393
	PT2	132	515.17	3.34	143	518.58	3.59	0.490
	PT3	117	549.04	5.28	121	560.36	5.74	0.149
	PT4	89	529.22	6.46	96	531.42	6.09	0.805
ADG	Induction-PT1	137	0.574	0.010	142	0.563	0.010	0.450
BCS	PT1							
	PT2	132	4.02	0.02	143	4.02	0.03	0.799
	PT3	117	4.17	0.02	120	4.21	0.03	0.282
	PT4	89	3.78	0.04	96	3.72	0.03	0.258
Inter-conception Interval	PT2-3	90	395.13	4.06	104	393.88	4.43	0.838
	PT3-4	74	365.67	5.65	82	355.19	4.30	0.138
Conception Date	PT2	112	17.86	2.96	121	18.77	3.15	0.834
Conception Date	PT3	105	46.75	2.72	113	47.63	2.60	0.815
Conception Date	PT4	79	48.94	3.74	90	40.16	2.82	0.059

		VACCINE		CONTROL		
		n	%	n	%	p
Corpus Luteum (% present)	PT1	137	100.0	142	100.0	
Pregnant (% positive)	PT2	132	88.6	143	87.4	0.755
	PT3	117	89.7	122	92.6	0.432
	PT4	90	87.8	96	93.8	0.158
Lactating (% wet)	PT3	117	86.3	121	81.8	0.343
	PT4	90	93.3	96	96.9	0.261
Rollcall (% present)	PT2	139	95.0	145	98.6	0.079
	PT3	130	90.0	135	89.6	0.921
	PT4	130	69.2	135	71.1	0.738

Table 2e: Comparison of Vaccine and Control Groups for Females 2003-09 **Gulf-1 2005 Cohort**

		VACCINE			CONTROL			
		n	mean	SE	n	mean	SE	p
Weight	Induction	287	203.68	1.42	275	206.66	1.50	0.149
	PT1	286	377.88	1.78	273	377.96	2.02	0.977
	PT2	135	452.89	5.09	142	453.06	5.03	0.981
	PT3	232	434.78	3.74	208	427.16	3.80	0.155
	PT4	230	462.87	3.84	214	466.16	3.89	0.547
ADG	Induction-PT1	286	0.479	0.004	273	0.471	0.004	0.183
BCS	PT1	286	3.89	0.03	274	3.87	0.03	0.617
	PT2	265	3.75	0.03	246	3.76	0.03	0.623
	PT3	233	3.67	0.03	211	3.60	0.03	0.106
	PT4	231	3.28	0.03	216	3.27	0.03	0.880
Inter-conception Interval	PT2-3	104	391.49	4.75	81	393.00	4.50	0.821
	PT3-4	104	368.24	4.97	81	372.21	5.55	0.596
Conception Date	PT2	148	30.76	3.91	132	28.28	4.16	0.665
Conception Date	PT3	155	46.79	3.26	124	44.78	3.23	0.667
Conception Date	PT4	151	44.39	3.57	132	45.11	3.69	0.889

		VACCINE		CONTROL		
		n	%	n	%	p
Corpus Luteum (% present)	PT1	285	99.6	274	99.6	0.978
Pregnant (% positive)	PT2	265	71.7	246	70.7	0.809
	PT3	233	71.7	212	63.7	0.071
	PT4	231	64.9	217	60.8	0.369
Lactating (% wet)	PT3	233	71.7	212	75.5	0.365
	PT4	233	79.4	217	80.2	0.836
Rollcall (% present)	PT2	287	92.0	275	89.8	0.364
	PT3	272	85.7	253	83.8	0.552
	PT4	272	85.7	253	85.8	0.972

Table 2f: Comparison of Vaccine and Control Groups for Females 2003-09 **Gulf-3 2005 Cohort**

		VACCINE			CONTROL			
		n	mean	SE	n	mean	SE	p
Weight	Induction	180	200.15	2.21	174	196.12	2.36	0.213
	PT1	180	330.13	2.99	173	331.33	3.05	0.779
	PT2							
	PT3							
	PT4							
ADG	Induction-PT1	180	0.286	0.006	173	0.297	0.006	0.170
BCS	PT1	179	2.95	0.03	172	2.95	0.03	0.936
	PT2	120	3.68	0.03	137	3.72	0.03	0.235
	PT3	30	3.40	0.10	47	3.32	0.06	0.469
	PT4							
Inter-conception Interval	PT2-3	8	377.00	9.92	15	401.24	15.14	0.286
	PT3-4							
Conception Date	PT2	70	57.22	5.07	88	48.62	4.09	0.184
Conception Date	PT3	9	65.90	13.36	16	61.48	12.13	0.819
Conception Date	PT4							

		VACCINE		CONTROL		
		n	%	n	%	p
Corpus Luteum (% present)	PT1	180	68.3	172	64.0	0.385
Pregnant (% positive)	PT2	121	59.5	138	66.7	0.233
	PT3	30	33.3	47	36.2	0.799
	PT4					
Lactating (% wet)	PT3	30	73.3	47	78.7	0.586
	PT4					
Rollcall (% present)	PT2	180	98.9	174	100.0	0.163
	PT3	57	52.6	74	63.5	0.210
	PT4					

Table 2g: Comparison of Vaccine and Control Groups for Females 2003-09 **Barkly-3 2005 Cohort**

		VACCINE			CONTROL			
		n	**mean**	**SE**	**n**	**mean**	**SE**	**p**
Weight	Induction	161	203.08	2.50	156	201.56	2.53	0.670
	PT1	156	433.08	4.28	153	429.32	4.13	0.527
	PT2	156	440.26	5.71	150	432.15	6.34	0.342
	PT3	74	463.39	8.18	70	464.97	9.40	0.899
	PT4	69	483.45	8.05	59	483.66	10.35	0.987
ADG	Induction-PT1	156	0.441	0.008	153	0.434	0.006	0.505
BCS	PT1	156	3.86	0.03	153	3.82	0.03	0.348
	PT2	156	3.55	0.04	150	3.54	0.04	0.878
	PT3	131	4.05	0.04	119	4.03	0.04	0.845
	PT4	70	3.47	0.04	64	3.52	0.06	0.459
Inter-conception Interval	PT2-3	21	349.10	12.56	15	331.56	12.50	0.343
	PT3-4	12	393.45	20.96	12	373.21	18.73	0.479
Conception Date	PT2	84	91.21	4.43	79	92.08	5.03	0.897
Conception Date	PT3	35	41.23	7.83	28	32.70	7.98	0.453
Conception Date	PT4	28	39.31	12.16	28	19.77	12.51	0.268

		VACCINE		CONTROL		
		n	**%**	**n**	**%**	p
Corpus Luteum (% present)	PT1	140	97.9	136	97.1	0.673
Pregnant (% positive)	PT2	156	53.8	150	52.7	0.836
	PT3	131	49.6	120	43.3	0.319
	PT4	74	37.8	67	41.8	0.632
Lactating (% wet)	PT3	131	58.8	119	58.8	0.994
	PT4	74	94.6	67	83.6	**0.034**
Rollcall (% present)	PT2	161	96.9	156	96.2	0.719
	PT3	161	81.4	156	76.9	0.330
	PT4	161	46.0	156	42.9	0.589

10.4 Summary of all measured reproductive and growth performance for females by cohort

		NW Downs-1 03		NW Downs-1 04		Gulf-1 04		NW Downs-1 05		Gulf -1 05		Gulf-3 05		Barkly-3 05	
		n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean
Weight (kg)	Induction	272	208.41	380	210.65	581	209.71	284	239.22	562	205.15	354	198.18	317	202.34
	PT1	268	321.66	379	352.75	577	321.13	279	372.97	559	377.93	353	330.72	309	431.22
	PT2	249	397.80	369	398.45	562	469.21	275	516.95	277	452.98			306	436.28
	PT3	252	431.66	276	487.62	508	437.96	238	554.79	440	431.20			144	464.17
	PT4	216	466.96	220	535.19	475	477.22	185	530.35	444	464.47			128	483.57
ADG (kg/day)	Induction-PT1	268	0.23	379	0.36	577	0.31	279	0.57	559	0.48	353	0.29	309	0.44
BCS (Scale 1 – 5)	PT1	268	3.32	379	3.66	576	3.62			560	3.88	351	2.95	309	3.84
	PT2	248	3.99	365	3.20	562	4.66	275	4.02	511	3.76	257	3.70	306	3.55
	PT3	248	3.85	276	4.08	511	4.11	237	4.19	444	3.64	77	3.35	250	4.04
	PT4	216	3.88	220	4.12	480	3.95	185	3.75	447	3.27			134	3.50
Inter-conception Interval (d)	PT2-3	168	380.29	231	343.10	237	379.55	194	394.43	185	392.21	23	392.66	36	341.87
	PT3-4	192	340.32	191	373.03	257	372.36	156	360.20	185	369.89			24	383.33
Conception Date *	PT2	195	47.11	323	71.95	409	58.57	233	18.43	280	29.45	158	52.72	163	91.55
Conception Date *	PT3	226	58.60	239	41.88	356	39.00	218	47.22	279	45.85	25	63.18	63	37.40
Conception Date *	PT4	195	29.35	203	52.11	349	40.57	169	44.29	283	44.70			56	29.54

		NW Downs-1 03		NW Downs-1 04		Gulf-1 04		NW Downs-1 05		Gulf -1 05		Gulf-3 05		Barkly-3 05	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
Corpus Luteum (% present)	PT1	267	86.1	379	99.5	574	94.1	279	100.0	559	99.6	352	66.2	276	97.5
Pregnant	PT2	249	78.3	369	87.5	571	71.6	275	88.0	511	71.2	259	63.3	306	53.3
(% positive)	PT3	250	90.4	276	86.6	518	71.0	239	91.2	445	67.9	77	35.1	251	46.6
	PT4	216	90.3	220	92.7	480	73.8	186	90.9	448	62.9			141	39.7
Lactating (% wet)	PT3	250	78.4	276	90.6	516	61.2	238	84.0	445	73.5	77	76.6	250	58.8
	PT4	216	96.8	220	95.5	481	79.4	186	95.2	450	79.8			141	89.4
Rollcall	PT2	272	91.5	380	97.1	581	98.3	284	96.8	562	90.9	354	99.4	317	96.5
(% present)	PT3	272	92.6	297	92.9	551	92.2	265	89.8	525	84.8	131	58.8	317	79.2
	PT4	272	79.4	297	74.1	551	87.3	265	70.2	525	85.7			317	44.5

* Days from 15 December

10.5 Comparison of progeny birth, growth and weaning data from two Cohort groups for North West Downs 1 property.

		NW Downs-1 2003		NW Downs-1 2005		Males		Females	
		n	mean	n	mean	n	mean	n	mean
progeny 1	Birth Weight (kg)	156	34.65	192	29.09	162	32.81	186	30.93
	Birth Date (d from Dec 15)	156	289.86	192	283.54	162	290.23	186	283.17
	Weaning Weight (kg)	147	227.94	172	259.32	146	250.13	173	237.13
	ADG (kg/d)	147	0.831	172	1.021	146	0.963	173	0.889
progeny 2	Birth Weight	203	35.27	168	35.81	186	36.97	185	34.12
	Birth Date	203	295.55	168	292.85	186	294.46	185	293.94
	Weaning Weight	196	225.81	160	243.73	176	247.23	180	222.31
	ADG	196	0.793	160	0.972	176	0.931	180	0.834
	Inter-calf Interval	129	370.69	149	374.76				
progeny 3	Birth Weight	172	30.87			82	31.88	90	29.96
	Birth Date	172	285.92			82	285.72	90	286.11
	Weaning Weight	167	265.72			81	278.00	86	254.18
	ADG	167	1.055			81	1.106	86	1.008
	Inter-calf Interval	161	355.88						
progeny 4	Birth Weight	144	35.69			79	35.95	65	35.39
	Birth Date	144	287.84			79	290.53	65	284.57
	Weaning Weight	144	243.32			79	248.50	65	237.07
	ADG	144	0.946			79	0.980	65	0.905
	Inter-calf Interval	133	366.86						

10.6 Summary of number of calves raised per cow for all female Cohorts during the project, 2003 - 2009

		NW Downs-1 03	NW Downs-1 04	Gulf-1 04	NW Downs-1 05	Gulf -1 05	Gulf-3 05	Barkly-3 05
		%	%	%	%	%	%	%
For pregtests 1-4	N	272	380	581	284	562		317
	0 calves	5.5	31.1	9.5	21.1	15.1		11.0
	1 calf	12.5	15.8	26.7	21.8	31.4		35.3
	2 calves	59.6	52.4	51.1	56.7	41.9		34.1
	3 calves	19.9	0.8	11.5	0.4	11.5		16.1
	4 calves	2.6	0.0	1.2	0.0	0.0		3.5
For pregtests 3-4	N	272	380	581	284	562		317
	0 calves	9.2	31.1	15.7	23.9	22.6		39.7
	1 calf	32.7	16.8	48.5	19.4	33.0		34.4
	2 calves	58.1	52.1	35.8	56.7	44.4		25.9

10.7 Stratified Analysis of Calves Raised for Each Cohort of Females

Table 4a: Comparison of Vaccine and Control Groups for Calves Raised 2003-09 for **NW Downs-1 03**

		VACCINE	CONTROL	
		%	%	p
For pregtests 1-4	N	134	138	
	0 calves	5.2	5.8	0.916
	1 calf	13.4	11.6	
	2 calves	61.2	58.0	
	3 calves	17.9	21.7	
	4 calves	2.2	2.9	
For pregtests 3-4	N	134	138	
	0 calves	11.2	7.2	0.396
	1 calf	29.9	35.5	
	2 calves	59.0	57.2	

Table 4b: Comparison of Vaccine and Control Groups for Calves Raised 2003-09 for **NW Downs -1 04**

		VACCINE	CONTROL	
		%	%	p
For pregtests 1-4	N	182	198	
	0 calves	30.2	31.8	0.838
	1 calf	14.8	16.7	
	2 calves	53.8	51.0	
	3 calves	1.1	0.5	
	4 calves	0.0	0.0	
For pregtests 3-4	N	182	198	
	0 calves	30.2	31.8	0.945
	1 calf	17.0	16.7	
	2 calves	52.7	51.5	

Table 4c: Comparison of Vaccine and Control Groups for Calves Raised 2003-09 for **Gulf-1 04**

		VACCINE	CONTROL	
		%	%	p
For pregtests 1-4	N	294	287	
	0 calves	10.9	8.0	0.228
	1 calf	27.9	25.4	
	2 calves	46.6	55.7	
	3 calves	13.3	9.8	
	4 calves	1.4	1.0	
For pregtests 3-4	N	294	287	
	0 calves	19.0	12.2	0.076
	1 calf	46.6	50.5	
	2 calves	34.4	37.3	

Table 4d: Comparison of Vaccine and Control Groups for Calves Raised 2003-09 for **NW Downs-1 05**

		VACCINE	CONTROL	
		%	%	p
For pregtests 1-4	N	139	145	
	0 calves	20.9	21.4	0.778
	1 calf	22.3	21.4	
	2 calves	56.1	57.2	
	3 calves	0.7	0.0	
	4 calves	0.0	0.0	
For pregtests 3-4	N	139	145	
	0 calves	23.0	24.8	0.807
	1 calf	20.9	17.9	
	2 calves	56.1	57.2	

Table 4e: Comparison of Vaccine and Control Groups for Calves Raised 2003-09 for **Gulf-1 05**

		VACCINE	CONTROL	
		%	%	p
For pregtests 1-4	N	287	275	
	0 calves	12.8	17.5	0.210
	1 calf	34.0	28.7	
	2 calves	43.1	40.7	
	3 calves	10.0	13.1	
	4 calves	0.0	0.0	
For pregtests 3-4	N	287	275	
	0 calves	20.8	24.4	0.259
	1 calf	36.1	29.8	
	2 calves	43.1	45.8	

Table 4f: Comparison of Vaccine and Control Groups for Calves Raised 2003-09 for **Barkly-1 05**

		VACCINE	CONTROL	
		%	%	p
For pregtests 1-4	N	161	156	
	0 calves	8.1	14.1	0.444
	1 calf	36.6	34.0	
	2 calves	35.4	32.7	
	3 calves	15.5	16.7	
	4 calves	4.3	2.6	
For pregtests 3-4	N	161	156	
	0 calves	36.6	42.9	0.487
	1 calf	35.4	33.3	
	2 calves	28.0	23.7	

10.8 Mixed Effects Models for steer Average Daily Gain for Grower, Backgrounding and Feedlot periods

Table 10.6.1: Results of mixed effects model for grower period ADG

		Coef	se	z	p-value	95% CI Lower	Upper
Group	**Control**	**reference**					
	Vacc	0.003	0.004	0.77	0.44	-0.005	0.012
Year	**2003**	reference					
	2004	-0.071	0.014	-4.96	<0.01	-0.099	-0.043
	2005	-0.141	0.031	-4.51	<0.01	-0.202	-0.079
	2006	-0.086	0.031	-2.74	0.006	-0.148	-0.025
Origin	**Barkly**	reference					
	Gulf	0.022	0.030	0.75	0.45	-0.036	0.081
	NW Downs	0.093	0.032	2.87	0.004	0.030	0.156
Destination	**Grow_BG_FL**	reference					
	Grow_ES	0.022	0.017	1.3	0.19	-0.011	0.056
	Grow_FL	0.056	0.008	7.29	<0.01	0.041	0.071
	Grow_Slaught	-0.136	0.020	-6.94	<0.01	-0.174	-0.097
	Unspecified	-0.032	0.053	-0.61	0.55	-0.137	0.072
Intercept		0.508	0.025	20.12	<0.01	0.458	0.557
Random effects		Variance	se	95% CI Lower	Upper		
Property level		0.00123	0.00090	0.00029	0.00520		
Residual error		0.01106	0.00032	0.01045	0.01171		

Table 10.6.2: Results from mixed model for backgrounding period ADG

		Coef	se	z	p-value	95% CI	
						Lower	Upper
Group	Control	reference					
	Vacc	0.0000	0.0157	0	0.998	-0.0309	0.0308
Year	2003	reference					
	2004	-0.4174	0.0367	-11.38	<0.001	-0.4893	-0.3455
	2005	-0.1260	0.0321	-3.92	<0.001	-0.1889	-0.0630
	2006	-0.2766	0.0308	-8.98	<0.001	-0.3370	-0.2162
Origin	Barkly	reference					
	Gulf	0.3563	0.0272	13.1	<0.001	0.3030	0.4097
	NW Downs	0.0499	0.0191	2.61	0.009	0.0124	0.0874
Intercept		0.5748	0.0290	19.84	<0.001	0.5181	0.6316

Random effects	Variance	se	95% CI	
			Lower	Upper
Property level	4.62E-24	1.09E-22	3.55E-44	0.000601
Residual error	6.25E-02	2.78E-03	5.73E-02	0.068198

Table 10.6.3: Results of mixed model for feedlot period ADG

		Coef	se	z	p-value	95% CI	
						Lower	Upper
Group	Control	reference					
	Vacc	0.0230	0.0194	1.19	0.234	-0.015	0.061
Year	2003						
	2004	-0.1269	0.0657	-1.93	0.054	-0.256	0.002
	2005	-0.2068	0.0573	-3.61	<0.01	-0.319	-0.094
	2006	-0.2177	0.0599	-3.63	<0.01	-0.335	-0.100
Origin	Barkly						
	Gulf	0.2721	0.3845	0.71	0.479	-0.482	1.026
	NW Downs	0.0314	0.0873	0.36	0.719	-0.140	0.202
Destination	Grow_BG_FL						
	Grow_FL	0.1195	0.0370	3.23	0.001	0.047	0.192
	Unspecified	0.0622	0.0835	0.75	0.456	-0.101	0.226
Days on feed	Bet90-120						
	More than 120	-0.4697	0.1062	-4.42	<0.01	-0.678	-0.262
	UpTo80	-0.3754	0.1110	-3.38	0.001	-0.593	-0.158
Intercept		2.2063	0.2474	8.92	<0.01	1.722	2.691

Random effects		Variance	se	95% CI	
				Lower	Upper
Property level		0.1691	0.1457	0.0312	0.9154
Residual error		0.1805	0.0058	0.1695	0.1923

10.9 Mixed Effects Models of Meatworks data from steers finishing in the feedlot

Table 10.7.1: Results from mixed effects model for HSCW from steers slaughtered after feedlot period

		Coef	se	z	p-value	95% CI	
						Lower	Upper
Group	**Control**	**reference**					
	Vacc	0.741	1.237	0.6	0.550	-1.683	3.167
Year	**2003**	reference					
	2004	-24.625	7.428	-3.32	0.001	-39.185	-10.066
	2005	-4.944	6.989	-0.71	0.480	-18.644	8.756
	2006	-2.111	6.905	-0.31	0.760	-15.644	11.422
Origin	**Barkly**	reference					
	Gulf	-9.098	14.408	-0.63	0.530	-37.338	19.142
	NW Downs	-22.730	4.897	-4.64	<0.001	-32.325	-13.127
Days on feed	**Bet90-120**	reference					
	More than 120	1.507	10.458	0.14	0.900	-18.990	22.010
	UpTo80	-79.980	10.889	-7.35	<0.001	-101.330	-58.650
Intercept		359.620	10.946	32.85	<0.001	338.167	381.075

Random effects	Variance	se	95% CI	
			Lower	Upper
Property level	180.07	160.16	31.50	1029.28
Residual error	704.22	23.25	660.10	751.28