On farm

Tick Fever in the Northern Beef Industry:

Prevalence, Cost/ Benefit of Vaccination, Considerations for Genotypes, Livestock Management and Live Cattle Export

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EXECUTIVE SUMMARY

Cattle producers in Northern Australia need more information on the economic significance of tick fever in extensive cattle herds and the benefit to cost ratio of vaccination programs. While well documented for *Bos taurus* cattle, the factors that influence the eventual outcome of tick fever infection are not well understood for *Bos indicus* cattle and their crosses. Meat and Livestock Australia was approached by key northern producers to help address this deficiency and DAQ107 was developed and carried out by QDPI. This project aims to present the information that is available and provide new information to assess the risk of losses due to tick fever in northern herds and to define the benefit to cost of tick fever vaccination.

Table of Contents

1. METHODOLOGY

The project established the seroprevalence of the three tick fever parasites (A marginale, B bovis and B bigemina) in cattle by cross-sectional surveys on cattle properties in north-west Queensland over a period of 3 years. B indicus and crossbred cattle from north-west Queensland were moved to a highly endemic area and monitored to estimate losses due to tick fever in a worst case scenario. The information from the surveys and natural exposure as well as expert opinion was used in a spreadsheet model to produce disease prediction and production loss information linked to discounted cashflow analysis.

2. KEY FINDINGS

Endemic stability was not observed in any of the shires surveyed for any of the 3 tick fever parasites and large numbers of cattle in the region are naive for the three tick fever parasites. The exposure trials showed that B indicus cattle are very resistant to both babesia parasites, but they and crossbred cattle are very susceptible to A marginale. Crossbred cattle are resistant to B bigemina but B bovis will cause significant mortalities in crossbreds. Increasing the B taurus content of cattle will substantially increase the risk of tick fever losses.

The spreadsheet model to predict the benefit cost of vaccination has been tested using this information. The producer’s attitude to risk, as well as long-term view of markets and breed structure have to be considered, but the model allows producers to assess the risk more accurately for their particular herd and therefore make more informed decisions on tick fever control.

3. RECOMMENDATIONS FOR CONTROL OF TICK FEVER IN NORTHERN AUSTRALIA

3.1 Tick fever vaccination

In balance, it is our opinion that northern cattle producers should carry out an annual weaner tick fever vaccination program. This is because of:

- low natural transmission and therefore poor naturally acquired immunity;
- the need to protect overseas live cattle market access which can be denied for 6 to 12 months after a tick fever outbreak on individual properties;
- high susceptibility of B indicus and cross-bred cattle to anaplasmosis;
- the trend to increase the B taurus herd content.

The bivalent vaccine (B bovis and A centrale) can be considered for B indicus cattle, but to ensure broad-spectrum protection, trivalent vaccine (B bovis, B bigemina and A centrale) should be used especially in cross-breds and B taurus cattle.

3.2 Quality assurance system

Currently, when live cattle export protocols require tick fever vaccination it has to be given near the time of shipment. Because of the age of and added stress to these cattle they are more likely to have severe vaccine reactions during shipping, quarantine or feedlotting and this may impact on their performance. These protocols should be amended to accept vaccination at weaning. This age group has far fewer vaccine reactions and there is the added benefits of protection from weaning to shipment and improved cattle quality at the destination. An on-farm quality assurance system that will ensure proper use of the vaccine and identification of immunised cattle that is also accepted by the importing country would be required, but the benefits would be considerable.

4. APPLICATION

4.1 Vaccination

The Tick Fever Research Centre (TFRC) produces tick fever vaccine that is readily available for use in extensive areas. Producers must assess the risk of tick fever from the information available and make a decision on vaccination that is consistent with their own attitude to risk. If supply of chilled vaccine is a problem in the more remote areas they can use the frozen tick fever vaccine which has a five-year shelf life stored in liquid nitrogen.

4.2 Decision support service

Using the information generated from this project and the spreadsheet model it is possible to offer a decision support service tailored to individual herds. We suggest that this be operated on a fee for service basis which would entail the serological testing of approximately 50 weaner age cattle from a herd or in the case of larger properties a number of subgroups to adequately assess the current seroprevalence on the property. This information along with herd data would then be entered into the model to estimate the return on vaccination costs. Various scenarios looking at changes in the risk over the 8-year outlook of the model can be demonstrated to allow a more complete picture and give some information on the sensitivity of the output to scenario changes.

4.3 Sentinel herds

Annual serological tests on weaners from ‘sentinel herds’ in specific shires of interest would give an estimate of changes in risk over time. This information processed through the spreadsheet model could be used to advise producers in a shire on possible changes in tick fever risk.

5. GENERAL DETAILS

Start Date: 01 July 1995 (Actual January 1996)
End Dates - Proposed: 31 December 1998 Actual: 31 March 1999

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6. OBJECTIVES

Perform survey of the current prevalence of the three tick fever parasites (A marginale, B bovis and B bigemina) in cattle on a cross section of properties in northern cattle industry over a period of 3 years.

Estimate the losses due to tick fever in the breeds currently utilised on selected properties in the northern cattle industry.

Provide the northern producers with information that will allow them to make rational decisions regarding breed type, vaccination strategy, tick control and cattle movements in relation to the management of tick fever.

6.1 Expected outcomes

The project will yield information on tick fever in North Queensland as follows:

- Distribution
- Spread
- Immune status of herds (Export quality assurance)
- Genotype Susceptibility
- Cost/Benefit analysis of control

This should lead to:

- Better understanding of conditions under which tick fever can be maintained in N Qld (effect of genotype, location, droughts) and this information can be extrapolated to others areas of Northern Australia.

- Estimation of potential losses if tick fever occurs in Northern Australia

- Assessment of risk in existing breeds in Northern Australia

7. BACKGROUND

The cattle tick, Boophilus microplus, and tick fever parasites, Babesia bovis, Babesia bigemina and Anaplasma marginale are endemic in Northern Australia. However, cattle tick numbers have evidently been declining in north-west Queensland in recent years. Cattle ticks were not seen on many of the properties within the officially tick infested parts of north-west Queensland from 1990 to 1996 (AC Rayner, unpublished observations). Limited serological surveys in north-west Queensland have failed to find evidence of Babesia transmission on several properties previously known to have cattle tick (Queensland Department of Primary Industries structured surveillance 1990 to 1995, unpublished). This reduction in tick numbers is presumed to be due to the combined effects of resistant cattle and recent droughts. Two surveys (O'Rourke et al 1992; Bock et al 1995) showed that virtually all beef producers in far Northern Australia are using cattle with greater than 3/8 Bos indicus infusion.

Mahoney et al (1981) in a study comparing B bovis transmission in Bos taurus and cattle with 3/8 to ½ B indicus infusion in south-east Queensland concluded that, in an environment unfavourable for tick survival, stocking with crossbred cattle would lead to the virtual disappearance of the ticks. However, if the area was then occupied with pure B taurus cattle their low tick resistance more than compensated for environmental effects on the tick reproduction and the tick population flourished. Mahoney et al (1981) further predicted that tick resistance in crossbred cattle combined with the finding that they produce fewer B bovis infected tick larvae under similar levels of tick infestation to B taurus cattle might lead to the eventual disappearance of this parasite from crossbred herds.

Few producers on extensive cattle producing enterprises in Northern Australia vaccinate their herds against tick fever (O'Rourke et al 1992; Bock et al 1995). These producers are posing a number of questions that need to be addressed: (a) what will be the impact of tick fever on different breeds of cattle if ticks move back into these areas? (b) are the cross-bred cattle being exported to South-east Asia sufficiently resistant or immune to withstand the possible tick fever challenge levels at their destination (c) what is the cost/benefit of control options in different cattle breeds in the region?

Simply put, they are asking: is tick fever of economic significance in extensive cattle herds in north-west Queensland, Northern Territory and Kimberley's region and should producers be vaccinating? The factors that can influence the eventual outcome for tick fever infection is fairly well documented for Bos taurus cattle. However, there are deficiencies in our knowledge of tick fever in Bos indicus cattle and their crosses. Meat and Livestock Australia was approached by key northern producers to help address the issues and DAQ107 was developed. The aim of this project is to present the information that is available and provide new information to assess the likely risk of losses due to tick fever in northern herds and the question of the need for vaccination.

7.1 Field evidence of tick fever in NW Queensland

The QDPI maintains records of all laboratory submissions and diagnoses with an on-line information system (LOIS). These laboratory records show only 11 outbreaks of tick fever were confirmed in north-west Queensland from January 1990 to December 1998.
The histories are given in Table 1 and they indicate that the parasites are present, but there are very few submissions.

Table 1: Laboratory records from January 1990 to December 1998 showing only 11 outbreaks of tick fever confirmed in north-west Queensland by QDPI laboratories.

No.	Shire	Aetiology	At risk	No sick	No dead	Breed	Sex
1	Burke	*A marginale*	2700	?	200	*B indicus*	female
2	Burke	*B bigemina*	?	1	0	*B indicus*	female
3	Carpenteria	*B bovis*	960	?	30	*B indicus*	female
4	Carpenteria	*B bovis*	40	1	2	Charolais	male
5	Carpenteria	*B bigemina*	?	1	0	Santa	male
6	Carpenteria	*B bovis*	800	90	50	*B indicus* cross	female
7	McKinley	*B bigemina*	1600	80	35	Santa and Braford	female
8	Dalrymple	*B bovis*	?	?	?	*B indicus*	female
9	Dalrymple	*A marginale*	?	?	?	*B indicus*	female
10	Dalrymple	*B bovis*	800	1	?	Shorthorn	male
11	Dalrymple	*B bovis*	90	3	2	X-bred	steers

Outbreak 3 involved cattle being mustered and held in a bullock paddock as part of a tuberculosis destocking program. Cases occurred in the bullock paddock, on route to a feedlot in the Beaudesert area and in the feedlot. Outbreak 4 is interesting because it involved naive Charolais bulls introduced to a property in Carpenteria shire that ran high content *B indicus* cattle. The manager had not noticed ticks on the property for several years, but with the arrival of the *Bos taurus* bulls ticks were soon noticed and so was tick fever. Outbreak 6 was in crossbred heifers and both *B bovis* and *A marginale* were confirmed in some cases with *B bovis* predominating. Later on Salmonellosis was confirmed in cohorts being fed in yards so the mortalities may not all be due to tick fever. Outbreak 7 was in cattle vaccinated with bivalent vaccine that were droving the stock routes having originated from a cattle tick free area. As most of these outbreaks were only confirmed because a stock inspector or company veterinarian was on hand, it is also probable that on these extensive properties many more limited outbreaks are occurring which remain undetected. A similar situation is apparent in the tick infested areas of Western Australia and the Northern Territory (Table 2 and 3).

Table 2: Laboratory records from January 1990 to December 1998 showing only 10 outbreaks of tick fever confirmed in the Kimberleys region of Western Australia by Agriculture WA laboratories (From Dr Jeremy Allan personal communication)

No.	Region	Aetiology	At risk	No sick	No dead	Breed	Sex
1	West Kimberley	*B bigemina*	168	0	2	Shorthorn	steers
2	East Kimberley	*Babesia spp*	158	?	14	*B indicus*	steers
3	Kununurra	*B bovis*	300	1	3	Friesian	female
4	Kununurra	*B bovis*	700	3	3	?	steers
5	Kununurra	*B bigemina*	700	3	1	*B indicus*	steers
6	Kununurra	*B bigemina*	700	4	2	*B indicus*	female
7	Kununurra	*B bigemina*	700	5	4	*B indicus*	female
8	West Kimberley	*B bovis*	700	7	20	*B indicus*	steers
9	West Kimberley	*B bovis*	720	25	20	Shorthorn	steers
11	West Kimberley	*B bovis*	120	3	3	Shorthorn	female

Table 3: Laboratory records from January 1995 to December 1998 showing 5 outbreaks of tick fever confirmed in the Northern Territory by DPIF laboratories
(From Dr Diana Pinch personal communication)

No.	Region	Aetiology	At risk	No sick	No dead	Breed	Sex
1	Darwin	*A marginale*	19	?	1	*B indicus* cross	steers
2	Darwin	*A marginale*	20	?	0	*B indicus* cross	female
3	Darwin	*A marginale*	150	?	9	*B indicus*	female
4	Katherine	*Babesia spp*	189	6	22	Shorthorn	steers
5	Katherine	*Babesia spp*	200	6	4	Friesian	female

Table 4 provides summary information from LOIS on tick fever outbreaks in the period from January 1990 to July 1996 for the whole of the State. It must be remembered that this is a biased dataset, many outbreaks go unconfirmed, data is not always complete and specimens are usually taken at the height of the outbreak so mortality figures are incomplete. However, the information gives some indication of the relative importance of the three tick fever parasites and indicates that, while far less common, tick fever outbreaks do occur in Bos indicus herds. Approximately 65% of cattle herds in the cattle tick infested area of Queensland are greater than 3/8 Bos indicus (O'Rourke et al 1992) and 77% of cases were from Brisbane/Moreton and Wide Bay/Burnett Australian Bureau of Statistics regions.

Table 4: All Tick fever cases confirmed at QDPI laboratories from 1/1/90 to 30/6/96

Breed	*A marginale*	*B bigemina*	*B bovis*	Grand Total	Percentage
Bos indicus	12	5	78	95	5.1%
Bos indicus cross	17	8	136	161	8.6%
Bos taurus	119	67	731	917	49.0%
mixed	3	5	44	52	2.8%
X-bred*	6	9	131	146	7.8%
unknown	49	47	404	500	26.7%
Grand Total	206	141	1524	1871	
Percentage	11.0%	7.5%	81.5%		

* It is not always known what submitters define as X-bred but a large percentage of these can be expected to have at least 3/8 *Bos indicus* infusion.

In a 1992 survey (Bock *et al* 1995) of Queensland beef producers in the *B microplus* infected area producers were asked to rank animal health factors reducing production in their herds based on mortality, reduced growth rates, carcass damage, treatment of disease and preventive measures. In North Queensland Botulism, Buffalo fly infestation, Ephemeral fever and plant poisoning were considered the most important problems. Tick fever did not rate as a problem in North Queensland.

7.2 Tick fever vaccine

The Tick Fever Research Centre (TFRC) of the Queensland Department of Primary Industries (QDPI) currently produces the only tick fever vaccines in Australia. Standardised vaccines are produced using splenectomised donor calves to obtain large numbers of parasites with predictable, lower levels of virulence (Callow and Dalgliesh 1980; Callow 1984). The vaccines are based on live attenuated strains of B bovis and B bigemina and on A centrale, a usually benign parasite that induces partial immunity to A marginale. The A centrale organism was imported from South Africa in 1934 (Rogers and Shiels 1979). The vaccines are supplied as chilled trivalent (B bovis, B bigemina and A centrale) or bivalent (B bovis and A centrale) vaccines. The chilled vaccine has a shelf-life of only 4 days. The production of chilled monovalent (B bovis) vaccine was discontinued in 1995. The vaccines are sold on a cost recovery basis.

TFRC also produces a frozen vaccine stored in liquid nitrogen and using glycerol as the cryoprotectant (Dalgliesh et al 1990). Vaccine is prepared by thawing cryovials in water at 37oC and then diluting the contents 1 in 5, in 1.5M glycerol PBS solution containing glucose and antibiotics. The contents of different vials can be mixed in the diluent to provide mono, bi or trivalent vaccine as desired. The vaccine has a shelf-life of 5 years in liquid nitrogen, but the thawed vaccine has to be used within 8 hours of thawing. Storage and handling requirements, the need to use the vaccine within 8 hours of thawing and the ready availability of easy-to-use chilled vaccine has restricted the frozen products acceptance in Australia. It is ideal for overseas markets and areas of Australia where the short shelf-life of chilled vaccine makes use of this product impracticable.

On the whole, B bovis vaccine consisting of one attenuated strain affords sound protection against field challenge. Results of a field trial on five Queensland properties suggested that vaccinated cattle were 15 to 16 times less likely to contract babesiosis than unvaccinated cattle (Emmerson et al 1976). Failures are uncommon and are likely to be due to an animal-related ability to mount an immune response, immunogenicity of the strain of B bovis used in the vaccine or vaccine viability (Bock et al 1995). Time-dependency of immunity does not seem to be a factor and is discussed in section 5.3.

Indications are that a single inoculation of B bigemina provides adequate to excellent protection against challenge.

A centrale provides partial, variable protection against A marginale challenge. Protection against challenge in Australia is adequate and use of the vaccine in this country is justified.

In a 1992 survey (Bock et al 1995) of Queensland beef producers in the B microplus infected area it was found that only 15% of North Queensland cattle producers used tick fever vaccine.

7.3 Factors involved in the occurrence of tick fever

7.3.1 Transmission of tick fever

Babesiosis

Both B bovis and B bigemina are transmitted transovarially with a further period of development taking place in the larval stage and maturation in the salivary glands after tick attachment before transmission to the host.

B bigemina

B bigemina is transmitted by late nymphal and adult stages of *B microplus* (Hoyte 1961). Transmission can occur throughout the rest of the nymphal stage and by adult females and males (Callow and Hoyte 1961; Riek 1964; Dalgliesh *et al* 1978). Interhost transfer of these ticks can lead to a much-shortened prepatent period (6-12 days), but it is usually 12-18 days after tick attachment (Callow 1984).

B bovis is transmitted by the larval stage of *Boophilus microplus* only and infective forms are present in the salivary glands 2-3 days after attachment (Riek 1966). This period can be even shorter if larval ticks are exposed to temperatures above 30^{o}C on the pasture (Dalgliesh *et al* 1979). Prepatent periods are generally 6-12 days and peak parasitaemias are reached about 3-5 days after that (Callow 1984). This means that unvaccinated naive cattle exposed to *B microplus* larvae can develop clinical babesiosis before the vaccine has time to produce a protective immunity, which normally occurs within 21 days of vaccination.

One infected tick is sufficient to transmit *B bovis*, but tick infection rates are usually low and the rate of transmission to cattle is therefore usually slow. Studies in Australia found only 0.04% of field ticks to be infected with *B bovis* in *B taurus* cattle and even less in the case of *B indicus* (Mahoney and Mirre 1971; Mahoney *et al* 1981). Tick infection rates with *B bigemina* are higher (0.23% in Mahoney and Mirre 1971 study) and transmission rates in this species are therefore higher.

Anaplasmosis

Anaplasma marginale in Australia is usually transmitted by the vector *Boophilus microplus* (Rogers and Shiels 1979) although mechanical (Ristic 1968) and *in utero* (Potgieter and Van Rensburg 1987) transmission may also be significant. Transmission of *A marginale* by the one-host tick *B microplus* has been shown in pen trials to be both transstadial and intrastadial as this species is incapable of transovarial transmission (Connell 1974; Leatch 1973). Mason and Norval (1981) demonstrated the transfer of larval and adult male *B microplus* from tick infested to uninfested cattle under field conditions. The transmission of anaplasmosis by interhost transfer of male *B microplus* from *Anaplasma* infected to susceptible cattle may be most important because males can survive for periods exceeding two months (Callow 1984). For ticks to transmit the infection, it is therefore necessary to have *A marginale* infected cattle in close contact with susceptible cattle.

7.3.2 Breed resistance to tick fever

To assess the natural resistance of breeds to tick fever parasites, Bock et al (1997) inoculated 18 month-old naive Bos indicus, cross-bred and Bos taurus steers sequentially with blood infected with B bovis, B bigemina and then A marginale. Criteria to assess reactions after infection included parasitaemia, fever, depression in packed cell volume (PCV) and the need for specific therapy as determined by preset treatment criteria. The treatment proportions are shown in Table 5.

Table 5: Proportion of 18 month-old naive steers of differing breeds requiring treatment when inoculated with blood infected with virulent isolates of *B bovis*, *B bigemina*, or *A marginale*. (Adapted from Bock *et al* 1997)

Group	Breed	Treatment proportion		
		Trial 1 ***B bovis***	**Trial 2** ***B bigemina***	**Trial 3** ***A marginale***
1	Pure *B indicus*	$^{0}/_{10}$	$^{0}/_{10}$	$^{5}/_{10}$
2	half *B indicus*	$^{3}/_{10}$	$^{0}/_{9}$	$^{7}/_{10}$
3	quarter *B indicus*	$^{2}/_{10}$	$^{0}/_{10}$	$^{8}/_{10}$
4	Pure *B taurus*	$^{8}/_{10}$	$^{0}/_{10}$	$^{10}/_{10}$

B indicus breeds almost invariably experience milder primary reactions than B taurus when infected with either species of Babesia (Lohr KF 1973; Anon 1975; Anon 1981; Callow LL 1984). This phenomenon is thought to be a result of the evolutionary relationship between B indicus cattle, the cattle tick and babesia (Dalgliesh RJ 1993).

The results in Table 5 confirm information on breed susceptibility to B bovis available in the literature (Callow LL 1984; Daly and Hall 1955; Johnston and Sinclair 1980). The B bovis isolate used induced highly pathogenic infections in B taurus cattle, but the B indicus cattle, in contrast, overcame the infection without difficulty. An important finding is the relative susceptibility of the two crossbred cattle groups with 25% requiring treatment. This suggests that in crossbred cattle the resistance conferred by the B indicus component may not be adequate to prevent economically significant losses due to B bovis infection.

Bock et al (1997) found that A marginale infection caused significant disease in all breeds studied (Table 5). This confirmed the work of Wilson et al (1979) and Otim et al (1980) who reported no difference in susceptibility of B taurus and B indicus cross-bred cattle (½ to ¾ B indicus) to A marginale. These reports suggest that A marginale could be a significant cause of disease in B indicus and B indicus crossbred herds.

There is some ambiguity in the literature concerning the relative susceptibility of B indicus and B taurus breeds to B bigemina. This parasite is usually of low pathogenicity in Australia and infections are usually not lethal even when fully susceptible cattle are introduced to an enzootic area (Callow LL 1979; Meehan 1969). Daly and Hall (1955) reported no observable difference between the susceptibility of B indicus (Zebu), crossbred (Santa Gertrudis and Africander) and B taurus (British) breed cattle to this parasite during vaccination. Johnston (1967) reported similar findings based on relative parasitaemias in thick blood films from naturally infected B taurus (Hereford) and crossbred (Droughtmaster) cattle. Although Parker et al (1985) demonstrated that pure B indicus were significantly more resistant than B taurus (Shorthorn) cattle, he conceded that the former may not have a distinct advantage in field situations due to the severity of reactions seen in both breeds. Lohr (1973) concluded that B indicus (Sahiwal) cattle were more resistant than B taurus (Charolais).

The B bigemina isolate used by Bock et al (1997) produced a mild response in all groups, but pure B indicus cattle as well as crossbreds with half and quarter B indicus were more resistant to challenge than B taurus cattle (Table 5). In a more recent study Bock et al (1999) using a more virulent B bigemina isolate again found pure B indicus cattle and crossbreds to be more resistant to challenge than B taurus cattle (Table 6). The results were generally uniform within groups, but one of the crossbreds was significantly more affected and one of the B taurus animals significantly less affected than group cohorts. This suggests that although B indicus and B indicus cross animals are generally more resistant than B taurus cattle, the susceptibility of individuals within these breeds does vary. This individual variation coupled with the variation of virulence of B bigemina field isolates, may help to explain the ambiguity in the literature with regard to breed susceptibility to B bigemina as well as the occasional severe outbreaks seen in B indicus and B indicus cross cattle.

Table 6: Comparison of the innate immunity of steers of differing breed when infected with the virulent Euthella isolate of *B bigemina* showing pure *B indicus* and *B indicus* cross *B taurus* steers to be more resistant than *B taurus* steers. (From Bock *et al* 1999)

Breed	Mean maximum percent PCV depression	Mean total parasitaemia score	Maximum temperature rise (^{o}C)
Pure *B indicus*	22.4^{A}	6.3^{A}	0.5^{A}
half *B indicus*	31.4^{B}	14.3^{A}	0.7^{A}
Pure *B taurus*	50.9^{C}	32.1^{B}	1.8^{B}
Least significant difference at 95% level	7.7	12.0	0.8

Values in columns are the group means. Within column means with different superscripts are significantly different to the 5% level of probability. Group 2 had only 6 animals.

Johnston et al (1978) showed that immunity of Bos indicus cross cattle to B bovis lasted at least 3 years despite the fact that most of the trial cattle eliminated the infection during that time. Unfortunately, Johnston and coworkers did not monitor antibody levels in the cattle. In a different study, however, Callow et al (1974) showed that indirect fluorescent antibody tests (IFAT) on sera from vaccinated cattle sterilised with Imizol were generally negative within six months of treatment, but this decrease in IFAT titre was not associated with a loss of immunity. In a long-term study of immunity in Bos taurus cattle to B bovis, Mahoney et al (1979a) found that 30% to 50% of the vaccinated or infected trial cattle became sero-negative in an indirect haemaglutination test during the trial period. However these cattle were still immune 4 years after initial vaccination or exposure.

There is also little field evidence of immunity waning to A marginale in Australia, despite the observation that antibody titres will fall off rapidly (author's observations). Animals inoculated with A centrale remain infected for a long time, probably for life (Krigel et al 1992) and there is no indication that the immunity following A centrale infection will wane with time. However, there is some evidence that cattle vaccinated at a young age when non-specific resistance is high, may experience such mild reactions that the immune response is insufficient (Anon 1984). Wilson et al (1980) found that there was no field evidence to suggest that vaccination of young animals is not effective in Australia. Where the A marginale challenge is strong, cross-immunity between the species may not be sufficient. In Australia the A marginale strains appear to be of moderate virulence and the protection provided by A centrale is usually adequate (Anon 1984).

So it appears that a persistent, detectable antibody titre is not a prerequisite for immunity. However, it is a very effective indicator of recent infection either naturally or by vaccination.

7.3.3 Endemic stability

Endemic stability is defined as the state where the relationship between host, agent, vector and environment is such that clinical disease occurs rarely or not at all (Perry 1996). Young cattle have higher innate resistance to most tick-borne diseases (Mahoney and Ross 1972) and consequently disease incidence and corresponding mortality are typically lower for this stock class.

Because of the low and variable rate of infection in B microplus, tick fever infection does not always follow exposure to ticks. When the number of ticks infected is low, thousands need to bite an animal to ensure it becomes infected. In tick-infested areas, droughts or dipping practices and use of resistant cattle may delay transmission of tick fever parasites for months or even years.

7.3.4 Age resistance

The age of cattle at the time of first exposure to tick fever usually determines the disease outcome. Older cattle will be more severely affected. Calves from immune mothers receive colostral protection against tick fever lasting about 2 months (Callow and Dalgliesh 1982). In most calves an age resistance that lasts a further 4-7 months (Callow 1984) follows this. Resistance then gradually wanes with time and the cattle can become very susceptible to tick fever (Trueman and Blight 1978; Paul et al 1980).

Calves exposed to tick fever during the first 6 to 9 months when the age resistance is at its peak, rarely show clinical symptoms and usually develop a solid long-lasting immunity. Cattle not exposed as calves to tick fever may develop severe, life threatening disease if they are exposed later in life, depending on their breed. Mahoney estimated that if at least 75% of calves were exposed to tick fever by 9 months of age the disease incidence would be very low and a state of endemic stability would exist.

B bigemina infects more cattle as calves because higher proportions of ticks carry it compared to B bovis (Mahoney and Mirre 1971). Calf exposure is hard to predict for A marginale because tick infection rates are variable and depends on access to infected cattle in the herd, but can be up to 100% (Dallwitz 1987).

7.4 Models of endemic stability and disease prediction

7.4.1 Mahoney model

Simple mathematical models can be used to predict the level of endemic stability for tick fever in a herd. Mahoney and Ross (1972) developed a babesiosis model, which utilises the rate in infection in calves (serological). The probability of occurrence of babesiosis outbreaks is directly related to the proportion of non-immune cattle in a herd and to the inoculation rate (Mahoney and Ross 1972; Mahoney 1974). The inoculation rate is the average daily probability of infection and depends on the number of ticks that bite each animal daily, the proportion of ticks infected with the babesia organisms and the proportion of bites from infected ticks that transmit infection. Inoculation rate is related to host infection, which can be measured by serological tests (Mahoney and Ross 1972; Mahoney 1973; Mahoney 1974).

If the inoculation rate is high, young animals (less than 9 months old) are exposed to infection before passive protection from maternal antibodies or non-specific immunity wanes and may not experience overt clinical disease when they are exposed to infection as adults. For endemic stability to be achieved Mahoney and Ross (1972) estimated the inoculation rates in B taurus cattle should be between 0.005 and 0.01. This is an average tick infestation of greater than 20 adult ticks/day/animal or averages of 1 infective tick bite per calf every 100 to 200 days. For B indicus cattle and their crosses Mahoney (1979) estimated infestations of 40 ticks per day per animal under favourable conditions for tick survival are necessary to achieve endemic stability.

The bovine babesiasis inoculation rate model described by Mahoney and Ross (1972), has been used in Australia to predict the proportion of cattle that will become exposed to B bovis after a particular number of years ranging from one to seven years (Mahoney 1973). The model, however, has some limitations in that it is less accurate in B indicus cattle due to the low tick numbers infecting these cattle and their natural resistance.

7.4.2 Ramsay's disease prediction/vaccination and discounted cashflow analysis model

Ramsay (1997) designed an alternative model, which can be used to predict babesia infections in both Bos indicus and Bos taurus cattle. The Ramsay disease prediction/vaccination spreadsheet model involves the use of a method to transform seroprevalence data to incidence risk, which is incorporated into a Markov chain disease prediction model. The Markov model simulates the movement between disease states over time using conditional probability. The disease model is in turn linked to a herd model. The disease model predicts the proportion of animals in each age and sex class that would be affected by different severities of disease. The herd model then converts these proportions to estimates of the number of animals in each disease severity class. The model is not designed to examine epidemic spread of disease between properties and is restricted to endemic disease that cycles within a herd.

Predictions are made for eight age classes from zero years to seven years for male and female classes. Because of the lack of a suitable method to classify the severity of disease following infection a simplified method was adopted that divided disease into categories which could be reclassified, as additional information became available. The model includes disease states, which are thought to have an effect on health and production.

The five states included in the model for infected cattle are:

Category 1 subclinical disease;
Category 2 mild disease with recovery;
Category 3 severe disease with recovery;
Category 4 acute disease with death;
Category 5 chronic disease with death.

The relationships between these states are illustrated in the transition diagram in Figure 1

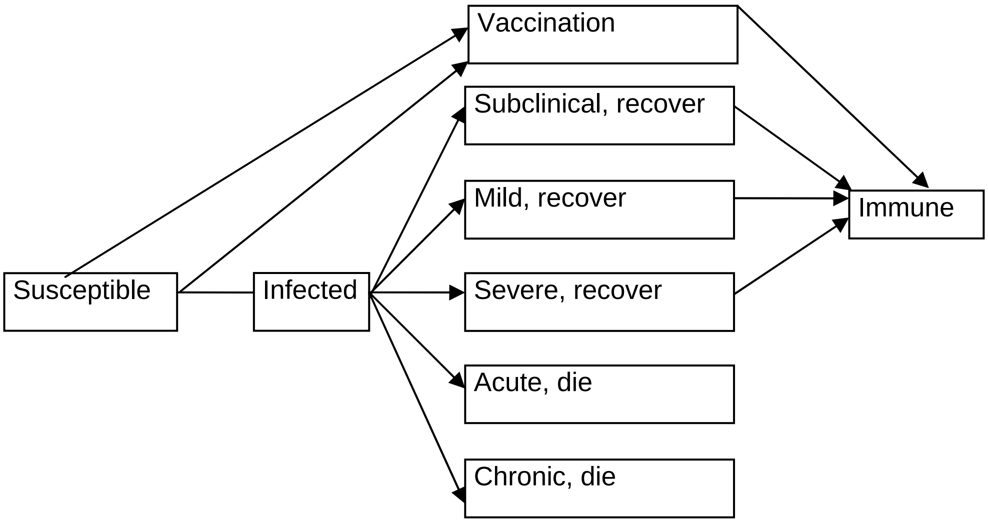


Figure 1: Transition diagram for different states in the disease prediction model including vaccination (Ramsay PhD Thesis 1997)

Inputs and outputs of the model and the principles involved in the calculations are illustrated in Figure 2. State probabilities for the various levels of resistance were estimated from trial data and expert opinion (Appendix 3).

7.4.3 Disease prediction model

Ramsay uses a formula from Lilienfeld and Lilienfeld (1980) to calculate incidence risk from age specific seroprevalence.

Incidence risk of seroconversion = 1 – (10 (log (1-Pn)/n))

This formula calculates the incidence of seroconversion and where significant mortalities occur with differences between age groups, adjustments need to be made. In the case of tick fever, considerable variation occurs between types of cattle. The disease response is therefore estimated in the Ramsay model for 3 levels of susceptibility to the disease. These susceptibility classes are susceptible (B taurus), intermediate (B taurus cross B indicus) and resistant (B indicus) breeds. Additionally, age has an important effect on susceptibility to disease with animals less than one year old less likely to show clinical signs or die from infection. Disease susceptibility is assessed for two age classes, less than one year and greater than one year old for each susceptibility class.

$$\text{Incidence risk of infection} = \frac{Incidence\_risk\_of\_seroconversion}{(p1 + p2 + p3)}$$

Where p1 equals the probability of infected animals being in category 1 and p2 equals the probability of infected animals being in category 2 etc. The probability of category 4 and 5 (p4, p5) is not used in the formula as animals that die cannot obviously be subsequently sampled or counted.

This gives the probability of progression from susceptible to infected in one year and is calculated from the serological data. The seroprevalence can be taken from survey data for the shire in which a property occurs or more accurately using serology on weaner age cattle from the property being assessed.

The proportion of animals in any age group that have become infected in the past year can be calculated as:

Proportion infected = proportion susceptible x IR of infection

The proportion susceptibles being (1 – proportion seropositive) and the proportion of the age group that are in a specific disease category eg Category 4 can be calculated as:

Proportion infected for age group = proportion infected x proportion in category 4

The conditional probability of progression from infected to each of the five severities of disease has been estimated from trial data and expert opinion and using this information Ramsay's model simulates the disease occurrence over several years (Appendix 3).

The input parameters and flow of the model is illustrated in figure 2.

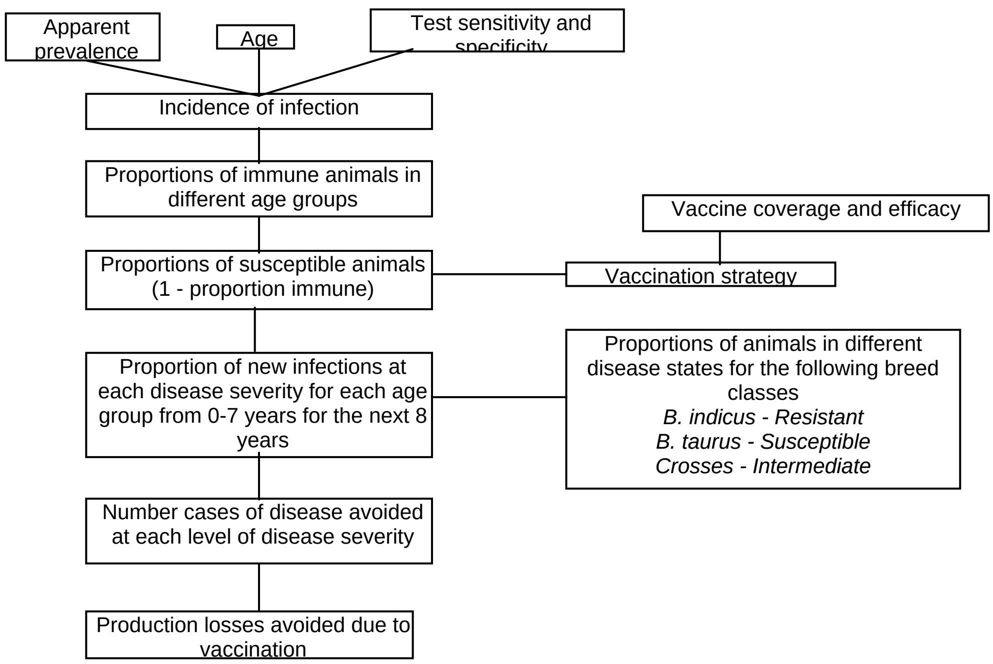


Figure 2: Inputs (shown in italics) and outputs of the disease prediction model (adapted from Ramsay, 1997)

7.5 Assumptions of the disease prediction model

The disease prediction model is based on the following assumptions:

- Immunity following natural infection does not wane
- It is assumed the carrier state does not affect production
- Recovery from disease is complete and there is no recurrence of disease in recovered animals
- An animal that is seropositive for a disease is immune to that disease and an animal that is not seropositive is susceptible
- The incidence risk of infection is constant between age groups and years and is independent of the sex of the animal
- Vaccination immunity to tick fever does not affect transmission rate

There is ample evidence in the literature that babesia antibodies directed against babesia parasites might not be detected in animals which were originally infected. This is largely due to a time-related decrease in antibody levels in infected cattle. The period of time varies from less than 1 year in Bos indicus cattle to at least 4 years in Bos taurus (Johnston et al 1978; Callow et al 1984; Mahoney et al 1979). It has also been shown that disease transmission and survival of ticks on pasture is dependent on climatic conditions like temperature, humidity and rainfall, which vary between years (Dalgliesh et al 1979; Hartley 1966; de Vos 1979). Incidence risk of infection of babesia is therefore not constant between years. No attempt has been made to estimate what these changes may be, but instead the model is constructed so that incidence risk (that is transition probability to go from susceptible to infected status) can be varied between years and age groups. To enable variation in the incidence risk of infection the model, from the serological data, determines the steady state and then the incidence rate can be manually varied.

Age specific data for herd structure, mortality rate and culling rate are put into a herd model, which then maintains a constant herd size and structure. The herd can be actual data or a model herd for the particular region or shire. All cows are culled at 8 years of age and the proportion of males sold for each age group is set. The results of the project surveys and trials are used throughout the costing analysis, and supplemented with expert opinion where data deficiencies exist (Appendix 2).

7.5.1 Vaccination strategies

The model developed by Ramsay provides a way to determine the effect of vaccination on herd immunity and predict the number of cases of disease that would be prevented by a vaccination program. This allows producers to estimate the benefit of vaccination for particular incidence risks of infection and herd resistance.

Two vaccination strategies are used in the model:

- Vaccination program 1 - In this program only animals one year old are vaccinated in each year of the program.
- Vaccination program 2 - In this program all animals are vaccinated in the first year of the program and animals one year old are vaccinated in subsequent years.

The model also allows for the estimation of production loss avoided by vaccination. The production loss is divided into loss due to deaths, weight lost and not regained by the time of sale and reproductive loss. Data for the weight and reproductive loss comes from expert opinion, but mortality is by far the most important production loss parameter for the tick fevers.

7.5.2 Vaccine coverage and efficacy

In the model vaccination coverage which is dependent on mustering rate etc and infectivity of the vaccine as well as vaccine efficacy can be adjusted. In the worked examples we have used 100% musters and the proportion vaccinated reflects infectivity. For the babesia vaccines the infectivity and efficacy are usually set at 99% and 95%, respectively. For the A centrale infectivity is set at 95% and efficacy at 90%. This gives a transition probability from susceptible to immune of 94% and 85.5% for the Babesia and Anaplasma vaccines, respectively.

7.5.3 Discounted cash flow analysis

The aim of discounted cashflow analysis is to reduce the costs and benefits of the control program to a common unit, money at a set point in time, usually the present, by the use of discounting. The Ramsay model generates three commonly used criteria: benefit to cost ratio, net present value and the internal rate of return to compare the performance of the vaccination strategies.

The cost of vaccination is estimated in the model using the number of doses used and vaccine prices as well as mustering and application costs. Also the sale prices of cattle and disease and treatment costs are factored into the overall model as outlined in appendix 3. In the worked example, sale prices were taken from the Country Life sales report February 1999. Vaccine prices are calculated as the bivalent price of $1.74 per dose with half of this being allocated to B bovis and half to Anaplasma vaccine. It is assumed that vaccination is carried out in conjunction with a routine muster so no additional mustering cost is added. A vaccine application cost of $0.25 per dose was allocated to B bovis and Anaplasma vaccine to cover freight and the labour costs of the actual inoculation. If B bigemina vaccine is used the cost is calculated as 60 cents per dose (rounded up) as it is only available with the other two parasites in the Trivalent vaccine. No application cost for B bigemina vaccine is added in the worked example as this is factored into the other B bovis and A marginale components of the vaccine.

The Ramsay model uses as the default discount rates of 4%, 8% or 12%. These rates can be modified and the current discount rate is estimated to be about 7% (Trevor Wilson QDPI economist, personnel communication)

The effect of vaccination programs on the economic performance criteria can therefore be rapidly assessed for various levels of age specific seroprevalence (incidence risk of infection) and susceptibility of cattle within different herd profiles.

7.5.4 Project objectives and findings

Serological survey (Objective 1)

Objective 1: Perform survey of the current prevalence of the three tick fever parasites (A marginale, B bovis and B bigemina) in cattle on a cross section of properties in northern cattle industry over a period of 3 years.

During 1996, we conducted a serological survey to determine the current prevalence of tick fever parasites in weaner cattle in north-west Queensland.

The sampling unit was the herd. The herds were randomly selected from a sampling frame of the 530 herds with greater than 1000 head in Burke, Carpenteria, Croydon, Etheridge and ‘tick infested’ areas of Cloncurry, Dalrymple, McKinley Mt Isa, Richmond and Flinders shires. As herd sizes tend to vary along shire boundaries, herds were stratified by shire and selected accordingly. Cattle numbers in the shire and the number of properties in the shire weighted the number of herds selected per shire. A total of approximately 60 non-vaccinated cattle aged between 6 and 12 months were sampled from each of 116 herds. This age group was selected, as antibody levels to tick fever will not persist in cattle particularly B indicus types.

A total of 7067 samples were tested for antibody to B bovis with an ELISA (Molloy et al 1998a), B bigemina ELISA (Molloy et al 1998b) and Anaplasma with a Card Agglutination Test (CAT) (Amerault and Roby 1968). A summary of results are presented in Table 7

Table 7: Summary of 1996 serological survey of herds in NW Queensland

		Percent of animals seropositive per herd					
		B bovis		***A marginale***		***B bigemina***	
Shire	**Herds**	**average**	**range**	**average**	**range**	**average**	**range**
Burke	8	22	0-65	50	0-97	39	0-88
Croydon	8	0	0-2	2	0-7	3	0-18
Carpenteria	8	10	0-52	44	0-93	34	0-82
Cloncurry	8	1	0-4	10	0-20	14	0-77
Dalrymple	18	3	0-30	6	0-25	9	0-42
Etheridge	13	1	0-3	2	0-5	14	2-33
Flinders	19	1	0-7	3	0-20	5	0-63
Mt Isa	4	1	0-3	1	0-2	2	0-5
McKinley	14	3	0-17	10	0-75	6	0-30
Richmond	16	1	0-7	1	0-6	2	0-13
Total	116	4	0-65	10	0-97	11	0-88

The survey indicates that transmission of both *B bovis* and *A marginale* was very low for all shires except Burke and Carpenteria. *B bigemina* transmission was also generally low, but the range was much broader indicating higher property to property variation. The results are similar to those of smaller pilot surveys and structured surveillance carried out in this area between 1990 and 1995 and some follow-up sampling in 1997 (Table 8).

Table 8: Summary of additional serological sampling in 1997 of herds in NW Queensland

		Percent of animals seropositive per herd					
		B bovis		***A marginale***		***B bigemina***	
Shire	**Herds**	**average**	**range**	**average**	**range**	**average**	**range**
Burke	7	37	0-100	62	0-95	55	0-100
Croydon	8	0	n/a	0	n/a	8	0-50
Carpenteria	6	15	0-62	61	20-80	59	9-87
Cloncurry	2	0	n/a	7	1-13	25	15-35
Dalrymple	1	0	n/a	0	n/a	0	n/a
Etheridge	7	1	0-3	2	0-8	3	0-6
Flinders	2	0	n/a	0	n/a	7	4-9
Mt Isa	0	n/a	n/a	n/a	n/a	n/a	n/a
McKinley	5	1	0-17	0	n/a	5	0-22
Richmond	2	0	0-7	0	n/a	0	n/a
Total	40	9	0-100	21	0-95	23	0-100

This indicates an endemically unstable situation in the region. Given the generally high *B indicus* content of these herds, the risk that this represents needs further assessment. In Burke and Carpenteria shires in particular the risks would appear to be very high and significant losses would be expected and in fact have occurred in the few outbreaks that are reported.

Estimate of losses (Objective 2)

Objective 2: Estimate the losses due to tick fever in the breeds currently utilised on selected properties in the northern cattle industry.

A longitudinal cohort study was set up as part of the project to meet the second objective. The study was designed to compare mortality rates, over 3 years, of cattle infected with tick fever as calves (and thus immune) relative to cattle with no previous exposure to tick fever in an ‘on property’ situation.

Five properties were sampled during 1996 (2075 samples) and 2 of these had been sampled in 1995. In 1997 only 2 properties could be sampled with large numbers missing from Armraynald and some missing from Dunbar (Table 9). The owner of Escott had sold the cattle and the Lawnhill group was not available for testing.

It proved impossible to meet this objective with the initial strategy for the following reasons:

- finding large enough groups of suitable cattle that can be kept together for the duration of the study is even more difficult than was anticipated originally;

- seasonal and property management variations made it impossible to get a good return during musters and some musters were cancelled;

- high transmission rates of tick fever parasites disqualified some properties before the end of the first year of the project.

Table 9: Herds sampled for longitudinal study

Property	Shire	1995	1996	1997
Armraynald	Burke	0	479	381
Escott	Burke	0	446	0
Lawnhill	Burke	462	228	0
Dunbar	Carpenteria	0	275	240
Belmont	Rockhampton	647	647	0
Total		1109	2075	621

Although high transmission rates in 1997 precluded the further use of the Belmont herd in the longitudinal study, interestingly breed and sex factors were found to influence transmission rates in the weaners tested.

All these weaners sampled at Belmont were F1 crosses of various breeds and were born between August and December 1994 and sampled in June 1995. The heifers were paddocked as a group separate to the bulls, but the two groups rotated through the same paddocks. Some of the Belmont data is illustrated in Table 10 and shows that the tick resistance of Bos indicus calves may reduce exposure to B bovis parasites. This is more apparent in heifer calves. The effect of this on the development of endemic stability is not clear as it must be balanced by their natural resistance to tick fever. The Anaplasma transmission rate was high in both sexes for all breeds.

Table 10: Tick Fever seroconversion rates in weaner/yearlings bulls and heifers of the main breed groups sampled on Belmont station

			% positive	
Breed	**Sex**	**Number**	***B bovis***	***Anaplasma***
Hereford/Shorthorn	Bulls	46	78	98
	Heifers	38	71	97
Brahman X Simmental	Bulls	13	77	100
	Heifers	11	73	91
Belmont Red	Bulls	18	78	89
	Heifers	15	60	100
Brahman x (Hereford x Shorthorn)	Bulls	16	69	94
	Heifers	18	39	94
Brahman X Belmont Red	Bulls	22	73	91
	Heifers	21	43	95
Brahman	Bulls	19	58	100
	Heifers	27	33	89
Total	Bulls	134	72	95
	Heifers	130	53	94
Overall Total		264	63%	95%

Alternative strategy to meet objective 2

An alternative strategy was discussed with David Skerman (MRC) and industry representatives at the TFRC on 4 March 1997. It involved the movement of naive Bos indicus and crossbred cattle from a tick free area to a highly endemic area to monitor their response to a ‘natural’ field infection. The aim was to provide information on a worst case scenario to use as a reference for risk assessment in NW Qld.

Objective: To assess the tick transmission rates and innate resistance of 15-18 month old Bos indicus and crossbred cattle to tick fever parasites when placed in a paddock infested with cattle ticks carrying B bovis (Trial 1) and when mixed with tick infested A marginale infected cattle (Trial 2).

The results of both these trials are in press with the Australian Veterinary Journal, but a synopsis is given here.

Trial 1 Babesia challenge at Mutdapilly (Bock et al 1999 in Press)

The objective of trial 1 was to assess the effect of breed of cattle on the transmission rates of and innate resistance to Babesia bovis and B bigemina parasites transmitted by Boophilus microplus ticks.

Groups of 56 pure B indicus, and 52 B indicus cross B taurus (50%, F1 generation Charolais cross Brahman) steers were placed in a paddock seeded with and also naturally infested with B microplus. The ticks were the progeny of females ticks fed on B taurus cattle specifically infected with a virulent isolate of B bovis. The cattle were placed in the infested paddock 50 days after seeding had started.

Cattle were inspected daily on horseback for 50 days. Clinical cases were brought to yards and assessed by monitoring fever, depression of packed cell volume, parasitaemia and severity of clinical signs. Any animals that met preset criteria were treated for babesiosis. Blood samples were collected from all cattle on day 28, 35 and 42 after exposure and antibodies to Babesia spp and packed cell volume measured.

All steers, except for one crossbred, seroconverted to B bovis and B bigemina by day 35 and 75% of the crossbred steers showed a maximum depression in packed cell volume of more than 15% due to infection with Babesia spp compared with only 36% of the B indicus group. Ten of the 52 crossbreds and one of the 56 B indicus steers showed severe clinical signs. Two of the crossbreds required treatment of which one died 2 weeks after initial treatment.

We were unable to accurately determine which Babesia parasite was having the most effect in this particular trial as serology and smear examination showed that mixed infection predominated. B bigemina has been found to be usually of low pathogenicity in Australia even when fully susceptible cattle are introduced to an enzootic area (Callow 1979; Meehan 1969). Field evidence in Queensland suggests that B bovis would have been the principal pathogen in the current study although B bigemina as shown by Bock et al (1999) and even tick worry would have contributed to the clinical signs.

All the steers remained seronegative for Anaplasma.

The results illustrated in Table 11, confirm that pure-bred B indicus cattle have a high degree of resistance to babesiosis, but crossbred cattle are sufficiently susceptible to warrant the use of preventative measures such as vaccination. Transmission rates of B bovis and B bigemina to pure B indicus and crossbred cattle previously unexposed to B microplus were the same.

Categories	Maximum percent PCV depression	Number of animals in each category: Crossbreds n = 52	B indicus n = 56
Unaffected	≤15	13	36
Mild	16-20	7	11
	21-25	9	4
Moderate	26-30	6	3
	31-35	7	1
Severe	36-40	5	0
	41-45	3	1
Treated	46-50	2	0
Mean percent PCV depression		25	14
Least Significant Difference at 1% level		5	

Trial 2 A marginale challenge at Mutdapilly (Bock et al 1999 submitted)

The objective of trial 2 was to assess the innate resistance of and transmission rates in naive Bos taurus cross Bos indicus and pure Bos indicus cattle when placed in a paddock with cattle infected with Anaplasma marginale and carrying Boophilus microplus ticks.

A naive group of fifty pure B indicus, and fifty-one B indicus cross B taurus (50%, F1 generation) 24 month old steers were kept in a paddock to which cattle artificially infected with a virulent isolate of A marginale and seeded with Boophilus microplus were added. The cattle were seronegative for A marginale at the start of the trial but had previously been exposed to Babesia bovis and B bigemina.

Cattle were monitored by twice weekly paddock inspection for 118 days. Packed cell volumes, blood smears and serum samples were collected from all the trial cattle on day 37 post-exposure and then at regular intervals to day eighty-three post exposure to check packed cell volume levels, parasitaemias and antibody to A marginale. Any animals that met preset criteria were treated for anaplasmosis. Transmission was terminated on day 83 by removing A marginale infected steers and treating all steers with an acaricide.

A marginale was detected on blood smears in 14 crossbred and nine B indicus steers between days 56 and 72 after exposure. Five and two of the infected crossbred and B indicus steers required treatment, respectively. One of the Bos indicus cattle died as a result of the A marginale infection despite treatment. The 23 infected cattle all seroconverted to Anaplasma. The mean maximum percent depression in packed cell volume from pre-trial levels was 40% and 37% in the affected crossbreds and Bos indicus groups, respectively. There was no significant difference detected in susceptibility between these two groups (Table 12 and 13).

Transmission rates to and innate resistance of pure-bred B indicus and crossbred cattle were not significantly different. The results confirm that pure-bred B indicus and crossbred cattle are sufficiently susceptible to warrant the use of preventive measures such as vaccination.

Table 12: A comparison of packed cell volume, parasitaemia and the number treated for tick fever in groups of *B indicus* and crossbred steers when infected with *A marginale* transmitted by *B microplus*.

Breed	Mean maximum PCV depression (%)	Mean maximum Parasitaemia (PPE)	No treated
B indicus	37 ± 17	6 ± 5	$^{2}/_{9}$
half *B indicus*	40 ± 8	5 ± 2	$^{5}/_{14}$
Least Significant Difference at the 5% level.	14	4	
Values in columns are the group mean ± the 95% confidence limits The F value for both parameters were not significant			

Table 13: The number of pure-bred *B indicus* and crossbred (50% *B indicus*) steers that showed different degrees in maximum percent packed cell volume depression after infection with *A marginale*

	Number of animals at each level	
% PCV depression	**Crossbreds**	***B indicus***
<u><</u>20%	1	3
21-25%	1	1
26-30%	1	0
31-35%	2	0
36-40%	2	0
41-45%	1	2
46-50%	3	1
>50%	3	2
Total infected	14	9

Tick fever control decision support (objective 3)

Objective 3: Provide the northern producers with information that will allow them to make rational decisions regarding breed type, vaccination strategy, tick control and cattle movements in relation to the management of tick fever.

The Ramsay spreadsheet model as outlined in section 6.2 was used to meet this objective. Model simulations can be carried out using inputs from the disease prediction/vaccination and production loss spreadsheets as inputs into a discounted cashflow analysis. The effect of vaccination programs can therefore be rapidly assessed for various levels of herd resistance and age specific seroprevalence. Data from a model herd as outlined in Appendix 2 and 3 was used to generate benefit/cost ratios as illustrated in figures 4,5 and 6 for B bovis, Anaplasmosis and B bigemina, respectively at an 8% discount rate. In these simulations the effect of variation in seroprevalence of yearling cattle on economic performance criteria is examined at nine levels, namely 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% for each of 3 levels of host resistance.

Two vaccination programs are examined as defined in section 6.2.2.

B bovis

In the model herd for resistant B indicus cattle the B/C ratio was poor for both vaccination programs and is only greater than one in program 1 when the seroprevalence is 30%, 40% or 50%. The B/C ratio for crossbred cattle is above 1 for both programs except at the 90% seroprevalence level and is very favourable for B taurus cattle. The B/C ratio for vaccination program 1 exceeds program 2 at all seroprevalence levels for all 3 breed types. Details are illustrated in figure 4.

Anaplasma

The B/C ratio for B indicus, crossbred and B taurus cattle is very favourable for all seroprevalence levels. The B/C ratio for vaccination program 1 exceeds program 2 at all seroprevalence levels for all 3 breed types. Details are illustrated in figure 5.

B bigemina

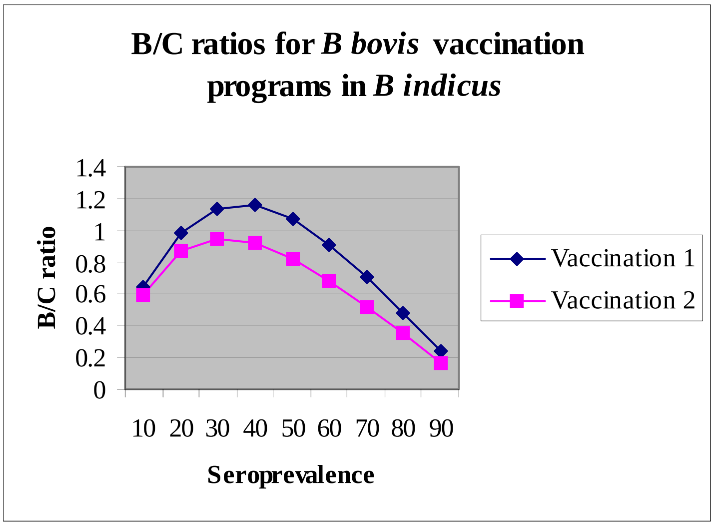
In the model herd for resistant B indicus cattle the B/C ratio is very poor for both vaccination programs reaching a peak of 0.03 and 0.02 for vaccination programs 1 and 2, respectively. The B/C ratio for crossbred cattle is above 1 at a seroprevalence of from 20% to 60% and 20% to 50% for vaccination programs 1 and 2, respectively. Both programs are very favourable for B taurus cattle. The B/C ratio for vaccination program 1 exceeds or equals program 2 at all seroprevalence levels for all 3 breed types. Details are illustrated in figure 6.

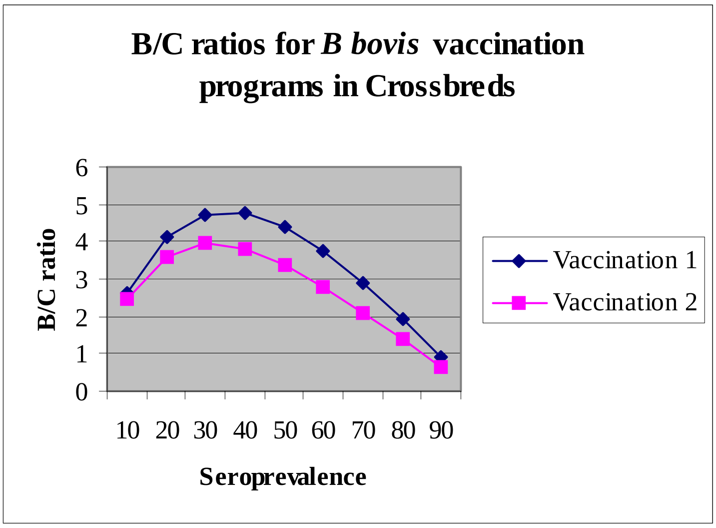
General

Vaccination program 2 tends to produce most benefit relative to program 1 at the low incidence risk of infection.

This occurs because where the incidence risk of infection is low many cattle in the older age groups have not been exposed to infection and are therefore susceptible to disease. The vaccination of older animals therefore has a greater impact on herd immunity and the number of cases of disease prevented is greater than where the incidence risk of infection is high. As the incidence risk of infection increases the proportion of older cattle that have been exposed to infection increases and the effect of vaccination program 2 on herd immunity decreases. Program 2 would have most appeal to producers who are highly risk averse or where the immediate risk to the whole herd is deemed to be very high.

Figure 4: Benefit cost ratios for B bovis vaccination programs at a discount rate of 8% for herds of varying degrees of resistance and varying seroprevalence in yearlings.





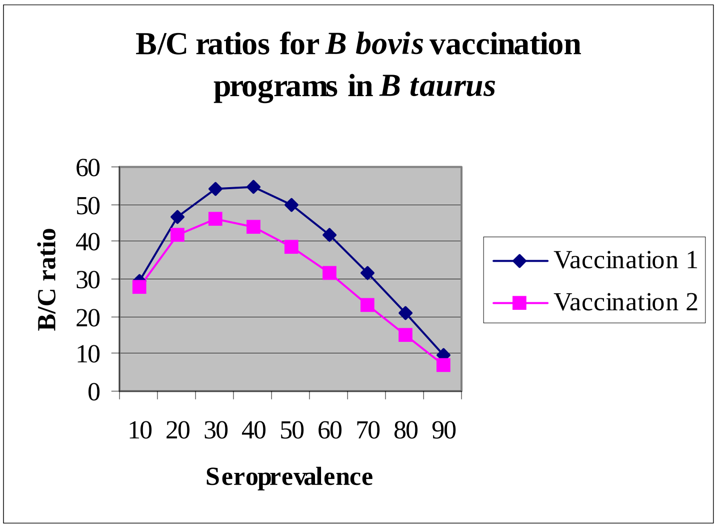
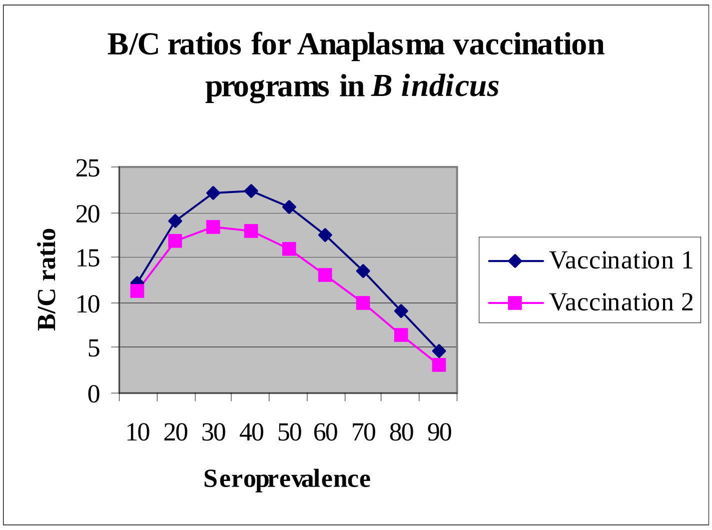


Figure 5: Benefit cost ratios for Anaplasma vaccination programs at a discount rate of 8% or herds of varying degrees of resistance and varying seroprevalence in yearlings.



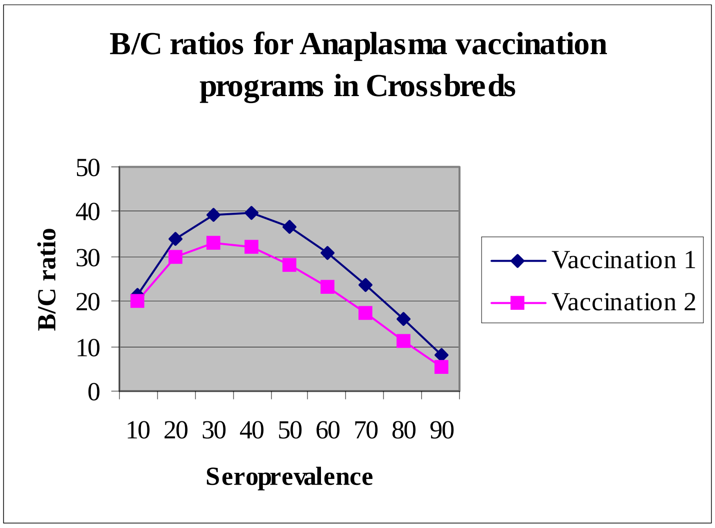
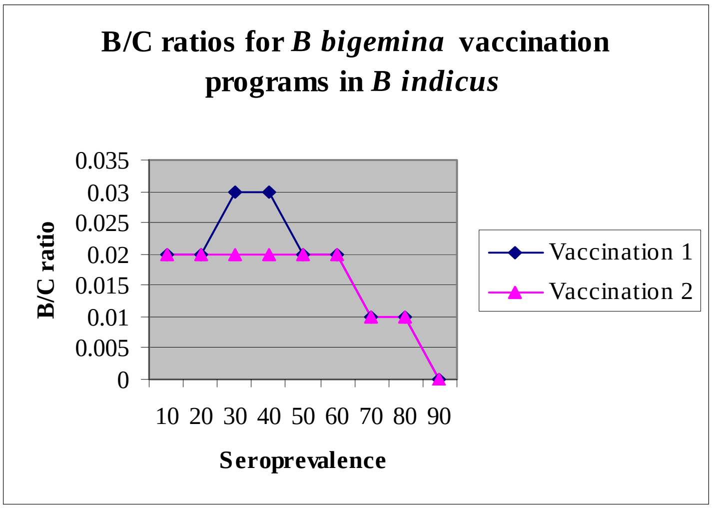
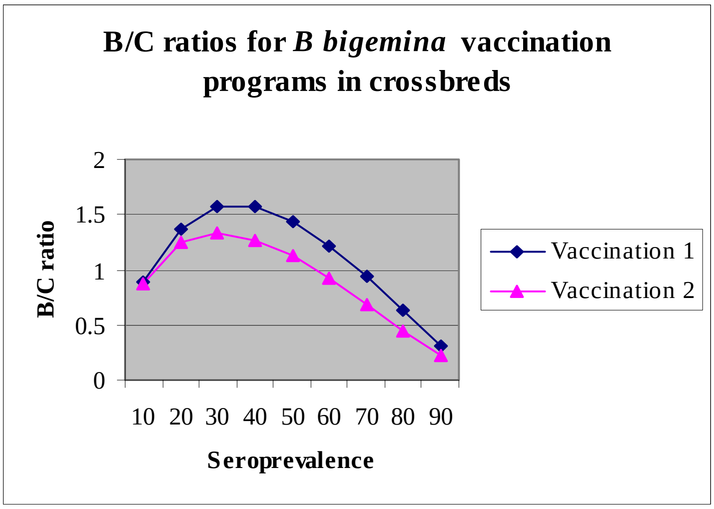
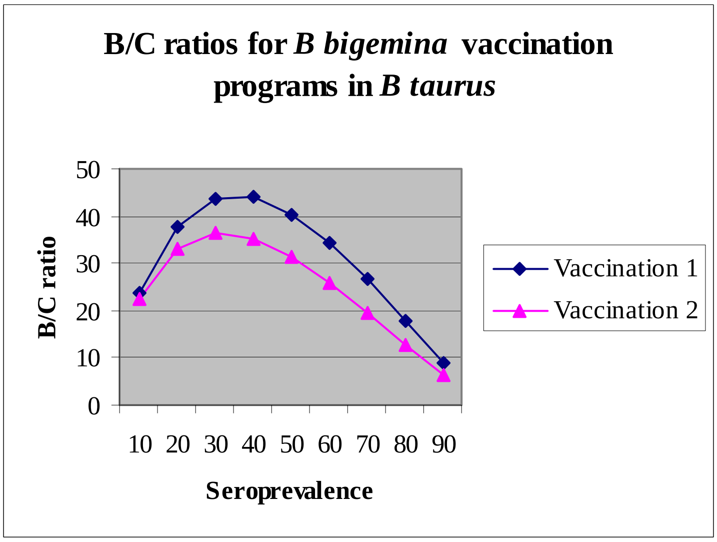


Figure 6: Benefit cost ratios for B bigemina vaccintion programs at a discount rate of 8% or herds of varying degrees of resistance and varying seroprevalence in yearlings.







8. CONCLUSIONS

There are an estimated 1 million cattle in the officially tick-infested parts of north Queensland and a further 700,000 in ticky areas of Northern Territory and Western Australia (Chudleigh, 1991). An economic analysis of the consequences of tick fever in B indicus and crossbred cattle breeds in Northern Australia has not been attempted before because quantitative measurement of the disease's effect has always presented difficulties, especially under extensive conditions. The disease usually has a short course that results in either death or survival, and compensatory weight gains and complete recovery usually follow survival within a few months. As a result, the principal parameters available (confirmed morbidity and mortality) are usually only measurable under conditions of intensive management (Guglielmone et al 1992). Bartholomew and Callow (1979) performed a benefit-cost study of the development and introduction of a live vaccine against B bovis infection and found a high return. However, the data on which the study was based originated almost exclusively from observations on B taurus cattle.

8.1 Key findings

- Endemic stability was not observed in any of the shires surveyed for any of the 3 tick fever parasites.
- Susceptibility of B indicus, crossbred and B taurus cattle has been more adequately defined from this study.
- A model to predict the benefit cost of vaccination in Northern Australia has been used and tested using this information and can be used to more accurately assess the incidence risk of tick fever for a range of herd structures and associated scenarios.

So if we come back to the questions being asked by northern producers:

(a) **What will be the impact of tick fever on different breeds of cattle if ticks move back into these areas?**

From the surveys we now know that the majority of adult cattle in north-west Queensland's officially tick infested areas are naive to tick fever parasites and that Burke and Carpenteria shire herds are very unstable. Pilot surveys within the Northern Territory and the Kimberley's show that a similar situation occurs in these regions. From trials and associated studies we know that if naive adult cattle are infected with A marginale, all breeds will have significant mortalities and that B bovis will cause significant mortalities in crossbreds and of course B taurus cattle. Increasing the B taurus content of cattle in this area will substantially increase the risk of tick fever and should only be done in conjunction with a vaccination program. Valuable animals such as bulls of any breed should be vaccinated.

(b) **(b) Are the cross-bred cattle being exported to South-east Asia sufficiently resistant or immune to withstand the possible tick fever challenge levels at their destination?**

Our 1996 survey and previous structured surveillance data suggests that in any group of export cattle from this region a significant proportion would be naive. Cattle that will be on pastures, feed green feed from tick infested pasture or in anyway likely to have exposure to cattle ticks should therefore be vaccinated with tick fever vaccine. Feeder steers going to well controlled feedlots in these countries may not be at significant risk, but if they are subsequently sent on to small holder feedlots the risk of tick exposure will increase substantially and regardless of breed they should be vaccinated. This also applies to cattle from the region being sent to areas within Australia that have high B microplus infestations.

(c) **(c) What is the cost/benefit of control options in different cattle breeds in the region?**

The available laboratory and trial information shows that B indicus cattle and their crosses can be affected by tick fever and that some of these outbreaks are economically substantial. Also, for producers supplying cattle to the live cattle export markets of south-east Asia, a confirmed case of tick fever on a property means that cattle from that property are ineligible for this trade for 6-12 months.

The producer's attitude to risk, as well as long-term view of markets and breed structure have to be considered. The Ramsay model with the data generated from this project now allows producers to assess the risk more accurately for their particular herd and to quickly test various scenarios.

8.2 Recommendations for control of tick fever in Northern Australia

8.2.1 In endemic areas

In balance, it is our opinion that the evidence would easily justify a vaccination program to prevent outbreaks and protect market access. In pure B indicus herds the benefit to cost is marginal for babesiosis, but the protection of market access is an important consideration and along with A marginale risk would usually tip the balance in favour of vaccination in most management programs even in this breed.

A single vaccination at 6 to 9 months of age will prevent serious risk of vaccine reactions as seen in older animals. There is no evidence of obvious loss of immunity with time and therefore no need to consider revaccination as a routine procedure. Revaccination is only recommended when there is uncertainty over the accuracy of previous procedures or when there has been a change in the strains used in the vaccine.

Cattle owners have two choices. They can either inoculate their cattle with all three organisms (trivalent vaccine) or against B bovis and A centrale (bivalent vaccine). The former is most commonly recommended for protection of Bos taurus breeds, valuable cattle and/or cattle originating from tick and tick-free properties. Bivalent vaccine is most often recommended in the case of Bos indicus and Bos indicus-cross cattle born in the endemic areas. Depending on the individual property/company management various strategies such as vaccinating replacement heifers only could be considered.

8.2.2 In live cattle export trade

Vaccination at weaning age (6-9 months) will continue to provide protection usually lasting the life of the animal, but at present when tick fever vaccine is stipulated export protocols require that it be done around the time of shipment. If these protocols could be amended to accept vaccination at weaning, this would negate the need to muster and hold cattle some time before export and avoid vaccine reactions during shipping, quarantine or in the feedlots. Vaccine reactions can occur from day 5 to day 60 after vaccination if trivalent vaccine is used. An on-farm quality assurance system that will ensure proper use of the vaccine and identification of immunised animals would be required, but the benefits would be considerable and it would protect cattle against tick fever from weaning to the time of shipment. To ensure broad-spectrum protection, the animals should be vaccinated against B bovis, B bigemina and A centrale.

8.3 Application

8.3.1 Vaccination

The TFRC produces tick fever vaccine that is readily available for use in extensive areas. Producers must assess the risk of tick fever from the information available and make a decision with regard to vaccination, which is consistent with their own attitude to risk. If supply of chilled vaccine is a problem in the more remote areas they can also consider use of the frozen tick fever vaccine which has a five-year shelf life stored in liquid nitrogen.

8.3.2 Decision support service

Using the information generated from this project and the Ramsay model it is also possible to offer a decision support service tailored to individual herds. We suggest that this be operated on a fee for service basis which would entail the serological testing of approximately 50 weaner age cattle from a herd or in the case of larger properties a number of subgroups as required to adequately assess the current seroprevalence on the property. This information along with herd data would then be entered into the model to produce the decision support output estimating the return on vaccination costs assuming the situation does not alter radically. Various scenarios looking at changes in the risk over the 8-year outlook of the model can also be demonstrated to allow a more complete picture and give some information on the sensitivity of the output to scenario changes.

8.3.3 Sentinel herds

The establishment of ‘sentinel herds’ in specific shires of interest to allow annual serology of weaners would give a better estimate of changes in risk over time. This information through the Ramsay model could be used to advise producers in the shire on possible changes in tick fever risk using the sentinel herd as a basis for assessment.

Acknowledgments

This work was supported by Meat and Livestock Australia (formerly Meat Research Corporation) and Queensland Department of Primary Industries. We thank the many stock inspectors who collected samples and are involved in ongoing extension efforts as well as Denise Stevenson, Katy Williams, Greg Kim and Neil Goetsch for their able technical assistance. We also thank the many producers who generously made their cattle available for sampling and hope the results make it worthwhile for them. We would also like to sincerely thank the Australian Agricultural Company for their assistance in obtaining suitable trial cattle for the work at Mutdapilly. The Australian Centre for Agricultural Research (project 9204 Animal Health in Thailand and Australia) supported the development of Dr Gavin Ramsay’s model.

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APPENDIX 1: WORK PROGRAM/MILESTONES (NON-BUDGET)

Milestone	**Completion Date**	**Achievement Criteria**
1. Survey of tick fever status of approximately 8000 cattle on approximately 150 sites in Northern Australia	31/12/96	Cattle tested for *B bovis* (ELISA), *A marginale* (CAT or ELISA) and *B bigemina* (IFAT)
2. Selection of 4-6 properties for estimation of economic impact of tick fever in Northern Queensland	31/12/96	4000 cattle tagged and tested for *B bovis* (ELISA), *B bigemina* (IFAT or ELISA) and *A marginale* (ELISA or CAT).
3. Estimation of the current on property losses due to tick fever in the northern beef industry	30/12/98	A total of 4000 cattle in high tick fever risk areas or on cattle moved from low to high-risk areas monitored annually. The number of surviving seronegative relative to seropositive cattle determined. Statistical analysis performed
3. (**Amended 1997)** Estimation of the expected losses due to tick fever in the Northern beef industry	30/12/98	Move naive *Bos indicus* and crossbred (50% *B indicus* cross *B taurus)* cattle from a tick free area to a highly endemic area to monitor their response to a 'natural' field infection. Assess the tick transmission rates and innate resistance of *Bos indicus* and cross-bred cattle to tick fever parasites when placed in a paddock infested with cattle ticks carrying *B bovis* (Trial 1 – 100 animals) and when mixed with tick infested *A marginale* carrier cattle (Trial 2 – 100 animals). Statistical analysis performed
4. Benefit cost analysis of tick fever control along with specific recommendations to industry re: livestock management and vaccination regimes and genotypes	30/12/98 (**Amended 1997 to 31/3/98)**	Report on benefit cost analysis of tick fever control received at MRC
5. Completion of final report and acceptance of the final report by MRC	30/12/98 (**Amended 1997 to 31/3/98)**	Acceptance of the final report acknowledged by MRC.

APPENDIX 2: INPUT PARAMETERS FOR RAMSAY MODEL

Inputs for epidemiology section

Serology	
Age	1
Seroprevalence	0.5

Test	
Sensitivity	1
Specificity	1

Vaccine

Vaccine efficiency	
Vaccine infectivity	Vaccine efficacy
95%	90%

Vaccine cost (per dose)		
Vaccine cost	Vaccine admin.	Mustering
$0.87	$0.25	$0.00

Variations in incidence risk of infection (*do not enter data if you do not want to vary IR)*

Age	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
0 to 1	0	0	0	0	0	0	0	0
1 to 2	0	0	0	0	0	0	0	0
2 to 3	0	0	0	0	0	0	0	0
3 to 4	0	0	0	0	0	0	0	0
4 to 5	0	0	0	0	0	0	0	0
5 to 6	0	0	0	0	0	0	0	0
6 to 7	0	0	0	0	0	0	0	0
7 to 8	0	0	0	0	0	0	0	0

Males	**Number in herd**	**Mortality rate for each age group**	**Proportion sold**
0-1 years	239	0.03	0
1-2 years	232	0.04	0
2-3 years	223	0.02	0.5
3-4 years	109	0.02	1
4-5 years		0.02	0
5-6 years		0.02	0
6-7 years		0.02	0
7-8 years		0.02	0
	803		

Females	**Number in herd**	**Mortality rate for each age group**	**Calving rate for each age group**
0-1 years	239	0.03	
1-2 years	232	0.05	
2-3 years	221	0.08	0.2
3-4 years	203	0.07	0.38

4-5 years	141	0.05	0.61
5-6 years	127	0.05	0.62
6-7 years	115	0.05	0.62
7-8 years	198	0.05	0.61
	1476		

Calving loss
Proportion of cows that would have calved that do not calve due to the disease

	Year 1	Later years
Mild	0	0
Severe	0	0.2
Acute die	1	1
Chronic die	1	1

Weight lost and not regained

Mild disease		
Age	**Females**	**Males**
0 years	0	0
1 year	0	0
2 years	0	0
3 years	0	0
4 years	0	0
5 years	0	0
6 years	0	0
7 years	0	0

Prices
Male sale price

Age	**Sale price male**	**Price per kg liveweight**	**Weight at sale (kg)**
Calves	$52.00	$0.52	100
1 year old	$270.00	$0.90	300
2 years old	$402.50	$1.15	350
3 years old	$460.00	$1.15	400
4 years old	$517.50	$1.15	450
5 years old	$517.50	$1.15	450
6 years old	$517.50	$1.15	450
7 years old	$517.50	$1.15	450
8 years old	$517.50	$1.15	450

Disease diagnosis and treatment
Diagnosis

	Proportion of cases	**Cost per case**
Mild disease	0	10
Severe disease	0.1	10
Acute die	0.1	10
Chronic die	0.1	10
Severe disease		
Age	**Females**	**Males**
0 years	0	0
1 year	5	5
2 years	5	5

3 years	3	3
4 years	3	3
5 years	3	3
6 years	3	3
7 years	3	3

Female sale price

Age	Sale price per head	Price per kg liveweight	Weight at sale
Calves	$52.00	$0.52	100
1 year old	$173.25	$0.77	225
2 years old	$192.50	$0.77	250
3 years old	$344.00	$0.80	430
4 years old	$352.00	$0.80	440
5 years old	$352.00	$0.80	440
6 years old	$352.00	$0.80	440
7 years old	$352.00	$0.80	440
8 years old	$352.00	$0.80	440

Treatment

	Proportion of cases	Cost per case
Mild disease	0	20
Severe disease	0.1	20
Acute die	0	20
Chronic die	0.1	20

APPENDIX 5: SPREADSHEETS IN THE MODEL

The spreadsheets are in Excel® and were originally written in Excel 5. To start the model simply open all of the spreadsheets, there is no need to re-establish links as once all sheets are open the links will be present. Some cells are protected but not all. If a cell has a formula it is best to not change that cell.

Turn calculation off and recalculate using the manual command as each recalculation takes a couple of minutes. Do not interrupt the model while it is calculating as this upsets it and the results are not reliable.

9cpredct.xls	
Inputs	Serological results
Probabilities	Probabilities of different disease severities after infection
I and P	Allows changes to the incidence risk between different years
Vaccination 1	The vaccination program
Vaccination 2	A second vaccination program
9dherd.xls	
Herd inputs	The number of animals in each age/sex category (herd structure)
9fcalc.xls	
Wt lost males	The weight lost and not regained by time of marketing (males)
9ffcalc.xls	
Wt lost females	The weight lost and not regained by time of marketing (females)
9gcalve.xls	
Calving inputs	The proportion of animals that would have calved that do not due to disease
10prices.xls	
Prices benefits	Prices of stock
Prices costs	Vaccination costs
Dx and Tx	Costs of diagnosis and treatment
10cba.xls	
Disc rates	Discount rates

APPENDIX 6: COMMUNICATION

Project publications

- Conference paper: Australian Veterinary Association 1997 Conference
- Bock RE, de Vos AJ, Rayner AC, Lehmann W, Singh S and Molloy JB. Assessment of the risk of tick fever mortalities in the north-western Queensland beef industry. In Proceedings 1997 Challenging the Boundaries, Australian Association of Cattle Veterinarians 1997 175-182.

Submitted publications:

- Bock RE, de Vos AJ, Kingston TG, Standfast NF. Effect of cattle breed on innate resistance to *Babesia bigemina*. *Aust Vet J* 1999; In Press.
- Bock RE, de Vos AJ, Kingston TG. Effect of breed of cattle on transmission rate and innate resistance to infection with *Babesia bovis* and *B bigemina* transmitted by *Boophilus microplus*. *Aust Vet J* 1999; In Press.
- Bock RE, de Vos AJ, Kingston TG. Effect of breed of cattle on the transmission rate and innate resistance to infection with *Anaplasma marginale* transmitted by *Boophilus microplus*. *Aust Vet J* 1999; In Press.

Field days

Date	Location	Nearest Town
April 97	Alroy Downs	NT
March 98	2 field days	Dalrymple shire
April 98	Swans Lagoon	Ayr
August 98	Gregory Downs	Burketown
September 98	Kalmeta Station	Julia Creek
October 98	Inkerman Station	Normanton
November 98	Burleigh Station	Richmond
May 99	Mt Sturgeon Station	Hughenden
May 99	Compton Station	Richmond

Press releases/newsletters

- Beef Improvement News July 1998. Assessment of the risk of tick fever mortalities in the north-western Queensland beef industry
- Animal Health News from the Northern Territory. Tick Fever - Assessing the risk. January 1997.
- Pastoral Memo, Kimberley Pastoral Region May 1998 on tick fever and live exports.
- Radio interviews were also given on ABC regional radio on 6 occasions.

Training

Specialist training in tick fever has been carried out for a number of stock inspectors located in Northern Queensland to assist with the MRC project especially the extension of information gathered as part of the project. This involves a 3-4 day intensive training program conducted at TFRC. It is planned to continue this in the future and invite participants from the Northern Territory and Western Australian Departments of Agriculture to participate with the next course scheduled for June 1999. In this way northern producers will have access to the best information regarding tick fever risk assessment and control options.

Northern Stock Inspectors with specialist training in tick fever		
Name	**Location**	**Date of course**
Warren Lehmann	Blackall	March 1996
Ted Vinson	Charters Towers	March 1996
Greg McDougall	Malanda	March 1996
Dave Doyle	Julia Creek	May 1998
Ben Mason	Georgetown	May 1998
Rod Robertson	Normanton	May 1998
Shane Laffey	Cloncurry	Nov 1998
Ed Beekhuizen	Richmond	Nov 1998
Steve Anderson	Townsville	Nov 1998
Glen Sibson	South Johnstone	Nov 1998
Lyle Torenbeek	Bowen	Nov 1998
Dan Hogarth	Mareeba	Nov 1998
Howard Smith	Malanda	June 1999
Ted Martin	Tennant Creek (NT)	June 1999
Greg Scott	Katherine (NT)	June 1999
Jim Kerr	Derby (WA)	June 1999