



Theileria Veterinary Handbook 2

Ministry for Primary Industries
Manatū Ahu Matua



NZVA
New Zealand Veterinary Association

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Introduction

Theileria Veterinary Handbook 2, August 2015

By editors Andy McFadden (MPI) and Roger Marchant (NZVA)

Since *Theileria orientalis* Ikeda type was first identified as a new disease problem many veterinarians have been to the fore: in developing treatment options when dealing with clinical cases; in working closely with MPI investigations of the disease; in development of strategies to manage the disease at the herd and regional level; and working closely with other industry players.

Theileria-associated bovine anaemia (TABA) will continue to have an impact on cattle farming for some years to come. The *Theileria Veterinary Handbook Two* is designed as a “ready-to-use” reference for veterinarians (and others) advising clients on management of TABA and contains a number of articles and resources that have been published over the last 12–24 months.

Since the initial diagnosis of TABA, the *Theileria* Working Group (with representatives from MPI, NZ Beef + Lamb, Fonterra, DairyNZ, AgResearch and the NZVA) has been formed to look at all aspects of TABA, with a particular focus on practical management options. Over the 2–3 years that the group has been together we have had a very productive relationship. We have built on the strengths of both government and industry and have sought to investigate, and to inform, educate and formulate tools and ideas to assist with decision-making and management of the disease at the farm level. In many ways the NZ theileriosis epidemic is a case example of how government and the wider industry can work together to manage a complex animal disease problem.

The tools developed have included laboratory molecular tests, risk management advice based

on cattle age, class, location and movement; the FANI card as a diagnostic aid, predictive modelling on the epidemic, and numerous publications and information-sharing workshops.

The future challenge remains around managing a disease where impacts are not always obvious, where the enthusiasm to report outbreaks will wane and become increasingly hidden through the transition of the disease to an endemic state. In the short to medium term the effects of the low dairy pay-out may result in less veterinary involvement at the farm level and potentially exacerbate any effects of reduced reporting on surveillance.

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Theileriosis – Management of the acutely affected herd

Author: M Love

The scenario of the acutely affected herd can occur where a previously naïve herd is first infected; clinical incidence of severely affected animals can be high. In this scenario often farmers may have minimal base knowledge of the disease.

The most at risk groups are newly infected, calving, dairy cows and/or previously naïve cattle moved into endemic/stable areas.

In Northland we have also witnessed outbreaks in beef calves, approximately two – four months old. Although the exact reasoning as to why this cohort is at risk is still under debate. Beef calves could potentially be an 'outbreak group' that occur elsewhere in the country as the endemic margins of theileriosis spread.

As vets we are all well versed in disease management; however, below are some extra notes to consider in an outbreak of theileriosis:

1. CONFIRM DIAGNOSIS

- Initially take bloods and measure PCV of affected animals to confirm anaemia (PCV<24%). Ideally use a portable centrifuge on farm to hasten diagnosis. This, in combination with clinical history of cattle movements (or neighbouring outbreaks), and clinical picture of lethargic, down +/- dying animals, is enough to give a preliminary diagnosis.
- Later, send blood samples for *Theileria* ikeda PCR and rule out other (or possibly concurrent) diagnoses including Facial eczema, Copper toxicity, Leptospirosis, BVD, etc.

2. MAKE A PLAN

- Spend quality time with the farm manager “around the kitchen table” explaining the disease and putting together a plan for the days ahead
- Putting together a flow chart for treatment of clinically affected animals can help the farmer

with decision-making, i.e. has she calved, is she down, how old is she, how anaemic is she, does she have any other problems? etc. which lead to what treatment(s) she will receive.

- For the herd, implement de-stressing interventions such as: once-a-day, skip-a-day, or no-milking mobs; once-a-day milking of the colostrum mob; extra feeding and shelter, etc.
- Consider a monitoring regime for at risk animals, i.e. regular repeat FANI scoring (or in the future perhaps bulk blood testing). Screening animals for anaemia and then treating early will help improve outcomes.
- Revisit and tweak this plan initially daily, and later as needed depending on how the outbreak progresses.

3. REMEMBER THE PEOPLE BEHIND THE OUTBREAK

- As with any major event affecting animal health, empathetic support to the farmer and staff is very important. As the initial infection of the herd has occurred long before cases appear, your biggest role is to guide the farmer through management of the disease, minimising losses and helping them get the affected mob back in order for future mating/growth.
- Communicate with all those secondary parties available to help secure more information and/or assistance where required. This includes other experienced vets country-wide, neighbouring vets, DairyNZ (including their emergency response service), MPI and the NZVA.

4. GET STUCK IN

- Mobilise several staff to attack the immediate case load. Even so this may take several days.
- Use your plan to check clinical cases choosing either euthanasia, aggressive treatment, or supportive care.
- Continue to advise on herd options and monitor new cases as they occur. Once the peak of parasitaemia and underlying stressors have passed the worst is over; then it is just a matter of getting things back on track.

Treatment options for clinical cases

Blood transfusions – are rewarding and beneficial in anaemic animals that have no other infections/complications. Sourcing blood can be difficult in an outbreak because of the volumes of blood required. I have used mass bleeding of local endemic cattle, catching blood from a home kill slaughtered beast, and via the local meat works – all have pro's and con's and all worked. Use the source most convenient to you. Use the resources on the NZVA website for a transfusion 'how to' guide.

Buparvaquone – essential and beneficial in non-lactating animals, particularly beef calves, and can be given in conjunction with a blood transfusion. Mass dosing of those at risk (i.e. a bought in beef-mob or dairy yearlings) to prevent further disease is also a good option. BPQ is difficult to justify in a lactating dairy cow because of the milk withholding period; although the use of it should still be discussed.

Antibiotics – are of no direct benefit. They should only be used in treating concurrent infections, i.e. metritis. If required then use the oxytetracycline family, I prefer drugs able to be given SQ.

Vitamin and mineral support – B group vitamin supplementation is advised for general support and anaemia recovery, although not essential.

Euthanasia – should be considered for anaemic cattle with other complicating problems, i.e. met-

ritis after calving or being down for several days.

Tickacide pour-ons – will have no effect on clinical cases as the inciting infection happened 1–2 months ago. Even whole-herd treatment is of little use in an outbreak situation.

Take home messages

- Be prepared to do blood transfusions. Have the equipment, sodium citrate, and even a laminated 'how to' card ready to go in the clinic.
- A fantastic reason to invest in a small, portable, centrifuge for on-farm PCVs.
- Record EVERYTHING – all cows treated and tested, and their outcomes.
- Stay involved – a farmer that decides not to treat clinical cases will still need assistance as the season progresses.
- In a severe outbreak it is likely numerous cattle deaths will have occurred – be very mindful of the huge stress and tension this creates for the farmer, their family, and their workers. This is where talking over options, liaising with those around you and setting a plan of action is essential.



Diagnostic tree for anaemia in cattle

AMJ McFadden, J Thompson, M Love

ANAEMIA PRESENT AND CLINICAL SIGNS INCLUDING:
lethargy/depression, pale/white/jaundiced mucous membranes,
fever, possible haemoglobinuria

Regenerative anaemia

1. Is *Theileria* present on a blood smear or detected by PCR?

2. Is there evidence of haemorrhage?

Trauma or haemorrhage into the body cavities and lungs?

3. Are cattle acutely affected with signs of haemolytic anaemia?

Cu toxicity (Kidney copper levels most diagnostic or check serum/liver levels), post-parturient haemoglobinuria (Low PO₄; check levels), Check ration (Onions? Brassicas? Heinz bodies present on the blood smear?); Leptospirosis (vaccinated? High titres or rising titres?; Pomona mostly affects calves rather than adults).

Acute facial eczema (some animals may have haemoglobinuria; check liver enzymes).

Bacillary haemoglobinuria (Germination of *Clostridium hemolyticum* spores secondary to liver damage, e.g. from migrating liver fluke; very rare).

4. Is more than one animal affected?

If only one animal, Autoimmune haemolytic anaemia? (drugs administered recently?; very rare).

5. Is there a heavy burden of ticks present ?

Particularly in calves check around the neck on white patches.

6. Are there other agents or conditions or a history suggestive of secondary theileriosis?

BVD Ag test on affected animal (+/-Pooled herd/mob antibody test), Management stress through weaning or calving etc, Movement of cattle to or from Northland.

Non-regenerative anaemia

1. Is *Theileria* present on a blood smear or detected by PCR?

2. Are cattle in good condition?

(Cu, B12, Se deficiency; Check levels), Renal disease, Liver disease (Is it a facial eczema or liver fluke area; serum biochemistry/faecal egg test), Chronic disease (Johnes, parasitism).

3. Are only young animals affected?

Genetic disorders (e.g. congenital dyserythropoiesis in Polled Herefords and Murray Grey calves; often apparent from six weeks of age).

Coccidiosis (mild to moderate diarrhoea and weight loss; oocysts in faeces).

4. Are any metabolic disorders present?

(Mg deficiency "Taranaki anaemia").

Treatment and impact of *oriental theileriosis*: Notes from an Australian and New Zealand *theileriosis* workshop, Brisbane 29 May 2015

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***Oriental theileriosis* (*Theileria*-associated bovine anaemia: TABA) has become a significant disease for cattle production (both dairy and beef) in Australia and New Zealand over recent years. Dealing with an emerging condition has not been straightforward and has required development of a number of diagnostic tools, and clinical and herd management strategies. Understanding the epidemiology of the disease has been a key part to mounting an effective biosecurity response. Response experiences to date from both Australia and New Zealand provide a useful platform to build on for future control.**

In New South Wales (NSW), Australia, anecdotal reports indicated that outbreaks may have first occurred in February 1999 (there was another report of an outbreak of anaemia in NSW, October 2003). In addition to these there were some unsupported reports in Victoria from the 1980s and Queensland in 1966. However, clinical disease only occurred sporadically until 2006 from when a series of outbreaks were observed. The first official recognition of outbreaks in Victoria was in 2010; and in New Zealand (Northland region) August 2012; Western Australia in 2013; South Australia and New Caledonia in 2014. Cattle imported into Australia from Guam (originally from Japan) could have provided a pathway for introduction of the Ikeda strain into Australia.

The following notes are provided as an output from a workshop aimed at sharing information from Australian and New Zealand disease control experts on *oriental theileriosis*. Notes are focused around treatment and impact from the disease and reflect the experiences, opinions and observations of those attending the meeting, some of which will need further testing within a research environment.

1. Treatment of *oriental theileriosis* PHARMACEUTICALS

Buparvaquone (BPQ): The withholding periods for BPQ have a long duration and are based on the limits of detection. The meat residues in particular from BPQ have a long decay curve that is of concern because of the potential international trade impacts if residues were detected. Thus the decision when to use the drug must be carefully considered. There are a number of NZ government regulatory requirements that must be undertaken as prerequisite for using Buparvaquone as a treatment for *theileriosis*. Please refer to <http://www.foodsafety.govt.nz/elibrary/industry/ap-notice-specs-for-animals-treated-with-boparvaquone.pdf>. The true benefits of using BPQ and how to maximise the efficacy of its use need to be further clarified. If BPQ is truly an effective treatment there are animal welfare issues in leaving affected animals untreated for purely economic considerations. Use of the drug in New Zealand (the drug is not available for clinical treatment in Australia) could be considered under the following circumstances:

Treatment of clinical anaemia or acute disease:

- Limited trial work (both in Australia and New Zealand) has shown some effect from treatment of the clinically-affected animal. However, the efficacy may depend on when

the animal is treated during the clinical course of the disease. Efficacy is likely to be greater early in the course of the disease versus when animals are showing overt clinical signs.

Anecdotal reports from the field support this view. In order to detect and treat early-affected animals intensive surveillance is necessary e.g. using active monitoring of the levels of anaemia of individual cattle through measuring packed cell volume (PCV (or haematocrit), the NZ FANI card, and PCR of blood collected from at-risk cattle. This type of monitoring is only possible on intensively-managed dairy farms.

- It is also important to consider the efficacy of a one-off treatment versus multi-treatments (2 to 3 treatments) at 48-hour intervals.
- The economic value of treatment using BPQ may be limited in many situations due to the long withholding periods (particularly in dairy cattle) i.e. 42-day milk withholding and 18-month meat withholding period in NZ (although this will obviously vary with factors such as the dairy pay-out and meat schedule).

Prophylactic treatment:

- In endemic (stable) regions where calf disease commonly occurs, calves could be treated prophylactically between 2–5 weeks after potential exposure (Potentially reducing peak parasitaemia levels whilst allowing an immune response to occur). There are anecdotal reports that treatment of calves with Baycox (Toltrazuril; Bayer) around the same time may also be beneficial. Further trial work is necessary to understand the efficacy of both treatments either in combination or sole use.
- Naïve cattle (determined from pre-movement testing) moved into an endemic area (including bulls or high value stud animals) could be treated 2–5 weeks after likely exposure. Some consideration must be given to the animal welfare aspects of knowingly causing disease by moving animals into a situation where

disease is likely to occur as a result of that movement (particularly when that movement occurs in pregnant cattle within a couple of months prior to the calving period).

Other pharmaceuticals that could potentially play a role in treatment (but need further work-up as to their suitability and efficacy) include:

- Baycox (Toltrazuril; Bayer), Erythromycin, BPQ with Primaquine (used for the treatment for human malaria). Anecdotal reports were given that there had been some success in treating calves prophylactically with Baycox at around three weeks of age.
- In general, oxytetracyclines as a treatment for the acute case have not been found to be effective by either Australian or New Zealand clinicians.
- Limited field studies by both Australian and New Zealand researchers did not show a beneficial effect from the use of Imidocarb for treatment of clinical cases.

ADJUNCTIVE TREATMENT OF THE ACUTE CLINICAL CASE

Adjunctive treatment options include:

- **Blood transfusion** in clinically-affected adult cows, especially with a PCV <12%. Blood transfusions have been used successfully if used early in the disease. Transfusions have not been entirely successful in beef calves because of the stress induced from being captured and restrained. The delay between diagnosis and treatment in calves may also contribute to the lower efficacy of treatment.
- **Temporary fencing/confinement/bedding:** the aim being to reduce movement and stress.
- **Reduce frequency of milking** in dairy cattle to once per day or every second day. In extreme cases dry cattle off.
- **Other ancillary treatments** including B vitamins, NSAID anti-inflammatories. However, it is unlikely that these will have any significant effect on clinical recovery.

- **Steroids** have also been suggested; although there is no evidence that these will be effective. A small field trial in NZ using non-immunosuppressive doses of steroids did not show these to be effective.

OTHER OPTIONS FOR FUTURE CONTROL

Acaricides: The use of acaricides was considered unlikely to prevent infection of cattle and resulting disease. Their use for prevention and control must be tailored for the specific circumstance. It is possible that tick control in many instances may not be an appropriate strategy because only low tick numbers may be necessary for transmission of infection. Treatment of service bulls used in endemic areas would seem to be appropriate general advice; however, it is not known whether this will be truly efficacious in preventing disease in these animals. There may also be application for treatment of cattle moved from areas where ticks are endemic to areas where ticks have not established, but have the potential to do so.

Stock management: There is no clarity on the role of other management techniques such as using other livestock as “vacuum cleaners” or calving onto clean ‘tick free’ pasture etc. The reason for uncertainty relates to our lack of understanding on the number of ticks required to induce infection (and more importantly disease) and the impossibility of preventing wild hosts from bringing more ticks on to a property

Biosecurity: There is a need to increase the level of farm biosecurity. Educating farmers, using oriental theileriosis as an example, may be a way to improve understanding of biosecurity.

- In surveys carried out in Australia, farmers rated biosecurity of low importance in comparison with other issues. At present the private veterinarian is the key provider of biosecurity advice, however, it is difficult for veterinarians to get an economically sustainable return for this service.
- Testing of livestock pre- and post-movement provides an opportunity to understand risk

and potentially mitigate introduction of Ikeda, or understand risk of certain movements. Management of various scenarios of livestock movements have been provided in the *New Zealand Veterinary Handbook*.

Immunity from other strains: There has been some speculation that prior infection with *Theileria orientalis Buffeli* may be protective for clinical disease associated with infection from the Ikeda type; however, this has not been tested and further work is necessary to investigate whether there is any real effect.

Vaccination: Possibly has a role in the future; however, there is no commercial vaccine currently available for oriental theileriosis. Literature on human malarial approaches may be of value.

- Experimental work in Japan has shown that a recombinant vaccinations made from the piroplasm surface protein (MPSP) and the whole piroplasm respectively have been partially protective. A vaccine using a sporozoite stabilate was found to be protective but was not commercialised. This is a further avenue for research.



Developing technology to determine herd status through bulk-milk testing may be of value.

- Given the unchecked movements of livestock between herds of varying status it may be difficult to interpret a positive or negative herd test i.e. a positive PCR could mean that a herd has positive animals introduced into the herd from an endemic region rather than infection of animals in that herd has occurred. Interpretation of results and planned actions (depending on aims for testing) may require understanding the approximate prevalence of infected cattle within a herd. Thus further testing of a sample of animals may be necessary.

2. Impacts

The cost to the economy of oriental theileriosis in both New Zealand and Australia has not

been calculated. Determining this underpins any future control actions taken and funding for research on how to manage the disease. In some acute outbreaks costs have been calculated (e.g. \$NZ 1 million on one large NZ dairy farm where naïve cattle were moved to an endemic area); however, the distribution of economic impacts across affected herds has not been determined. This will presumably be skewed towards low economic impacts being the most likely scenario with a few herds having significant impacts. In addition to the impacts in an acutely affected herd the impacts in chronically affected herds have not been determined.

At the individual cow level, physiological stress is a major determinant of whether disease occurs. Australian observations have been that in endemic regions pregnant heifers and young calves are generally the most severely affected. Other factors such as the total Ikeda parasite load and continual exposure of cattle to the Ikeda type may be important in determining the severity of disease. It is not known if there is a protective effect of cattle breed outside of the Wagyu breed of cattle.

In New Zealand, differences in the speed of recovery of cattle affected with oriental theileriosis within areas of different levels of tick infestation have provided evidence that ongoing challenge may influence the duration that animals are clinically anaemic. For instance in Northland, NZ (an endemically affected region) one study showed that cattle remained anaemic for up to eight months whilst in the West Coast, South Island, NZ where ticks were relatively scarce, cattle returned to a normal haematocrit within a matter of weeks. A field trial in Australia showed that the severity of disease in calves was determined by the dose of parasite (injected as a blood bolus from an acutely affected cow). There have been observations of other effects such as an increase in mastitis; however, these have not been studied under controlled conditions. Outside of clinical



effects from oriental theileriosis, concerns were raised regarding potential impact of the disease on international trade of cattle from the disease.

It was considered important that veterinarians provide good advice regarding the risk of moving naïve cattle to endemic regions. There was concern that endemic stability may not occur in a number of regional areas in Australia (and NZ), e.g. where tick challenge varies by year.

Key risk factors for cattle herd impacts were considered to be:

- Introduction of naïve animals.
- Cow health and condition e.g. impact from other diseases, e.g. BVD or facial eczema, herd immunity.
- Stage of the reproduction cycle e.g. significant impacts at the time of calving.
- The age of animal i.e. young calves and pregnant heifers vs. mixed-age cows.
- The level of vector activity.
- The presence of wildlife or vermin.
- Environmental stressors e.g. inclement weather, climate.
- Nutritional stressors (e.g., as trace element deficiencies) occurring at the time, and transitional feeding management if outbreak occurs in spring.
- Other environmental conditions such as soil types or presence of watercourses.
- General standard of stock husbandry.

REPRODUCTION

There was concern that movement of infected cattle to unaffected districts (where ticks present; endemically unstable regions) was undermining the reproductive potential of unaffected districts.

In the naïve herd there may be a significant impact at the time of calving through fetal hypoxia with subsequent death of the calf. Metritis in the cow can follow. The more important impact

can be from a higher cow mortality rate. The factors determining why a large number of cattle are affected in one herd but not in another (where there appear to be no obvious differences between herds) are not clear.

- In Australia mixed infections of *Babesia* and *Anaplasma* can occur in the same areas that *Theileria* is endemic. This can mean that making a diagnosis can be difficult.
- As *oriental theileriosis* is a diagnosis of exclusion there is a risk that anaemia caused by other agents can wrongly be assumed to be caused by Ikeda given that (in NZ) this is now the predominant cause of anaemias in cattle.

An Australian field study found that the effect on reproductive performance was mainly in clinically-affected animals. In NZ it was observed that oestrous may be delayed in affected cattle. Some participants believed that reproductive performance was apparently impacted for two seasons subsequent to animals being clinically affected; whilst others did not believe that there was a long-term impact on reproduction. It is likely that any impact is affected by the severity of disease (and possibly ongoing challenge as well as interactions between the disease and other factors).

The effect from ongoing challenge is not known; however, recrudescence has been shown where animals are placed under stress. The ongoing impact from oriental theileriosis in an endemically-affected herd is not known.

There may also be an indirect effect through service bulls being affected during the mating period. It is not known how long any effect on reproduction performance of male animal lasts.

The effect from infection can be variable depending on the period and severity of anaemia. The PCV may be a guide as to whether any effect is still occurring; however, we don't know for sure how long production is affected.

BEEF CATTLE PRODUCTION

The impact on beef cattle production maybe a one-off or sporadic event; although as with dairy any long-term effects have not been measured. The greatest impact is when disease occurs at the time of calving.

The experience of one Australian practitioner was that approximately 50 percent of naïve cattle infected with the Ikeda type were culled in the first 12 months after an outbreak.

Observations from a small field trial in Australia were that calves positive for *Theileria* were smaller in size than those negative. There has been little study into the period that production effects last.

The impact in calves seems to relate more to the severity of disease than the age at which calves are affected; although disease is generally seen in calves when they are 6–8 weeks of age. Disease in this age of animal implies that these cattle have been infected soon after birth. The impacts are hard to quantify due to extensive nature of beef cattle farming. However, in some Australian cattle herds, field experience indicated that there can be mortality of up to 10–15 percent of calves.

In New Zealand beef calves are approximately eight times more likely to be affected than dairy calves. Some reasons for this observation could relate to a later calving pattern in beef cattle, resulting in exposure of beef calves at the time of birth. Low rates of disease in dairy calves also suggest that housing calves may have a protective effect.

- The first high risk period is when infected nymphs come out of diapause in July and the second from infected adults in October.

To limit the impact it is very important not to shift livestock from non-endemic areas to endemically-affected areas.

ANIMAL WELFARE

There is an animal welfare issue by knowingly causing harm to livestock by bringing naïve livestock into endemically-affected areas.

Severely anaemic and/or downer animals need to be managed appropriately. It is important to make the decision to euthanase severely affected cattle early (development of a euthanasia decision tree may be a useful resource) and to manage the perceptions of the public observing a large number of sick, suffering and downer animals.

It is important to consider human welfare for those people under high stress that have to deal with a large number of sick and dying animals. Farmers may also be affected where the disease is diagnosed in non-endemic area, i.e. ostracized etc.

SOCIAL

Social impacts (on affected farmers and staff dealing with significant outbreaks) were considered significant but often ignored when the importance of the disease was considered.

ACKNOWLEDGEMENTS

The authors acknowledge the free and frank discussion of those veterinarians, scientists, and researchers that made contributions to the Australian and New Zealand *Theileria* meeting on 29 May 2015.

***Theileria*-associated bovine anaemia (TABA) decision support tool**

Author: D Vink

The purpose of this tool is to provide guided recommendations for control of *Theileria orientalis* (Ikeda) associated bovine anaemia (TABA). It is aimed primarily at farmers.

The tool follows a sequential series of steps to provide 'best practice' recommendations, based on current knowledge and understanding of the disease.

The prototype of the tool is available at <https://www.surveymonkey.com/s/3ZNZFLJ>.

Definitions

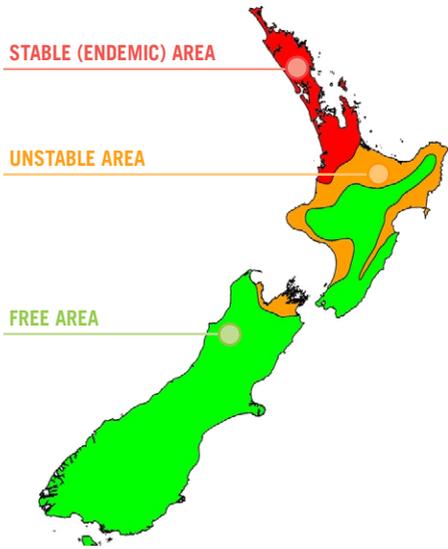
We subdivide the country into three general zones, based on our current knowledge of tick distribution and farms on which the disease has been confirmed.

The definitions for these areas have been based on current best information. This information has been derived from literature on *theileria* diseases elsewhere in the world (primarily in

Africa), as well as our experience of the disease in New Zealand.

Please note, however, that our scientific understanding in New Zealand is still very incomplete, due to the recent emergence of the disease. Consequently, we consider these to be working definitions; they are likely to be modified as better information becomes available.

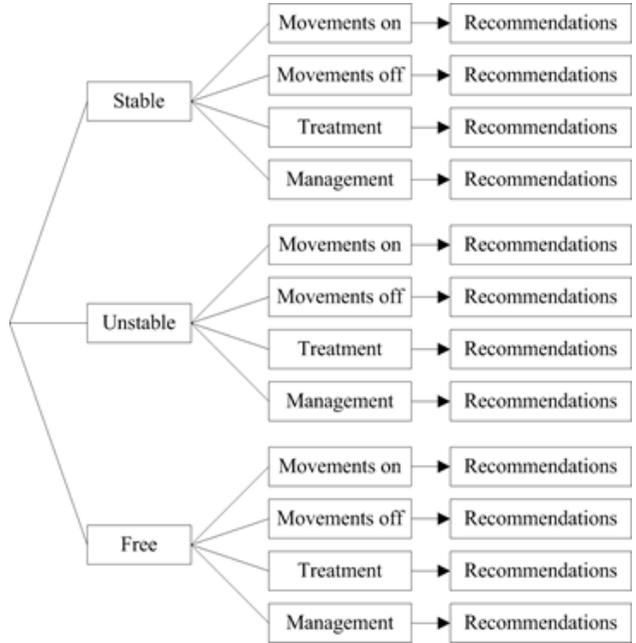




<p>STABLE (ENDEMIC) AREA</p>	<p>Every animal will become infected. This means that they carry the parasites in the blood. It does not mean that every animal will become diseased – only a subset will show clinical signs.</p> <p>After the initial epidemic spread, the disease reaches equilibrium.</p> <p>Subsequently, serious clinical disease in resident herds with no imports is unlikely in any animals except calves. It is possible that infected cows may develop episodes of disease during high-stress periods e.g. calving season.</p> <p>Predictability of disease is relatively high.</p> <p>Overall, there is NOT more disease in these areas than in endemically unstable areas, even if no tick control is practised.</p>
<p>UNSTABLE AREA</p>	<p>Animals may become infected depending on tick presence and activity (which will vary from year to year).</p> <p>Equilibrium is not established. Characterised by sporadic, prolonged outbreaks, with variable impacts.</p> <p>New disease cases will occur in adults as well as calves. Overall, may get more disease than in endemically stable areas.</p> <p>Predictability of disease is relatively low.</p> <p>Ticks fluctuate, but low occurrence overall. Increased risk when drought is followed by a warm winter.</p>
<p>FREE AREA</p>	<p>Ticks are assumed to be absent, or tick populations can't persist due to environment, so no disease is present.</p> <p>Imported disease is limited to individual cases and cannot be sustained (spillover infection).</p>

Recommendations

This chart shows the categories of actions for which recommendations have been developed, for farms in the three zones. Note that no specific recommendations have been formulated for dairy or beef farms.



STABLE AREA

Movements on

All animals bought in should be considered to be at risk of disease.

- The further the source herd is from the destination herd, the higher the risk is likely to be.
 - High-performing animals from free and non-stable areas moving into stable areas are at particularly high risk and **you are strongly recommended not to bring in pregnant heifers and cows from tick-free areas**. There is a very high risk of financial and welfare issues, on the short term as well as longer term.
 - If movements from free and non-stable areas need to be carried out, do this in a low risk season (if possible!). Avoid the spring and autumn calving periods.
-

Pregnant cattle are at highest risk. Other stock classes appear not to be as heavily affected.

- The disease impacts appear to be somewhat less for calves and non-pregnant heifers.
 - Movements of non-pregnant heifers are of relatively high volume but do not appear to cause as many problems.
 - Monitoring is strongly recommended, particularly if the cattle are moved from unstable or free areas.
-

Pre-movement tick treatments of susceptible cattle cannot be relied on to prevent clinical disease.

- Inspection for ticks is not a good indicator of whether cattle have been exposed, as the ticks may be difficult to see and exposure may have occurred previously.
 - To understand the status of a mob of cattle, testing of blood (rather than insisting on acaricide treatment) may be more effective. A pooled sample of a subset of animals is sufficient to establish whether the mob has been exposed to *Theileria*.
-

Movements off

The cattle you sell or move off may pose a risk for the destination herd.

- The further the destination herd is from your herd, the higher the risk is likely to be.
 - As a general rule, the risk increases for moving cattle within stable areas => from stable to unstable areas => from stable to free areas.
-

Pre-movement tick treatments of cattle you sell or move off cannot be relied on to prevent clinical disease at the destination.

- If the cattle you sell or move have been exposed and infected, they are likely to carry the parasites for life – that is, they will permanently represent a potential source of infection for other cattle at their destination.
 - The buyer/recipient may insist on pre-movement tick treatment, but this will only block transmission if:
 - it eliminates all ticks (i.e. is totally effective); and
 - there are no ticks at the destination.
 - If the buyer/recipient wants to know the status of the animals to be moved, inspection for ticks is not a good indicator of whether the cattle have been exposed, as the ticks may be difficult to see and exposure may have occurred in the past. To understand the status of a mob of cattle, testing of blood (rather than insisting on acaricide treatment) may be more effective. A pooled sample of a subset of animals is sufficient to establish whether the mob has been exposed to *Theileria*.
-

Treatments

Tick treatment aims to control exposure.

- In stable areas (i.e. where ticks and disease are both present continuously), tick treatment will **not** block transmission.
- However, if ongoing exposure results in prolonged disease, treatment may be useful to reduce the infection pressure.
- The benefit is dependent on the level of tick burden (i.e. how many ticks are present) and field challenge (i.e. what proportion of the present ticks are infected).

Tick treatment requires careful management.

- Proper application is labour-intensive and must be performed correctly if it is to be effective.
- As a measure of 'best practice', treatment prior to transporting animals out of stable areas is recommended if they are moving to unstable or free areas. Note that the recipient should be aware that
 - infected cattle will continue to carry the parasite in the blood; *and*
 - this is unlikely to remove all risk for transmission of disease to susceptible cattle at the destination.
- Treatments may be prioritised depending on the number and value of the cattle (e.g. stud bulls).

Management and husbandry

Ensure general husbandry and management are good.

- Particularly in high-risk periods (e.g. spring and autumn calving).
- Be vigilant: perform screening at strategic times.
- Ensure stress on animals is minimised, that adequate food is provided and any other health issues receive prompt treatment.

Know the disease.

- Work with your vet to develop a farm management plan.
 - Know what to look for, and where and when to get advice.
 - Make sure staff know the signs of disease and take action.
-

UNSTABLE AREA

Movements on

Know your status.

- As unstable areas are not as clearly defined, not every farm will develop disease.
- Finding out is important to inform your strategy for buying stock. Speak to your vet: testing a pooled blood sample of 25–30 animals *or* 10% of the herd/group (depending on what's most appropriate) will determine your status.

Testing for different *Theileria* strains, in combination with information on your tick status, determines your recommendations.

- As your situation varies from year to year, it is relatively complex. If you've had cattle with disease, you are likely to have periodic problems with disease; this may vary from year to year and can't be easily predicted.
- In terms of recommendations, if you have:
 - **Ticks present and cases of disease**, your movement recommendations are similar to those for stable areas;
 - **Not seen any ticks but you have cases of disease**, either they are present and you haven't been able to find them, *or* they are temporarily absent (depending on season and environment) *or* the disease is a consequence of diseased animals having been moved onto your farm. See movement recommendations for stable areas;
 - **Ticks present but no disease**, you meet the criteria for getting the disease on your farm. Hence you are at high risk and are likely to get the disease eventually. You may wish to purchase stock from free areas to preserve your status for as long as possible;
 - **No ticks and have not had disease**, your status is closer to a free area (even though you are in an unstable area). Diseased animals purchased from a stable area should not be able to infect resident stock. However, ticks may be present but unnoticed, so purchasing stock from free areas is recommended.

Movements off

There are risks associated with selling or moving off cattle, to stable areas as well as to free areas.

- If the destination is in a *free area*, the cattle you sell or move may be a source of disease and infect stock in the receiving herd.
- If the destination is in a *stable area*, and:
 - the cattle you sell or move *have been exposed* to disease already, there should be few problems;
 - the cattle you sell or move *have not been exposed*, they are at risk of developing disease.
- Therefore, in both cases, pre-movement tick treatments and post-movement vigilance are recommended.

Pre-movement tick treatments of cattle you sell or move off cannot be relied on to prevent clinical disease at the destination.

- If the cattle you sell or move have been exposed and infected, they are likely to carry the parasites for life – that is, they will permanently represent a potential source of infection for other cattle at their destination.

- The buyer/recipient may insist on pre-movement tick treatment, but this will only block transmission if:
 - it eliminates all ticks (i.e. is totally effective); and
 - there are no ticks at the destination.
- If the buyer/recipient wants to know the status of the animals to be moved, inspection for ticks is not a good indicator of whether the cattle have been exposed, as the ticks may be difficult to see and exposure may have occurred in the past. To understand the status of a mob of cattle, testing of blood (rather than insisting on acaricide treatment) may be more effective. A pooled sample of a subset of animals is sufficient to establish whether the mob has been exposed to *Theileria*.

Treatments

Tick treatments are specifically important in this case.

- As tick presence is not constant, a strategic approach is required: control is desirable in times when ticks are present and active, but not required when no challenge.
- As the disease is present in the area (albeit sporadically), your herd will develop disease sooner or later. The objective is to delay this while possible, and subsequently mitigate or reduce clinical impact.

A standardised recommendation may be required when there is not enough knowledge on tick presence and activity patterns to provide specific recommendations.

- The aim is to provide cover during the period:
 - when ticks are most active, i.e. in which there would be the highest risk of challenge, if ticks are present;
 - when the cattle are most susceptible for developing disease.
- General recommendations are to provide a safety net or insurance policy by treating:
 - all stock from 1 month pre- to 1 month after calving; plus
 - all incoming bulls;
 - at least twice, 3-4 weeks apart.

Management and husbandry

Ensure general husbandry and management are good.

- Particularly in high-risk periods (e.g. spring and autumn calving).
- Be vigilant: perform screening at strategic times.
- Ensure stress on animals is minimised, that adequate food is provided and any other health issues receive prompt treatment.

Know the disease.

- Work with your vet to develop a farm management plan.
 - Know what to look for, and where and when to get advice.
 - Make sure staff know the signs of disease and take action.
-

FREE AREA

Movements on

Incoming movements are relatively low-risk.

- If infected cattle carrying the parasites are imported, they may develop disease:
 - if they are tick-free, imported cattle cannot infect resident stock;
 - if they do carry ticks, it is possible that these ticks can infect resident stock; hence it may be recommended to have the cattle treated prior to shipping them in.
- However, as your area is tick-free and it is therefore assumed that conditions do not exist for viable tick populations to become established, this is 'dead-end' infection and will eventually be extinguished when the tick vectors die.
- Repeated introductions of infected cattle could lead to situations in which it appears that the disease has become present in a free area, but as there is no true transmission of infection, this is not the case. We call this 'spillover' infection.

It is possible that the tick distribution patterns are changing.

- A combination of factors may be contributing to the current, understood tick distribution areas to be expanding:
 - increasing frequency of livestock movements (including deer), potentially carrying ticks, from the North to South Island;
 - changing agricultural practises such as irrigation on the South Island;
 - climate changes, such as milder temperatures.
- If this is the case, we expect the geographical range of disease to expand too.
- However, our current understanding of this is poor.

Given the above, the same precautions apply as in other areas.

- For example, vigilance, good husbandry and management, and appropriate treatment if the disease does become manifest.

Movements off

Outgoing movements to other free *Theileria* areas should not be problematic.

In contrast, outgoing movements to stable and unstable *Theileria* areas are of critical concern, and should be avoided if possible.

- The cattle will be susceptible and are at high risk of developing severe clinical disease after movement.
- The further the destination herd is from the source herd, the higher the risk of disease is likely to be.
- The destination of the cattle should be to limited to free areas unless absolutely unavoidable.
- Considerations may include the following:
 - size of the consignment: consequences are likely to be more severe when the consignments are larger due to a reduced ability to provide one-on-one care to individual animals
 - age and physiological status: disease impacts appear to be somewhat less for calves and heifers; heifer movements are of relatively high volume but do not appear to cause as many problems, even to areas in which *Theileria* is present;
 - value of the animals: for high-value breeding stock, numbers are likely to be smaller and scope for precautions and monitoring (see below) is larger.

Precautions should be taken prior to any movements of cattle to stable and unstable *Theileria* areas.

- Failure to take precautionary measures is likely to result in animal health and welfare problems, and potentially major costs associated with disease outbreaks.
- While the recipient/ buyer is responsible post-movement, some of the measures to reduce disease impacts should be taken pre-movement, and hence require your cooperation.
- All such movements represent a degree of risk. Risk cannot be entirely eliminated, but is likely to depend on different factors:
 - time of year/season (i.e. tick activity and abundance at the destination);
 - age and class of stock, other stressors etc.
 - physiological condition (avoid moving in-calf cattle, late pregnancy in particular);
 - tick treatment before movement may confer some residual protection and reduce the risk of disease.

Treatments**As you are in a tick-free area, no tick treatment is required for resident stock.**

The only potential requirement for such treatment is before movement of cattle into *Theileria* stable and unstable areas (the recipient/buyer may request this).

- Such movements are strongly discouraged due to the disease risk: see Movements off farm.

Management and husbandry**No specific husbandry and management actions are recommended. However, maintain vigilance.**

- There have been disease cases in what are currently considered *Theileria* free areas. This is likely to be a consequence of cattle movements (see Movements on).
 - Early detection will limit the impact of such disease.
 - Discuss any concerns you have with your vet.
-

Surveillance for *Theileria*-associated bovine anaemia (Ikeda) in New Zealand

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Introduction

In late 2012 outbreaks of *Theileria*-associated bovine anaemia (TABA) were reported in dairy and beef-cattle herds (McFadden *et al.* 2013; Lawrence *et al.* 2013). Strain typing of *Theileria orientalis* was carried out on samples collected from cattle herds experiencing outbreaks. One of the strains was identified as *T. orientalis* Ikeda type. Analysis of data from the New Zealand outbreaks showed that there was a greater likelihood of *T. orientalis* Ikeda type being present in cattle from herds experiencing outbreaks of anaemia compared to non-outbreak herds. In addition, individual animals within an affected herd were more likely to be anaemic if the Ikeda type was present compared with animals with endemic strains of *T. orientalis* such as the Chitose type (McFadden *et al.* 2013; Lawrence *et al.* 2013).

Since the initial diagnosis of TABA, MPI has continued to monitor the New Zealand epidemic through various surveillance initiatives. Monitoring has been important to inform on risk, and understand the epidemiology and impact of the disease. This paper aims to describe methods of past and current surveillance, the spatial and temporal patterns of outbreaks that have occurred over the course of the epidemic, and resulting inferences made.

Surveillance methods

CASE REPORTS

Initially, surveillance of TABA (Ikeda) involved veterinarians and veterinary pathologists reporting suspect outbreaks to MPI using the 0800 hotline for exotic and emerging disease. Investigation of these early cases usually involved a standard

battery of tests to exclude other causes of regenerative anaemia, carrying out studies to determine the intra-herd prevalence of anaemia and risk tracing to determine any association with other infected farms (McFadden *et al.* 2013).

In late 2013, as the number of cases increased, the capacity of the Animal Health Laboratory (MPI, Wallaceville, NZ) to service farmers and veterinarians by testing blood samples for *T. orientalis* Ikeda was stretched. As a result, the technology to carry out the PCR was transferred to the private regional laboratories (New Zealand Veterinary Pathology, Hamilton, NZ and Gribbles, NZ). A subsidy from MPI to the regional veterinary laboratories was instituted for the cost of this test where specific criteria for a suspect case were met. A suspect case was defined as where one or more clinically affected cattle had a haematocrit of less than or equal to 0.24 and *theilerial* piroplasm were observed in a blood smear. The primary objective of the subsidy was to ensure the cost of testing wasn't a barrier for sample submission and in doing so was aimed at increasing both the sensitivity and specificity of surveillance for TABA (Ikeda). At the same time AsureQuality (Auckland, NZ) was employed to collect data related to the affected farm, including the spatial location and the type of farm affected, e.g. beef, dairy or dry stock. A standardised analysis (epidemic curve, spatial mapping of cases) was carried out and reported to disease control experts and field veterinarians. This surveillance strategy was revised for the North Island in January 2015 as the disease became increasingly widespread, and the value of identifying specific cases diminished. In

addition, as general exposure of herds to the Ikeda type increased, finding the presence of Ikeda in cattle with clinical signs of anaemia was no longer specific to cattle affected by TABA (Ikeda).

The current strategy for the North Island now involves analysing syndromic data from regional veterinary laboratories where case submissions from veterinarians to the laboratory include an indication that affected cattle had anaemia as part of the presenting syndrome i.e. cases not necessarily confirmed as being TABA (Ikeda) by PCR. Data were removed from analysis where a specific aetiological diagnosis had been reached i.e. anaemia due to Johne's disease; however, the majority of data did not have an associated aetiological diagnosis. Thus it is likely that the specificity of surveillance has diminished (the number of false positives increased) using this form of syndromic surveillance. Conversely the sensitivity of surveillance is likely to have increased (as a result of capturing data from more cases of TABA (Ikeda) where a PCR was not necessarily carried out).

Prior to cases of TABA (Ikeda) occurring in the South Island in late 2014, data did not indicate that *Haemaphysalis longicornis*, the vector for *T. orientalis*, was present in regions south of the Tasman and Marlborough regions. Thus, when a small number of cases were reported outside this geographical range (McFadden *et al.* 2015) we considered it important to identify precisely where and when future cases were occurring so as to inform on risk in this part of New Zealand. Thus, the MPI subsidy has continued for all cases fitting the case definition described, that occur in the South Island.

The identification of the cases in the South Island prompted further assessment of the current known distribution of *H. longicornis* in the South Island. A survey relating to the presence of ticks in the South Island was provided to all members of the New Zealand Veterinary

Association (NZVA) by email. Veterinarians were asked to submit tick specimens for confirmation of species, as well as data on location of the find and the species of animal the specimen was found on. The survey mainly targeted deer as a sentinel species because of: the timing of de-velvetting with ideal climatic conditions for tick seasonal activity, the ease of examination of stags whilst they were being restrained for de-velvetting, and pasture management conditions of deer often being more suitable for ticks than those of other species. Response was relatively poor, although reliable (veterinarian). First-hand reports of tick sightings at two localities on the West Coast around Hokitika and Camerons have been received, in addition to the two confirmed records near Murchison and Seddon respectively. Passive reporting as a result of heightened awareness of TABA resulted in a tick specimen from beef cattle reported from Kaikoura being positively identified as *H. longicornis*. Another find occurred from a household in the Rolleston area of Christchurch, reported as part of the Brown dog tick biosecurity response.

REGIONAL HERD EXPOSURE

In addition to the surveillance described above, to further understand exposure of cattle herds to *T. orientalis*, pooled serum samples from cattle herds that had been collected historically for the first six months of 2013 and 2014 were tested by PCR for Ikeda (McFadden *et al.* 2013b). This provided an indication of risk to both naive cattle transported into specific regions and to resident cattle already present in those regions.

BOVINE HAEMOPLASMAS

Surveillance from case reports identified a small percentage of cases where the TABA (Ikeda) was suspected based on the case definition but not identified by PCR (<7%). As a result investigation was carried out for the bovine haemoplasmas as an alternative cause of anaemia in cattle.

Spatial and temporal patterns of disease

EPIDEMIC CURVE

In broad terms the key features of the epidemic (Figure 1a) have been:

1. The number of cases has been steadily increasing over time.
2. There are two seasonal peaks in case numbers, that in autumn and spring; with the spring peak being the greatest. These coincide with nymph and adult tick activity peaks respectively.
3. Most of the cases detected have occurred in dairy rather than beef-cattle and dry-cattle (e.g. R1 and R2) herds.
4. Prior to TABA (Ikeda) being detected in late 2012, syndromic anaemia in cattle was relatively uncommon with approximately 11 cases detected per month for 2010 and 2011.
5. There was a close relationship between the number of syndromic reports of anaemia and the number of confirmed cases of TABA (Ikeda), ($P < 0.01$, Adjusted R-squared = 0.74; Figure 1b).
6. There was no indication that a significant number of cases were occurring in the South Island (Figure 3).

At a regional level (Figure 2):

1. The Waikato has been more significantly impacted than other regions with regard to the number of outbreaks occurring.
2. The epidemic appears to have increased in spring 2014 compared to 2013 in some of the less affected regions (East Cape, Manawatu-Whanganui, Taranaki, Bay of Plenty) versus Northland and Auckland.
3. In spring 2014, the epidemic extended south into areas that were previously considered to be of low tick risk.
4. There appeared to a large number of unconfirmed cases during the spring 2013 i.e. the difference between confirmed cases and unconfirmed cases (unconfirmed cases being determined from syndromic surveillance).
5. The highest proportion of unconfirmed cases in relation to confirmed cases was in Auckland.
6. The disparity between unconfirmed and confirmed cases appeared to lessen over time; perhaps indicating that the sensitivity of surveillance was increasing.
7. Relatively few cases have occurred in regions in the bottom half of the North Island.
8. Sporadic cases have started to occur in the South Island during spring 2014.



Figure 1a: Epidemic curve for confirmed (“Ikeda PCR positive” for the period August 2012 to December 2014) and unconfirmed (“Anaemia syndrome” for the period January 2010 to January 2015) TABA (Ikeda) in cattle for New Zealand as a whole.

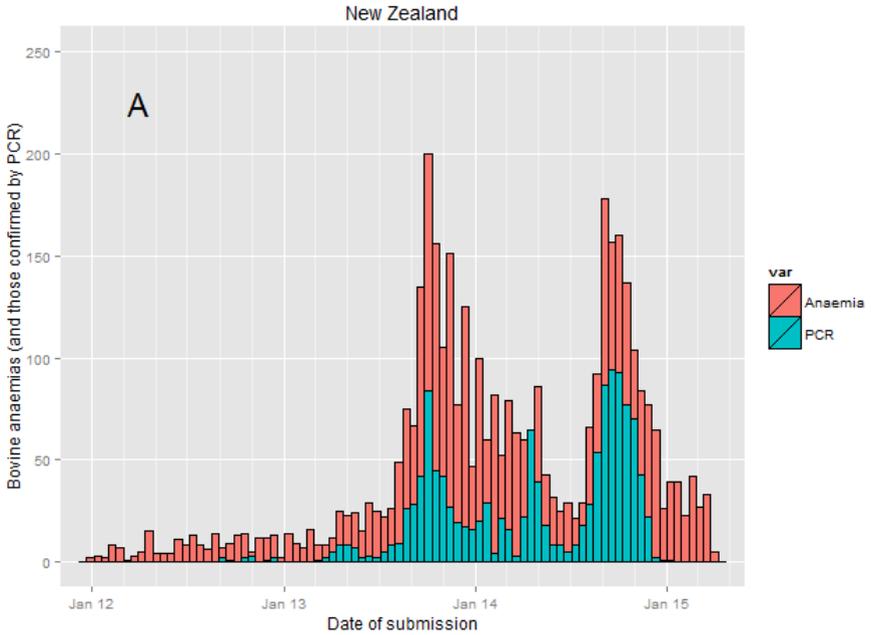


Figure 1b: Correlation between the numbers of cases confirmed and unconfirmed at two weekly intervals over the course of the outbreak (99% confidence interval for the regression line indicated by the dark shaded area).

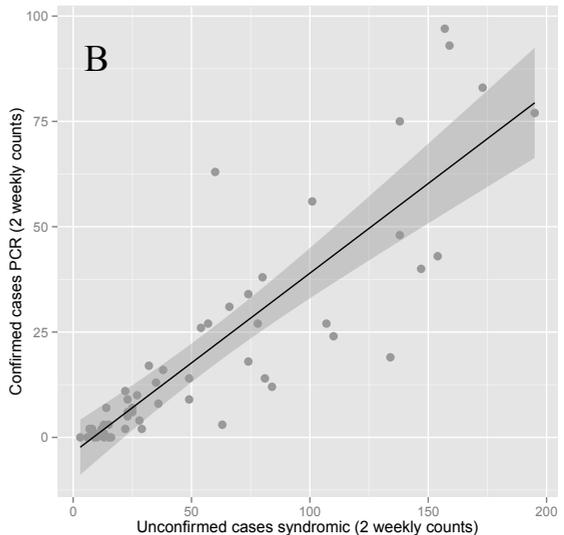


Figure 2: Epidemic curve for confirmed (“Ikeda PCR positive” for the period August 2012 to December 2014) and unconfirmed (“Anaemia syndrome” for the period January 2010 to January 2015) cases of TABA (Ikeda) in cattle herds for specified North Island regions (Northland, Auckland, Waikato, Bay of Plenty, Manawatū-Whanganui, East Cape and Taranaki). NOTE: The y axes scale for the Upper North Island regions is 250 compared to 100 for the Lower North Island regions.

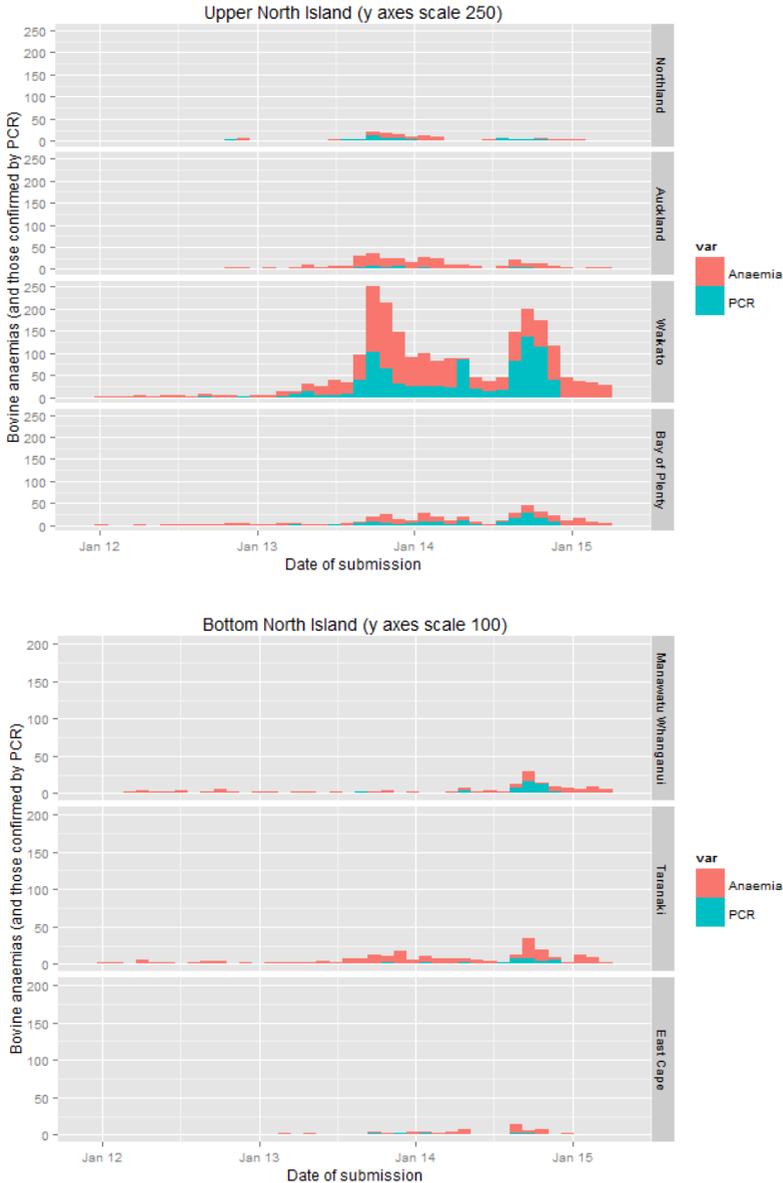


Figure 4: Spatial distribution of properties affected by *Theileria*-associated bovine anaemia (Ikeda) in New Zealand. The North Island cases represent cases from August 2012 until December 2014. The South Island cases are those cases from August 2012 until current (March 2015). Ticks detected outside of previous known distribution are indicated.

Legend

Year of detection

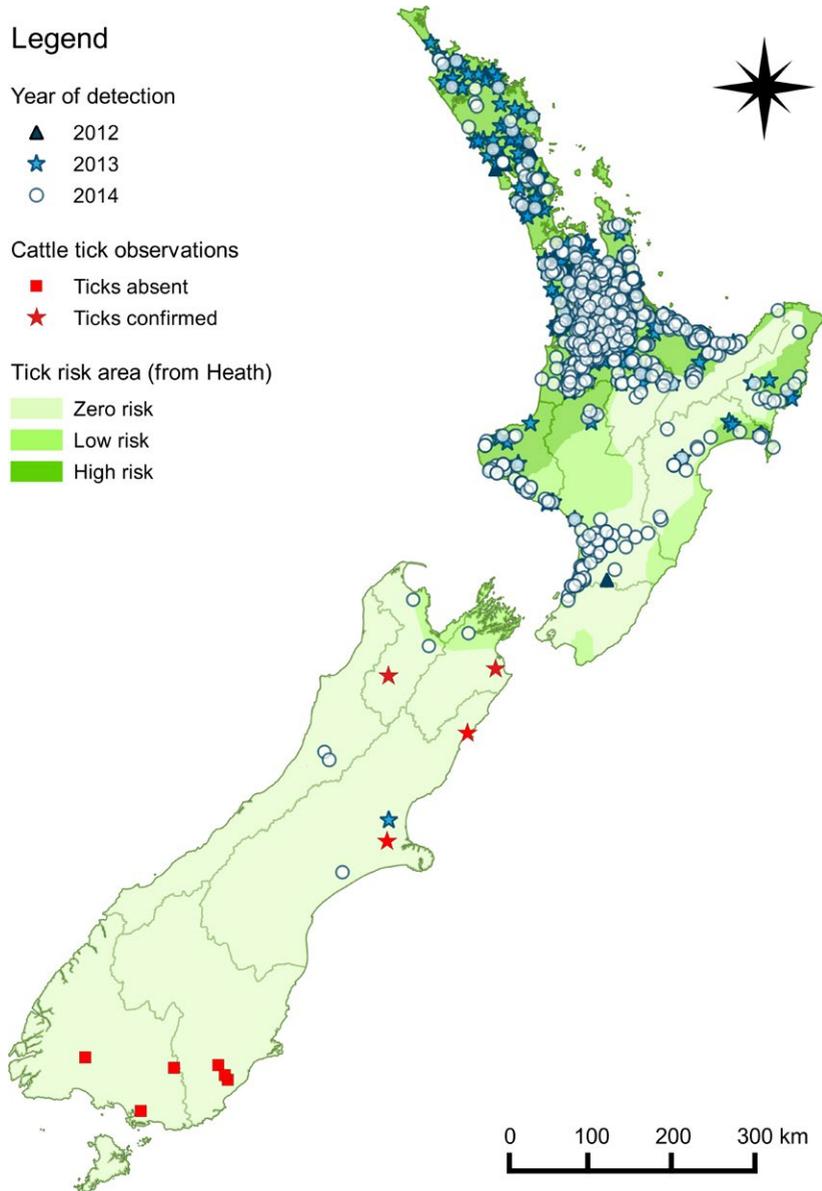
- ▲ 2012
- ★ 2013
- 2014

Cattle tick observations

- Ticks absent
- ★ Ticks confirmed

Tick risk area (from Heath)

- Zero risk
- Low risk
- High risk



population on one of these properties can be sustained through multiple years. While ticks have established for a short period in the southern parts of the South Island before, large parts of the South Island do not have a climate entirely suitable to sustain persistent established tick populations. Regardless, even short-term establishment for one or two seasons can have an impact. Further understanding of where ticks are present will enable a greater understanding of the risk of TABA.

HERD EXPOSURE BY REGION

Data from testing the 2013 and 2014 (Table 1) samples showed that cattle herds present in parts of Northland, Auckland and the Waikato regions had the highest prevalence of herds infected with Ikeda. Gisborne and Hawke's Bay (East Cape), Auckland, Waikato and Bay of Plenty were identified as regions where there was a high percentage of herds exposed to non-Ikeda types only.

The high levels of Ikeda detected in cattle herds

in Northland, Auckland and the Waikato regions represents risk to naive cattle being introduced into these regions. There is the potential for resident cattle herds in the East Cape, Auckland, Waikato and Bay of Plenty to experience future impacts from Ikeda.

Repeat sampling showed that the prevalence of herds infected with the Ikeda had steadily increased over the year in all of the North Island regions where herds were tested. However, there still remained a significant percentage of herds where non-Ikeda types only were present indicating that these herds were at risk of future Ikeda outbreaks. For the East Cape there had been a noticeable increase in the percentage of herds infected, yet with only a small increase in the number of outbreaks reported from the previous year. Thus, presumably outbreaks have gone unobserved or haven't been confirmed by testing. In this region a high proportion of beef herds, where farming is more extensive in comparison to dairy farming could be one explanation.

Table 1: Prevalence of cattle herds exposed to all strains of *Theileria orientalis*, and the Ikeda type by regional groups¹

North Island Region description	Prevalence <i>Theileria orientalis</i> (All types) 2013 ²	Prevalence <i>Theileria orientalis</i> (All types) 2014 ³	Prevalence Ikeda type 2013	Prevalence Ikeda type 2014
Northland	97% (34/35)		94% (33/35)	
Auckland and Waikato	55% (105/191)	70% (100/142)	33% (63/191)	54% (77/142)
Bay of Plenty	34% (10/29)	50% (8/16)	10% (3/29)	31% (5/16)
Gisborne and Hawke's Bay	35% (18/52)	53% (31/59)	12% (6/52)	34% (20/59)
Taranaki	14% (9/64)	26% (11/43)	6% (4/64)	9% (4/43)
Manawatū and Whanganui	5% (5/100)	19% (17/90)	1% (1/100)	12% (11/90)
Wellington and Wairarapa	2% (1/47)	11% (1/9)	0% (0)	11% (1/9)

¹ Based on testing serum samples pooled from approximately 20 cattle sera per herd. Surveys were carried out on samples collected from January to June 2013 and for the same period in 2014. The sensitivity of the test used in 2014 was greater for detecting all *T. orientalis* strains than in 2013 (Hence the increase in apparent prevalence of *T. orientalis* in 2014).

² HRM PCR used for the 2013 survey.

³ Multiplex Taqman PCR used for the 2014 survey.

BOVINE HAEMOPLASMAS

A proportion of samples submitted to MPI that fitted the case definition for suspected TABA (Ikeda) yet were negative to *T. orientalis* (Ikeda) were tested for bovine haemoplasma species (samples from 47 herds). The results showed that bovine haemoplasmas were relatively common in the samples tested, with 13 percent (6/47) and 28 percent (13/47) of samples with *Mycoplasma wenyonii* and *Candidatus Mycoplasma haemobos* present as the predominant species, respectively. The haemoplasmas



were present in blood from cattle herds widely distributed across New Zealand. Whilst bovine haemoplasmas have been implicated as causing anaemia, there did not appear to be a greater number of herds with these agents present exhibiting unexplained anaemia, 33 percent (6/20), (i.e. where anaemia was present without the detection of *T. orientalis*) when compared with negative control herds, 56 percent (10/18, non-diseased herds) and herds experiencing outbreaks of TABA (Ikeda), 33 percent (3/9). Thus, the presence of bovine haemoplasmas in blood does not establish causality for anaemia in cattle. Diagnosis would require exclusion of other causes of regenerative anaemia and an association of the agent with anaemia in affected cattle herds.

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Ticks and *Theileria*

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Tick life cycle and ecology

The cattle tick is permanently established in much of the North Island and in northern parts of the South Island. It has been a pest of livestock for over a century. Its deleterious effects have been enhanced following the introduction of *Theileria orientalis* Ikeda in cattle.

The cattle tick flourishes in warm regions with regular rainfall, but maintains populations in other less temperate parts as well, although prolonged moisture deficits are harmful to its survival. Recently, pockets of ticks have been found in north Canterbury and the West Coast, but it is not known whether these will become permanent populations. It is likely however that irrigation, deer farming and climate change are among environmental factors that may provide more tick-suitable areas in the South Island.

The tick life cycle involves an egg, and three active feeding stages: larva, nymph and adult. In New Zealand only females are found. Each feeding stage can take blood from a wide range of mammal and bird species which means ticks have the potential to be disseminated widely. Once replete the larval tick drops onto pasture and eventually moults to the nymph stage, which in turn feeds, detaches and moults to a female, who, once fed and detached, produces around 2000 eggs.

Each stage has a recognizable, defined activity period: larvae around January to March, nymphs from July to October, having overwintered between April and June, and females October to January. Notice there is some overlap, and it is also possible for all stages to occur in small numbers at uncharacteristic times; this asynchrony happening if members of an age cohort miss out on feeding. Because weather patterns differ from

year to year, tick numbers can be high in some years and low in others; the biggest determinant for the latter thought to be dry conditions when drought-intolerant larvae are active.

Cattle tick and theileriosis

The cattle tick is essential to *Theileria*. The protozoan carries out its sexual cycle in the tick; beginning in the tick gut, where gametes form which then merge to become zygotes. These are a motile stage which find their way from the tick gut cells to the salivary glands. Tick salivary glands are made up of 3 types of alveoli (acini) containing a variety of cells that carry out processes essential to tick feeding and physiology. Once the *Theileria* lodge there they become sporozoites, and as such are injected into the cow's blood stream when the tick starts to feed.

The sporozoites of *Theileria orientalis* Ikeda do not enter lymphocytes, in contrast to other species of *Theileria* such as cause East Coast Fever, where invaded lymphocytes are induced to proliferate. The sporozoites of *T. orientalis* Ikeda undergo proliferation (merogony) to become merozoites in the lymph nodes, spleen and liver of the cow. Sporozoites are not found in peripheral blood. Subsequently, the merozoites enter the RBC and are termed piroplasms, at which time fever may be observed and anaemia develops. A tick feeding on a cow at this time will become infected with piroplasms.

Critical factors

A number of factors determine the successful acquisition and transmission of *Theileria* organisms between the cow and the tick. Cattle develop a degree of tolerance to ticks but do not become completely resistant. A *Theileria*-infected cow will however become resistant to subsequent

injections of piroplasm, but will remain infective to naïve ticks, and can be for life. A naïve tick is one that is uninfected and has not fed, or has developed (moulted) from the previous stage which itself was not infected. An infected tick can be one that has just fed on an infected cow (systemic infection), or it can be a tick that has developed (moulted) from a previously infected tick (trans-stadial infection).

Take the tick larva as an example. If it feeds on a non-infected cow, engorges and drops to the pasture to moult, the result is a nymph which is also uninfected because the larva was. If however the larva feeds to repletion on an infected cow it passes on that infection during the moulting process to the next stage, the nymph. Thus when the nymph feeds it passes on the infection to its next host. If the next host is naïve, then theileriosis is the result. If the nymph feeds on a cow that already has circulating piroplasm, further infection may occur; although further disease may not necessarily occur.

It can be seen from these examples that the larva cannot be infective to a cow, but can only pass on the infection it acquires when it feeds and moults. This is because *Theileria* are not passed on from female ticks to their eggs. As such, newly-hatched larvae cannot have piroplasm but only acquire them on feeding.

Note however that an infected nymph once replete and moulted becomes an adult female which itself is infected because the preceding stage was. Thus only two tick stages can be infective to cattle; the nymph and the adult. This is important because the seasonal activity of both those tick stages is fairly circumscribed and is determined by the time both the engorged larva and engorged nymph take to moult, and these times are influenced by environmental factors such as temperature and humidity. Low temperature and low humidity can delay development in replete ticks.

A confounding factor can be introduced if some ticks in an age cohort miss having a feed, and so



lose the opportunity to moult to the next stage at the same time as others in their group. These late feeders can therefore be present at the same time as other (different) stages that have gone through their usual seasonal cycle. Thus a complex mix of infected and uninfected ticks of different stages can occur simultaneously leading to some uncertainty as to risk to cattle and how to manage the disease.

This is particularly apparent in late winter, early spring when infected nymphs that have overwintered (in behavioural diapause) start to become active and infect cattle. Simultaneously, unfed adults from the previous season who have had to overwinter also start to feed, allowing them to acquire piroplasms earlier than they otherwise would and throwing the infection cycle into some disarray. It is also possible for eggs and larvae to have deferred development over winter and survive to complete development in spring, again adding another dimension to the both the tick and disease cycles.

Time factors

It is possible to estimate minimum and maximum development and transmission times for theileriosis, providing knowledge that might be useful in managing the disease (and ticks) or anticipating when the next phase of infection might begin in a herd.

Minimum

When an infected nymph feeds on a naïve cow, the cow can become infective to ticks in 10 days. A naïve nymph, once attached to an infected cow acquires piroplasms after 2 days feeding. The nymph feeds for a minimum 3 days and, after detaching, moults in a minimum of 9 days (laboratory data). The resulting adult 'hardens-off' after 2 days and is then ready to feed. A further 2 days elapse before sporozoites are ready for release from the female's salivary glands, and she begins inoculating these after 2 days of

feeding. Thus the minimum time it takes from when a tick first finds a host and infects it, to when the next tick stage itself infects a host, is around 30 days.

Maximum

Alternatively, it can take as long as 32 days for a cow to become infective to naïve ticks after the cow itself has had piroplasms injected into it by an infected nymph. As before it takes around 2 days feeding for the tick to obtain piroplasms from the circulation of the host. The nymph can feed for a maximum of 8 days and then detaches to moult, which can take from 23 days to a maximum of 150 days (both recorded in the field in New Zealand). Once the adult 'hardens off' in 2 days she is ready to feed. Two days later sporozoites are ready for release and, assuming she finds a host straight away, begins inoculating sporozoites after 2 further days. Thus the maximum time from onset of an infected tick feeding to when the next tick stage infects a host can range from 71 to 175 days.

Note that these longer times are a more realistic in the New Zealand situation, especially in southern parts of the tick's range. Note also that ticks can survive unfed for a year or more and still remain infective to cattle for around 150 days when they finally find one to feed on, although their potency (ability to transmit sporozoites) will have declined with time. It is assumed too that just one infected tick with one infected salivary gland acinus is sufficient to infect a cow, so overwhelming numbers of ticks and *Theileria* organisms are not a necessary feature of the disease.

Control of ticks

Control of ticks is a misnomer; population suppression or diminution is a more realistic expectation, mainly because ticks have such high reproductive potential, and also because they can use so many different hosts which maintain and

disperse them beyond fenced boundaries.

Repeated, high rotation acaricide use can be targeted at larvae (more susceptible to dip chemical than nymph and adult). Fewer larvae can, or should mean, fewer infective nymphs. Acaricide use will also reduce tick 'worry', the specific damage ticks do in the absence of *Theileria* organisms.

Maintenance of acaricide pressure throughout nymphal and adult activity phases reduces risks to naïve stock. It also reduces the numbers of females that eventually lay eggs, but overall is unlikely to alter the course or progression of theileriosis in a herd. This is because in a stable area, one where theileriosis and ticks are always present and widespread, it is impossible to stop calves becoming infected by any sort of tick control. The best use of acaricides is to ensure that cattle from stable areas do not transport ticks to areas where ticks do not occur. Otherwise, dipping will reduce tick worry and may delay the spread of infection through a herd, but the cost and time involved in repeated, regular dipping has to be offset against potential production losses.

In addition to dips, reducing (not eliminating) tick numbers on a farm involves, grazing management (ticks are less numerous in short pastures), and 'sweeping' or 'vacuum-cleaning' ticks on heavily-infested paddocks by grazing with low capital-value stock which are then dipped after 3 days exposure (before ticks get a chance to drop off). Spelling pasture can work

but has to be for impractically-long periods (at least 12 months) for any effect on tick numbers. These labour intensive approaches coupled with strategic dipping will keep tick numbers low but not eradicate them. This is partly because it is impossible for every tick to be caught up in a control programme, and also because highly mobile wild hosts such as hares can re-introduce more ticks.

Such efforts are worthwhile, nevertheless, not because they are likely to change the course of theileriosis on a farm, but because they reduce the compounding effects of tick worry which cause additional stress to cattle.

FURTHER READING

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