

Epidemiological modelling of Bovine Johne's disease risk in Western Australia

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Abstract

Bovine Johne's disease (BJD) is an infectious fatal disease of cattle. BJD is endemic in all states of Australia, except in Western Australia (WA). National Australian deregulation of BJD control took place on 1 July 2016 and most individual states have adopted a deregulated approach for BJD management. WA's currently maintains a BJD control program to prevent the disease establishing by import restriction and to monitor disease freedom by surveillance activities. Under the changing circumstances, it needed to be determined what level of protection from BJD incursions and spread is required for WA. An "Economic impact evaluation of bovine Johne's disease (BJD) management options in Western Australia" was conducted. For this evaluation epidemiological modelling was used to estimate the number of BJD-infected farms in WA in 20 and 30 years' time in a deregulated environment. Assuming WA is currently free of BJD and that no regulations or eradication of BJD is conducted, the models showed that with 95% confidence (95% CI), in 20 years' time there will be between four and 30 BJD positive farms and in 30 years there will be between six and 54 BJD positive farms. In addition the intra-herd spread was estimated by using a simplified deterministic SIR model. On BJD infected beef farms there will be 0.72% (95% CI 0.60-0.84%) sub-clinically infected animals and 0.16% (95% CI 0.15-0.20%) clinically infected animals. On BJD infected dairy farms there will be 0.30% (95% CI 1.20-1.80%) sub-clinically infected animals and 0.30% (95% CI 0.25-0.40%) clinically infected animals.

Keywords: *BJD, Bovine Johne's disease, freedom, incursions*

Introduction

Bovine Johne's disease (BJD) is an infectious disease of cattle caused by *Mycobacterium avium* subsp. *paratuberculosis* (Mptb.) that can also affect other ruminants such as goats, alpaca, sheep and deer. It causes chronic wasting and incurable diarrhea leading to death in mature cattle. Sub-clinically affected animals may have reduced growth and milk production levels.

WA was a BJD Free Zone under the previous National BJD Strategic Plan (2012–2020). A Free Zone denoted an area that had been demonstrated to be free from BJD infection with a high level of confidence by epidemiological analysis. The Free Zone carried certain regulatory requirements around importation of BJD-susceptible livestock, as well as strict requirements for

disease eradication if it was found or suspected. These included regulatory restrictions to manage the potential risk of disease spread within the zone. In 2015 a review of the National BJD Strategic Plan conducted by Animal Health Australia (AHA) found strong industry support.

Nationally for deregulation and the development of 'on-farm' biosecurity management for BJD in Australia. National deregulation took place on 1 July 2016 and mend, amongst other things, that the zones and areas based on BJD prevalence no longer exist. Most jurisdictions have adopted a deregulated approach for BJD management. WA's BJD program therefore needs review and modification to meet industry needs in a nationally deregulated environment. It needs to be determined what level of protection from BJD incursion and spread is required for WA, including at the border, and how this is best achieved. To assist this decision-making process, the WA cattle Industry requested an economic evaluation of the potential costs of BJD within WA should it enter and become established and the costs of a regulatory control program (1). For this evaluation epidemiological modelling was used to estimate the number of BJD-infected farms in WA in 20 and 30 years' time in a deregulated environment. Using this epidemiological assessment, likely levels of economic impact were explored elsewhere for different industry sectors and locations (1).

Materials and methods

Intra-herd spread

BJD is typically introduced to a herd by the introduction of an infected animal. These animals are usually subclinically infected and not yet shedding the causative organism in their faeces or showing clinical signs of disease. Shedding starts at different ages and varies widely (2-14 years). In the model a conservative mean of four years was used. Therefore if an infected animal (the primary case) is introduced to a property at around 20-24 months of age, which is a common age for introductions, it will usually take at least two years for the animal to start shedding the BJD-causative organism. A property will only be at risk of spreading the disease within the herd after this time. A primary case could be shedding from the arrival date, although this is highly unlikely because of the young age of most imported animals, so modelling is based on the above numbers.

The risk of infection of secondary cases (i.e. spread within the herd) is dependent on environmental conditions and management practices on the property, and is considered low in extensive pastoral beef farming situations but relatively high on dairy farms. This is due to factors such as temperature and rainfall, stocking densities, age of culling, and stress/concurrent disease. There are 160 dairy farms in WA concentrated in the South-West where the milder, more humid climates and higher animal density and husbandry practices make secondary spread more likely. Cattle generally pick up infection very early in life, most commonly within the first 30 days. Cattle over 12 months of age are relatively resistant to infection. Secondary cases are also assumed to start shedding four years after infection. The primary case will typically die from clinical disease or be removed from the herd due to poor performance within a couple of years of beginning shedding, so the risk of that individual infecting further susceptible animals after two years of shedding is very limited, especially for extensive beef farms due to the reduced survival time of Mbpt in the relatively dry environments.

Intra-herd BJD spread was calculated by using a modified deterministic SIR (Susceptible > Infected > Recovered) model. SIR was converted in to a Susceptible > Sub-clinically > Shedding > Removed/dead.

Incursions into WA

BJD has been diagnosed in WA on 10 occasions during the past 58 years. Nine of these historical cases were associated with the introduction of infected cattle from other states of Australia, and in some cases disease had spread to the WA cattle herd. Infected herds were destocked and the disease eradicated. One case of BJD was first detected in WA cattle. Epidemiological evidence strongly suggests that infection was introduced into this herd with imported cattle in 1994, but a diagnosis of BJD was not made until 2006 and the original imported cattle were not available to test (2). BJD was eradicated from the farm by destocking.

These 10 incursions were used as the basis of modelling to predict the probability of future incursions of BJD into WA and the possibility of the disease becoming established. The probability (or risk) of an incursion was calculated over 20 and 30 years.

Inter-herd spread

There are two possibilities for inter-herd spread within WA: first, an infected imported animal (the primary case) moves from one WA property to another. The infected animal may be shedding the causative organism, contaminating both properties and potentially spreading infection, or may be infected but not yet shedding the organism and so move the BJD risk from one property to the next when it commences shedding. The second possibility is that infected home-bred animals (secondary cases) are moved to other uninfected properties where they commence shedding and spread disease to another herd.

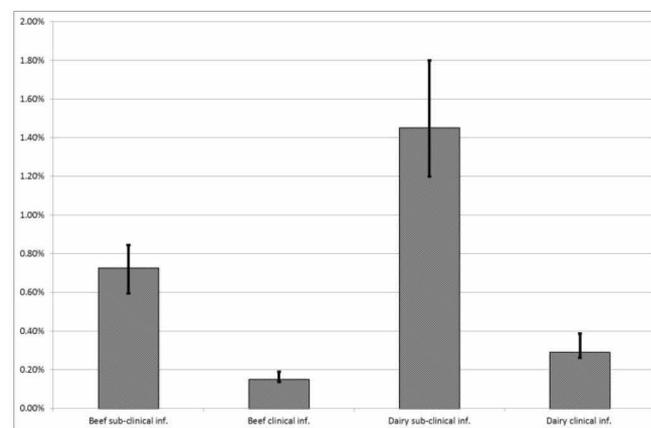
The majority of beef cattle ready for sale in WA go for live export or for slaughter. There is relatively limited trade of cattle between WA beef farms, including genetic breeding stock, once they are old enough to be at risk of shedding. There means there is a limited risk that infected (shedding or not yet shedding) animals are traded between grazing properties within WA and remain alive on the new property beyond the age they are likely to shed bacteria. This is supported by evidence that, in the 10 BJD introductions in the past 58 years, there has been no inter-herd spread detected within WA. Inter-herd spread, however, may be more likely in dairy farming areas. This is addressed below. The following formula was used to calculate the number of BJD positive farms in WA over time: $N_t = f_t (\alpha I * t) + \beta [\{ (\alpha I * (t - n)) \} + \{ (\alpha I * (t - 2n)) \} + \{ (\alpha I * (t - 3n)) \} + \dots]$ With: N_t = Number of BJD-infected farms in WA in year t , I = Number of current (probability of, and 95% binomial confidence intervals) BJD incursions into WA per year, t = (calendar year – 2016) α = factorial increase of risk of incursion, β = likelihood of inter-farm spread of BJD, n = number of years needed for BJD spread between two properties with $(t - *n) > 0$.

Results

Intra-herd spread

Figure 1 shows the predicted percentage of intra-herd spread for beef and dairy herds per year. The intra-herd spread will be the same over time, infection rates and the number of infected animals will remain stable after 20 years without regulatory interventions.

Figure 1. Intra-herd spread



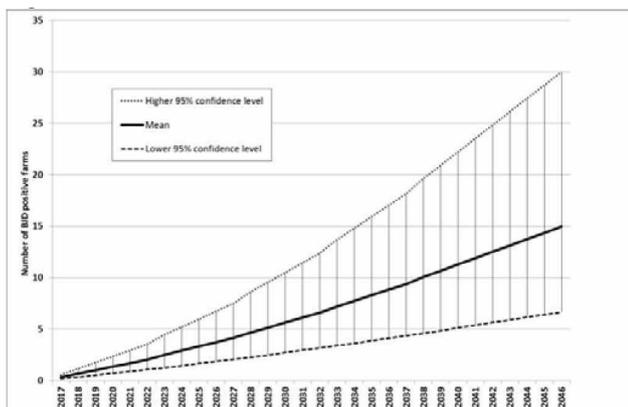
The blocks represent the average percentage of animals BJD-positive per farm (both at 20 and 30 years). The black bars show the 95% confidence interval.

Incursions and spread within WA

Assuming inter-herd spread, the number of BJD infected properties over time was calculated as follows. Ten BJD introductions into WA over 58 years give a yearly probability of an incursion of 0.17. Assuming the probability of a BJD incursion remains the same, after 20 and 30 years the number of incursions is estimated to be four and six respectively. National BJD deregulation is, however, likely to increase the risk of BJD introduction into WA. The literature (3,4) was reviewed and

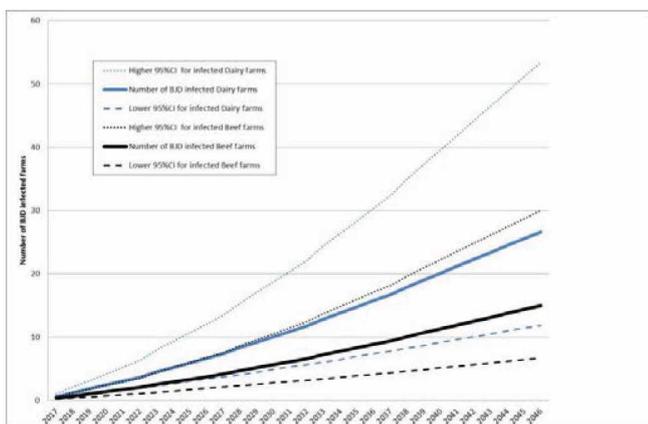
experts' opinions were sought to arrive at an estimated two-fold increase in risk of introduction. Figure 3 shows the predicted number of BJD-positive farms over time, without regulation of BJD in WA, and assuming limited inter-farm spread. After 30 years it is estimated there will be an average of 15 BJD-positive farms (95%CI 7-30). These figures assume a no-action scenario, that is, the disease is not eradicated if found.

Figure 2. Number of BJD-positive farms over time without regulation with 95% CI.



A literature review was undertaken to estimate the likely prevalence of BJD in dairy and beef herds under WA conditions if it were to enter and establish. Peer-reviewed research papers studying dairy and beef herds in Australia and overseas report a prevalence of BJD in dairy herds of 40–60% (5). BJD in beef herds on the other hand is reported at 1–2% (6). In early 2016 there were approximately 160 dairy herds in WA (all located in the South-West) and about 3000 beef herds. Herd sizes range from 50 to 30,000 cattle on a property (Australian Bureau of Statistics, 2016). Extrapolation of the literature data demonstrates a risk of BJD in dairy herds that is 50 times higher than in beef systems. The equation $\{(number\ of\ dairy\ farms * risk\ of\ BJD) / (number\ of\ beef\ farms * risk\ of\ BJD)\}$ applied for WA results in a risk of BJD in 160 dairy farms in WA 1.78 times higher than in all 3000 beef farms.

Figure 3. Prediction of the number of BJD-positive dairy farms, compared with beef farms over time (with 95% CI)



Discussion

Modelling discussion

The results as shown above are best estimates and do not take into account factors such as changes in farming practices, farming economics, climate change etc. over 30 years.

It is remarkable to note the significant difference intra-herd prevalence between dairy and beef herds where BJD is endemic. If BJD incursions were to occur in dairy farms in WA, the disease would likely spread within and between herds, and it is not unlikely that infection levels would be similar as seen in Victoria where over 30% of all dairy farms are infected (7). This is supported by the modelling shown in Figure 3.

The modelling considers most likely scenarios. There is always the possibility that multiple BJD incursions occur in WA over the next 30 years without detection, as surveillance is limited by low sensitivity (tests). There is also the possibility that no BJD incursions into WA occur in the next 30 years. This is considered extremely unlikely.

Repeated modelling increases the confidence of the predicted values generated and will better inform on risks of incursion and spread of BJD in WA. It is recommended that this be undertaken should there be any significant shift in the assumptions underlying this modelling.

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