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Economic impact evaluation of bovine Johne's disease (BJD) management options in Western Australia

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Important disclaimer

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Executive summary

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 diarrhoea leading to deaths in mature cattle. Subclinically affected animals may have reduced growth and milk production levels.

BJD is a complex disease to prevent and control due to its long incubation period and the disease-causing organism being able to survive for extended periods in the environment. In addition, diagnostics tests are of low sensitivity in detecting most stages of the disease, leading to diagnostic difficulties associated with false negative results, as well as a lack of specificity of some tests giving false positive results.

It is therefore difficult to identify if and when a herd becomes infected. Culling of identified clinical cases in an infected herd may reduce the environmental contamination and infection rate but subclinically infected animals continue to contaminate the herd environment through their faeces and their offspring have a high chance of becoming infected and passing on the disease despite control efforts.

Western Australia (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 means, 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.

The WA cattle industry needs to determine what level of protection from BJD incursion and spread is required for WA, including at the border, and how this is best achieved. The primary decision to be made is whether BJD is best managed on a statewide basis via regulation, or whether it is better managed according to individual producer needs using on-farm biosecurity.

To assist this decision-making process, the WA cattle Industry Management Committee has requested an economic assessment of the potential costs of BJD within WA should it enter and become established, compared to the likely costs of a regulatory control program.

Epidemiological modelling was used to estimate the number of BJD-infected farms in WA in 20 and 30 years' time in a deregulated environment. Different levels of economic impact were then explored, differentiating between industry sectors and locations.

This research was conducted under the agreed Terms of Reference (Appendix 2). The findings are presented below.

Assumptions

Epidemiological and economic modelling was undertaken using the following assumptions:

- The number of cattle and cattle enterprises in WA remains similar over the modelling period.
- The number of BJD-susceptible stock movements from other jurisdictions into WA remains the same.
- Intrastate trading patterns remain stable.
- International trading patterns and export numbers remain stable.
- The proportional size of sub-industries remains similar (e.g. proportion of dairy to beef).
- There are no significant changes in the WA environment.
- There are no significant changes in WA cattle farming systems and economics.
- There are no significantly better diagnostic, control or prevention measures being implemented.
- There are no other regulatory BJD control or eradication measures implemented.
- Johne's disease requirements of international trading partners remain the same.

Modelling was undertaken based on average cattle price and milk price.

Economic losses assume a no-action scenario at the state and farm level. Factors such as potential brand value of WA cattle as a result of statewide regulatory BJD controls and future impacts as a result of potential human health issues are outside the Terms of Reference and so are not considered.

Impact of deregulation of BJD control in WA by industry

Loss estimates – domestic trade properties

Without regulatory control of BJD nationally and on livestock movements into and within WA, the risk of BJD entering WA will increase over time and the disease will spread once established in WA.

In this situation, in 30 years' time, it is estimated that there will be 18 (95% confidence level [CI] 8–32) cattle properties infected with BJD in WA.

The financial losses caused by BJD at farm level are estimated using the following assumptions: cattle prices of $1200 per head, a farm herd size between 800 and 1600 animals, and 0.15% of animals clinically infected. The total loss on average is $39 000 (ranging from $15 000–$88 000), with a net present value (NPV)[1] loss per infected farm of $900 (ranging from $550–$1500) per year. These calculations are based on the assumption that none of the infected properties sell into BJD-sensitive markets and losses are due to reduced production and deaths.

[1] The net present value (NPV) is a measurement of the costs of an undertaking that is calculated by subtracting the present values (PV) of cash outflows (including initial cost) from the present values of cash inflows over a period of time.

Loss estimates – including exporting properties

Here the costs are calculated using the same epidemiological modelling for BJD-infected farms in 30 years' time but include several properties (3–5) exporting to BJD-sensitive markets.

As above, economic estimates depend on factors such as farm size and cattle price per head. In this scenario it is assumed that farm size varies in the range of 3000–10 000 head per property, although this is likely an overestimate for exporting properties outside of the pastoral regions.

An infected property will suffer losses due to reduced production and deaths. Those that export may also suffer losses caused by reduced cattle prices for slaughter compared to export prices where they are unable to access JD-sensitive markets. Losses could vary in the range of $0.25M–$1.5M per year per exporting property depending on the farm size. Overall losses will depend on the number of exporting farms affected. Most likely export losses over 30 years are in the $11M–$14M range (NPV) if export properties are diagnosed with BJD.

Loss estimates – export trade in Kimberley region

Sixty beef cattle properties in the Kimberley region of WA are live animal exporters. If an exporting property becomes clinically infected with BJD, it is likely they will lose access to BJD-sensitive export markets for at least five years based on current importing country requirements plus time taken to manage the disease.

Total live cattle exports for 2014/2015 were 249,861 head worth approximately $213M. Export to Indonesia was of the highest value ($67M), followed by Israel ($54M), Vietnam ($36M), Malaysia ($29M) and Egypt (12M). All of these markets have property-level requirements for BJD with the exception of Egypt. None of these markets have regional or state-based JD requirements.

A number of hypothetical scenarios were simulated with single property outbreaks for exporting properties. Cattle numbers at exporting properties in the Kimberley are in the range of 1000–60 000. Results below are based on a sample of medium-sized properties with an average of 6000 head per property and an average cattle price for export of between $690 and $910. The model showed that if BJD established in the Kimberley, in 30 years' time on average seven properties would be BJD positive.

These seven BJD-infected properties would incur total losses due to loss of access to JD-sensitive export markets of an estimated $22M (95%CI $9–$56M), with an NPV of $12M (95%CI $6–$26M) over a 5–7 year period. These values are based on sending cattle for slaughter at reduced prices instead of export and assume that export market access is regained after seven years. These losses do not take into account alternative export markets which do not have BJD restrictions (e.g. Bahrain, Kuwait and Singapore).

Loss estimates – dairy industry

When estimating the losses due to a potential BJD outbreak in the dairy cattle industry, losses of milk production have been taken into account[2]. Higher spread rates, both between farms and within farm, were applied to the dairy cattle industry.

[2] It is assumed subclinical dairy cows would suffer 4–6% milk losses. On average dairy cows produce 6000 litres of milk per year and the current farm gate price is 0.49 cents.

Over a 30-year period it is estimated that 32 (95%CI 14–57) properties with 1200 dairy cows each may be infected with 0.28% of animals showing clinical signs and 1.2% subclinically infected, resulting in a total loss of $122 000 (95%CI $12 000–$391 000) per year. These losses are caused by a decreased milk production (4–6%) and removal and replacement of BJD-affected animals from the herd. Average NPV loss per farm would be $2400 (95%CI $530–$4300) per year. It is noted that losses due to BJD in this scenario are less than the losses caused by milk price[3] fluctuations over the past eight years.

Loss estimates in cattle breeding properties

For breeding farms it is assumed that the value of breeding animals will be 1.7 times their slaughter or export value.

After 30 years it is predicted that 18 properties will be infected with BJD, with 0.15% of the infected herd showing clinical signs. Assuming all 18 properties are seedstock producers, maximum total losses over 30 years are $146 000, with an NPV of $61 000 (or $3200 per farm) based on production losses. These calculations do not take into account the potential for significant loss in value of stock if a breeding property becomes infected and potential clients are therefore lost.

Maintaining current regulatory equivalence for BJD control in WA

Current costs of the WA BJD annual surveillance program average about $86 000 per year. With the cessation of the National BJD Strategic Plan, management (regulatory or otherwise) of BJD in WA is to transition fully to an industry responsibility. For this reason, it is estimated that an annual surveillance and regulatory program equivalent to that currently in place will cost about $100 000 per year.

Despite previous regulatory import restrictions to prevent BJD incursion, there has been one incursion/outbreak of BJD in WA every 6–7 years over the past 60 years. Based on this evidence, it is estimated that between three and nine properties may become infected over the next 30 years even with the maintenance of regulatory border controls. Note, however, that this will likely increase due to changing disease prevalence elsewhere in Australia.

Maintenance of WA's negligible disease prevalence would require eradication of disease when incursions are detected. The cost to producers of disease eradication is estimated at an average $500 per head of cattle. The cost to eradicate BJD from an average WA farm would be $500 000 (95%CI 450 000–5 000 000) for each single infected farm.

Proof of freedom surveillance will cost an additional $100 000 per year (Loth, 2015), assuming it is conducted every five years. Total costs of a regulatory program over the 30-year modelling period are therefore in the range of $6.14M NPV.

Conclusion

It appears from this modelling that, given the likely inter-herd and intra-herd spread rate of BJD, it is unlikely that the disease will cause significant production and associated economic losses in the WA cattle industries. This is particularly applicable to producers who sell into a domestic market and includes the dairy industry, and is supported by previous studies (Williams, 2014).

[3] Milk prices fluctuated in the range of 42–49c/L between 2008 and 2015 (Dairy Australia).

In NPV terms, production losses in beef cattle, breeder and dairy farms are estimated to be quite small on a per-property basis ranging from $900–$7244 per infected farm per year once clinical signs are observed. These results are similar to recent finding in Victoria (Shephard et al, 2016).

Given the slow rate of inter-herd disease spread, these values are also small when applied on an industry level over the 30-year modelling period. At an industry level the costs of a regulatory program over 30 years are significantly greater than likely industry losses due to production impacts.

Economic losses associated with the loss of access to BJD-sensitive markets, however, could be significant. This includes some export markets. Four of WA's main international trading partners have property-level requirements for Johne's disease freedom, and so access to these markets is lost to individual producers if BJD is found on their property.

While the modelling undertaken should be valid across the industry generally, individual businesses will need to undertake their own analysis based on their business requirements and individual risks. For example, very large farms are likely to have a completely different risk profile and biosecurity requirements compared to average size cattle farms, and producers who regularly bring cattle on to their property are at higher risk of BJD incursion.

On-farm biosecurity measures and associated costs and impacts are not included in the modelling, and all losses are considered under a no-action scenario at state and farm level. The costs and impact of these would likely change the modelled costs and could be applied on a sub-industry level as appropriate.

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 diarrhoea leading to deaths in mature cattle. Subclinically affected animals may have reduced growth and milk production levels.

BJD is a complex disease to prevent and control due to its long incubation period and the disease-causing organism being able to survive for extended periods in the environment. In addition, diagnostics tests are of low sensitivity in detecting most stages of the disease, leading to diagnostic difficulties associated with false negative results, as well as a lack of specificity of some tests giving false positive results.

It is therefore difficult to identify if and when a herd becomes infected. Culling of identified clinical cases in an infected herd may reduce the environmental contamination and infection rate but subclinically infected animals continue to contaminate the herd environment through their faeces and their offspring have a high chance of becoming infected and passing on the disease despite control efforts.

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 which means, 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.

The WA cattle industry needs to determine what level of protection from BJD incursion and spread is required for WA, including at the border, and how this is best achieved. The primary decision to be made is whether BJD management is best managed on a statewide basis via regulation, or whether it is better managed according to individual producer needs using on-farm biosecurity.

To assist this decision-making process, the WA cattle Industry Management Committee has requested an economic assessment of the potential costs of BJD within WA should it enter and become established and the costs of a regulatory control program.

The following analysis uses epidemiological modelling 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 are explored for different industry sectors and locations.

This research was conducted under the agreed Terms of Reference (Appendix 2).

Definition of BJD

Under the previous National BJD Standards, Definitions, Rules and Guidelines (8th edition), BJD was defined as relating only to cattle strains of *Mbpt.* and specifically excluded sheep strains. Sheep strains were considered to be genetically and epidemiologically separate to cattle strains under Australian conditions.

The BJD Framework introduced on 1 July 2016 now considers BJD to be disease in cattle caused by any strain of *Mbpt.*, which includes sheep strain *Mbpt.*

For the purpose of this analysis, BJD is defined as disease caused by cattle and bison strains of *Mbpt.* only. Sheep strain *Mbpt.* is endemic in WA and outside the scope of this analysis.

Assumptions

Epidemiological and economic modelling was undertaken using the following assumptions:

- The number of cattle and cattle enterprises in WA remains similar over the modelling period.
- The number of BJD-susceptible stock movements from other jurisdictions into WA remains the same.
- Intrastate trading patterns remain stable.
- International trading patterns and export numbers remain stable.
- The proportional size of sub-industries remains similar (e.g. proportion of dairy to beef).
- There are no significant changes in the WA environment.
- There are no significant changes in WA cattle farming systems and economics.
- There are no significantly better diagnostic, control or prevention measures being implemented.
- There are no other regulatory BJD control or eradication measures implemented.
- Johne’s disease requirements of international trading partners remain the same.
- Modelling was undertaken based on average cattle price and milk price.

Economic losses assume a no-action scenario at the state and farm level. In reality it is likely that producers will undertake biosecurity practices to minimise losses or maintain their export and marketing status.

Individual economic analyses were undertaken using additional assumptions that are specific to the scenarios modelled. These are presented within the body of the analyses.

It should be noted that a change in any one of these assumptions may result in a different epidemiological and/or economic outcome. Repeated modelling increases the confidence of the predicted values generated and will better inform on risks of incursion, spread and impact of BJD in WA. It is recommended that repeated modelling and analysis be undertaken should there be any significant shift in the assumptions underlying this modelling.

Areas outside the Terms of Reference and so not covered in the analysis include:

- assessment of any potential link between BJD and human health impacts and associated economic impacts
- potential brand value associated with statewide BJD prevalence or controls
- additional individual producer costs such as those associated with individual property biosecurity plans. (On-farm biosecurity should be undertaken in both a regulated and deregulated scenario, but costs may be higher in a deregulated environment.)
- costs associated with participation in industry market assurance programs. These are likely to be the same regardless of whether a regulatory program exists or not.

Individual businesses should conduct their own risk assessment and implement biosecurity measures based on the outcome. The costs of individual property biosecurity plans vary widely according to individual property details, management practices and needs.

BJD spread modelling

Introduction of BJD 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 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 (Martin, 2008). 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.

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 to 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. Dairy farming in WA is 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. 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.

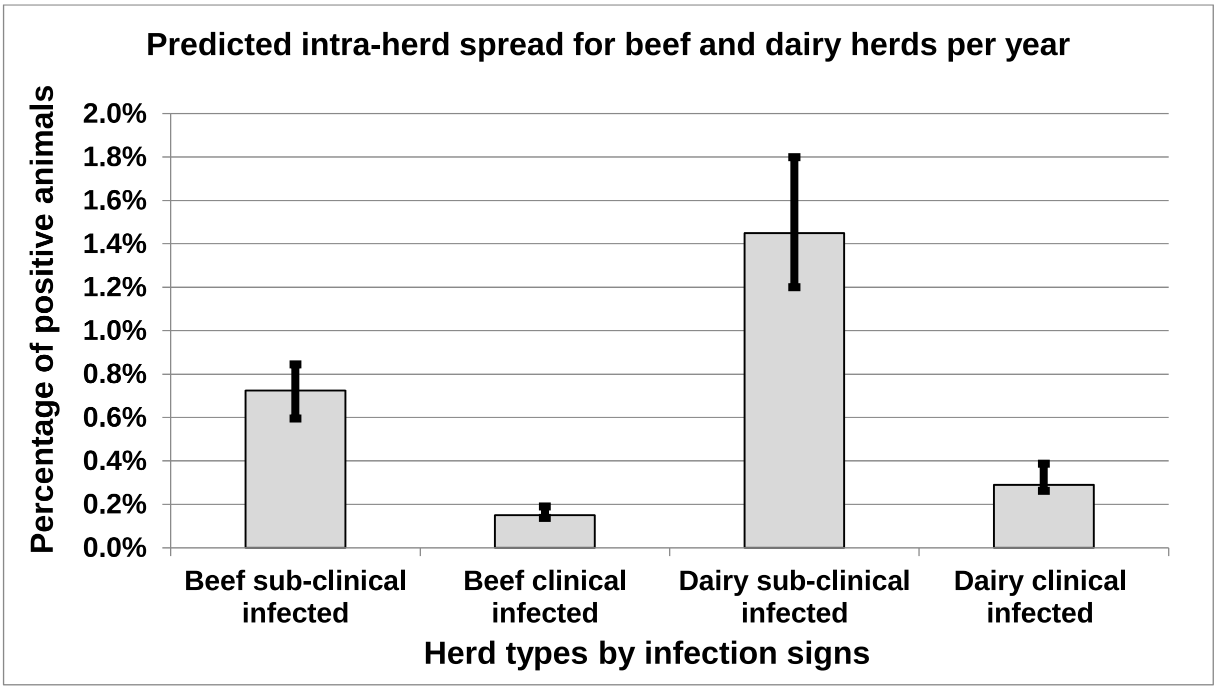

Figure 1 Intra-herd spread The blocks represent the average percentage of animals BJD-positive per farm (both at 20 and 30 years). The black bars show the range in the number of positive animals per farm that are estimated to exist in 95% of positive farms

Details and formulae of the intra-herd spread modelling can be found in Appendix 3.

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.

Assuming no 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 (AHA, 2015, 2016) was reviewed and experts' opinions were sought to arrive at an estimated two-fold increase in risk of introduction.

Figure 2 shows the predicted number of BJD positive farms in WA over time, maintaining current regulations and assuming no inter-farm spread. After 30 years it is estimated there will be an average of five BJD positive farms from importing infected animals (95%CI 3–9).

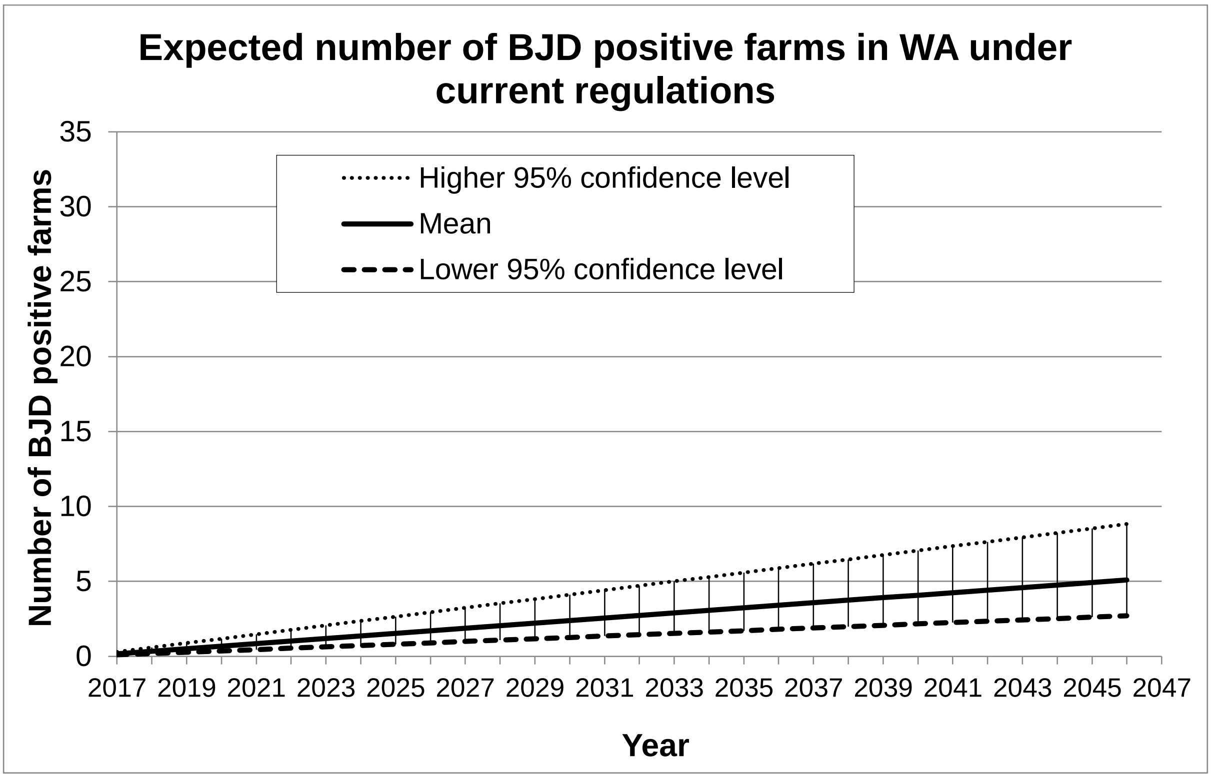

Figure 2 Number of BJD-positive farms over time The solid line represents an estimate of the average number of BJD-positive farms over time with the maintenance of current regulations assuming no inter-farm spread. The area between upper and lower lines represents the range in numbers of positive farms that could be expected to present 95% of cases.

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.

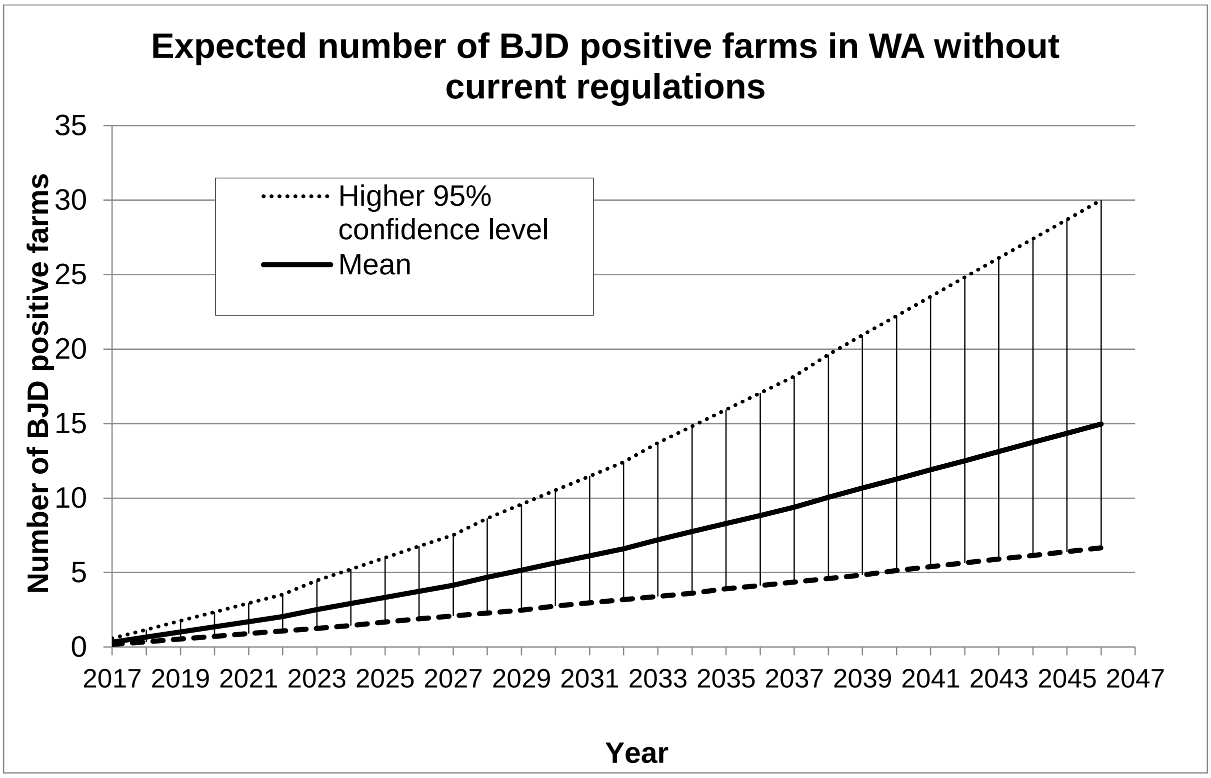

Figure 3 Number of BJD-positive farms over time without regulation. The solid line represents an estimation of the average number of BJD-positive farms without any regulations and with inter-farm spread. The area between upper and lower lines represents the range in numbers of positive farms that could be expected to present 95% of cases

Details and formulae of the inter-herd spread modelling can be found in Appendix 3.

Dairy versus beef farms

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% (Williams, 2014; Muskens, 2001; Stoneham, 1994). BJD in beef herds on the other hand is reported at 1–2% (Larsen, 2012). 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 4 shows the number of BJD-infected farms comparing beef and dairy herds over 20 and 30 years. Over a 30-year period it is estimated that 32 (95%CI 14–57) dairy properties may be infected.

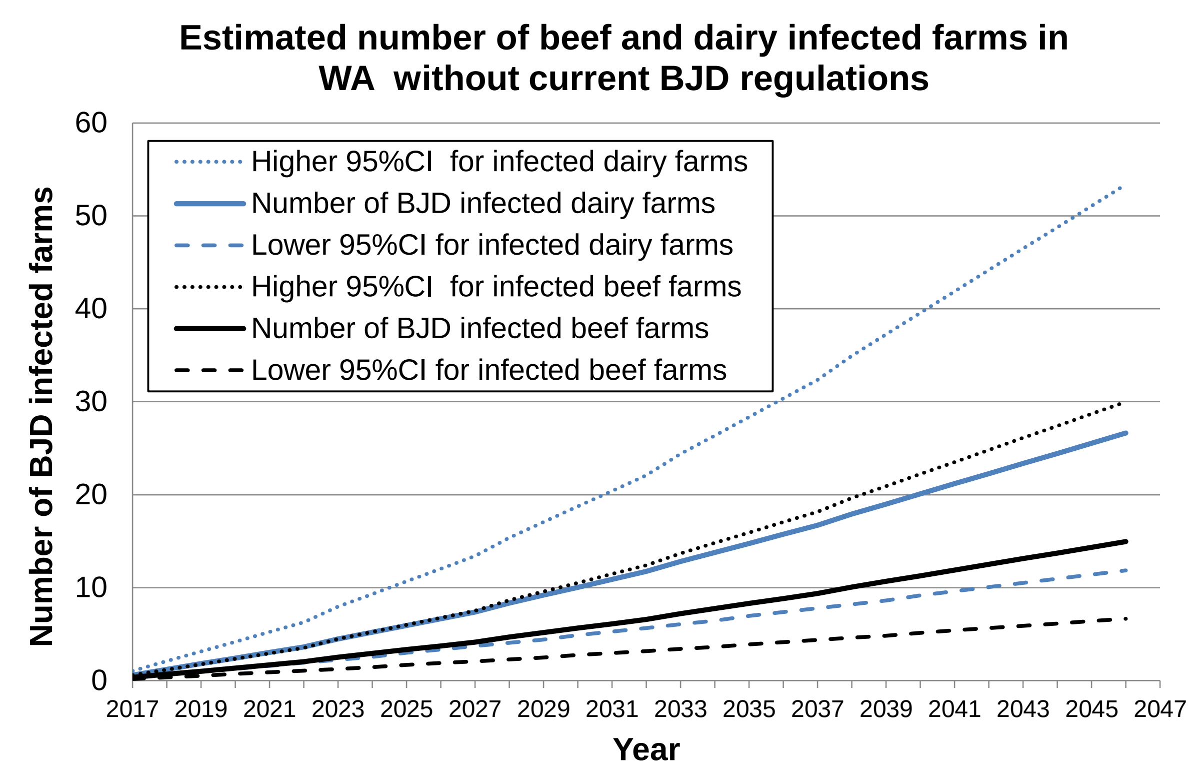

Figure 4 Number of BJD-positive dairy farms, compared with beef farms The solid lines represent an estimation of the average number of BJD-positive dairy (blue – top line) or beef (black – lower line) farms without any regulations and inter-farm spread. The area between upper and lower lines represents the range in numbers of positive farms that could be expected to present 95% of cases

BJD risk in northern WA compared to southern WA

The differences between farming practices and ecology between the extensive pastoral regions of WA and the agricultural region were explored; farm size, stocking density, farm density, climate and stock movements were taken into account. Extensive beef farming in a harsh dry hot semi-arid climate in the north (Kimberley, Pilbara and the northern Gascoyne regions) makes it less likely that BJD incursions onto properties would result in intra- and inter-herd spread. The more intensive farming in the south of WA, with higher stocking rates and a relatively wetter climate, would make within- and between-herd spread more likely. The differences were calculated and it is estimated that if a BJD incursion occurred in the north, after 20 years' an average of eight farms would be infected. Following a BJD incursion in the south, 11 farms would likely be infected over the same period. After 30 years, the BJD incursion in the north would on average result in 12 farms infected compared to 18 farms following an incursion in the south.

BJD in northern WA in exporting properties in 30 years

To estimate the number of exporting farms that may be infected with BJD in 30 years' time, the following assumptions were used:

First, only beef farms in the north of WA (north of the 26th parallel, latitude) were considered. Second, it is assumed there will be even spread in the Kimberley area and the Pilbara and northern Gascoyne regions. In the Kimberley region there are currently 60 exporting beef properties. The number of infected properties in 30 years' time was calculated using the ratio of exporters over non-exporters north of the 26th parallel. The results show that there will likely be seven exporters infected with BJD in 30 years' time (95%CI 3–13).

Modelling discussion

The results as shown above are best estimates and do not take into account factors such as changes in farming practices over 30 years. To make these predictions, the following assumptions were made:

- The number of cattle and cattle enterprises in WA remains similar over the modelling period.
- The number of BJD-susceptible stock movements from other jurisdictions into WA remains the same.
- Intrastate trading patterns remain stable.
- International trading patterns and export numbers remain stable.
- The proportional size of sub-industries remains similar (e.g. proportion of dairy to beef).
- There are no significant changes in the WA environment.
- There are no significant changes in WA cattle farming systems and economics.
- There are no significantly better diagnostic, control or prevention measures being implemented.
- There are no other regulatory BJD control or eradication measures implemented.
- Johne's disease requirements of international trading partners remain the same.

It is remarkable to note the significant difference in 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 (Stoneham et al, 1994). This is supported by the modelling shown in Figure 4.

The modelling considers likely scenarios. There is always the possibility that multiple BJD incursions occur in WA over the next 30 years but that the infected animal perishes without being diagnosed and with no-within herd spread. 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.

Economic impact of deregulation of BJD control in WA

The analyses below use the epidemiological modelling to estimate economic losses due to BJD on WA properties in an unregulated environment and are given under a no-action scenario at the state and farm level.

At the farm level, loss estimates are based on when clinical signs are first detected on the property. It is assumed that, in an unregulated environment, new farms are infected over time leading to different levels of loss for different farms over the 30-year period dependant on prevalence of infection and clinical disease.

Without regulatory control of BJD nationally, the risk of BJD entering WA will increase over time. This is for two reasons: lack of regulatory controls on livestock movements will increase the number of higher risk stock movements into WA, and over time the prevalence of BJD is likely to increase in other jurisdictions where the disease in unregulated (Loth, 2016).

A number of scenarios were calculated with a different number of farms being infected at different times over the 30 years to estimate the financial losses at farm level. The following parameters were used in the selection process:

- price of cattle in the range $1000–$1200
- number of properties infected based on the epidemiological models, however, some extreme worst case scenarios were simulated as well (including up to 45 properties infected)
- intra-farm spread rate as per epidemiological modelling.
- year of infection, and number of properties infected in a particular year
- clinical signs detected 4–6 years after introduction of disease
- percentage of animals clinically infected.

This process was applied to beef, dairy and breeding properties. Each simulation generally produced three or more scenarios. A number of simulations have been undertaken for each of the industry segments and nine relevant scenarios under three different simulations are presented here for beef and dairy. These nine scenarios were considered sufficient to cover a broad range of possibilities.

Six scenarios under two simulations are presented for breeding properties as losses for those farms were considered mainly market loss and not production loss. More simulations are presented in Table 9, Table 10 and 11 in Appendix 1.

Loss estimates – domestic trade properties

It is estimated that there will be 18 (95% confidence level [CI] 8–32) cattle properties infected with BJD in WA after 30 years of deregulation of the disease in WA.

The modelling shows that the most likely impact on domestic trade properties of BJD establishment in WA 30 years after deregulation is a total loss on average of $39 000 (ranging from $15 000 to $88 000) per year, with an NPV[4] loss of $900 (ranging

[4] The net present value (NPV) is a measurement of the profitability of an undertaking that is calculated by subtracting the present values (PV) of cash outflows (including initial cost) from the present values of cash inflows over a period of time.

from $550 to $1500) per infected farm per year. These calculations are based on the assumption that none of the infected properties sell into BJD-sensitive markets and losses are due to reduced production and deaths. Farm losses and industry losses occur when an infected animal starts showing clinical signs.

Other scenarios (under three simulations) using different prices/head, spread rate and cattle numbers are presented below with economic impact given for best case, most likely and worst case.

Simulation 1

Best case: Over 30 years, 18 (dairy and beef) cattle properties (1200 head, $1200/head) are infected with BJD and with 0.32% of the animals in the herds showing clinical signs, maximum financial losses are approximately $82 944 per year. In NPV terms, this equates to $34 391 for all properties per year. Losses per property in NPV terms will be $1911 per year.

Most likely: Over 30 years, 32 (dairy and beef) cattle properties (2000 head, $1200/head) are infected with BJD and with 0.42% of the animals in the herds showing clinical signs, maximum financial losses are approximately $322 650 per year. In NPV terms, this equates to $133 782 for all properties per year. Losses per property in NPV terms will be $4181 per year.

Worst case: Over 30 years, 45 (dairy and beef) cattle properties (2800 head, price $1200/head) infected with BJD and with 0.52% of the animals in the herds showing clinical signs, maximum financial losses are approximately $786 240 per year once all infected farms are showing clinical signs. In NPV terms, this equates to $326 000 for all properties per year. Losses per property in NPV terms are estimated to be $7 244 per year.

Simulation 2

Best case: Over 30 years, 11 (dairy and beef) cattle properties (800 head, $1200/head) are infected with BJD and with 0.26% of the animals in the herds showing clinical signs, maximum financial losses are approximately $27 456 per year. In NPV terms, this equates to $11 384 for all properties per year. Losses per property in NPV terms are estimated to be $1035 per year.

Most likely: Over 30 years, 24 (dairy and beef) cattle properties (1600 head, $1200/head) are infected with BJD and with 0.36% of the animals in the herds showing clinical signs, maximum financial losses are approximately $165 888 per year. In NPV terms, this equates to $68 783 for all properties per year. Losses per property in NPV terms will be $2866 per year.

Worst case: Over 30 years, 40 (dairy and beef) cattle properties (2400 head, $1200/head) are infected with BJD and with 0.46% of the animals in the herds showing clinical signs, maximum financial losses are approximately $529 000 per year. In NPV terms, this equates to $219 723 for all properties per year. Losses per property in NPV terms are estimated to be $5 493 per year.

Simulation 3

Best case: Over 30 years, 18 (dairy and beef) cattle properties (1500 head, $1000/head) are infected with BJD and with 0.21% of the animals in the herds showing clinical signs, maximum financial losses are approximately $56 700 per year. In NPV terms, this equates to $23 510 for all properties per year. Losses per property in NPV terms will be $1306 per year.

Most likely: Over 30 years, 32 (dairy and beef) cattle properties (2500 head, $1000/head) are infected with BJD and with 0.23% of the animals in the herds showing clinical signs, maximum financial losses are approximately $200 000 per year. In NPV terms, this equates to $82 927 for all properties per year. Losses per property in NPV terms will be $2591 per year.

Worst case: Over 30 years, 45 (dairy and beef) cattle properties (3500 head, $1000/head) are infected with BJD and with 0.27% of the animals in the herds showing clinical signs; maximum financial losses are approximately $456 750 per year. In NPV terms, this equates to $189 384 for all properties per year. Losses per property in NPV terms will be $4209 per year.

All scenarios are presented in Table 1 and Figure 5 below.

Table 1: Production losses after BJD deregulation (30 years)

Simulation	Simulation 1	Simulation 2	Simulation 3
Best case scenario ($'000)	83	27	56
Most likely scenario ($'000)	322	166	200
Worst case scenario ($'000)	786	529	456

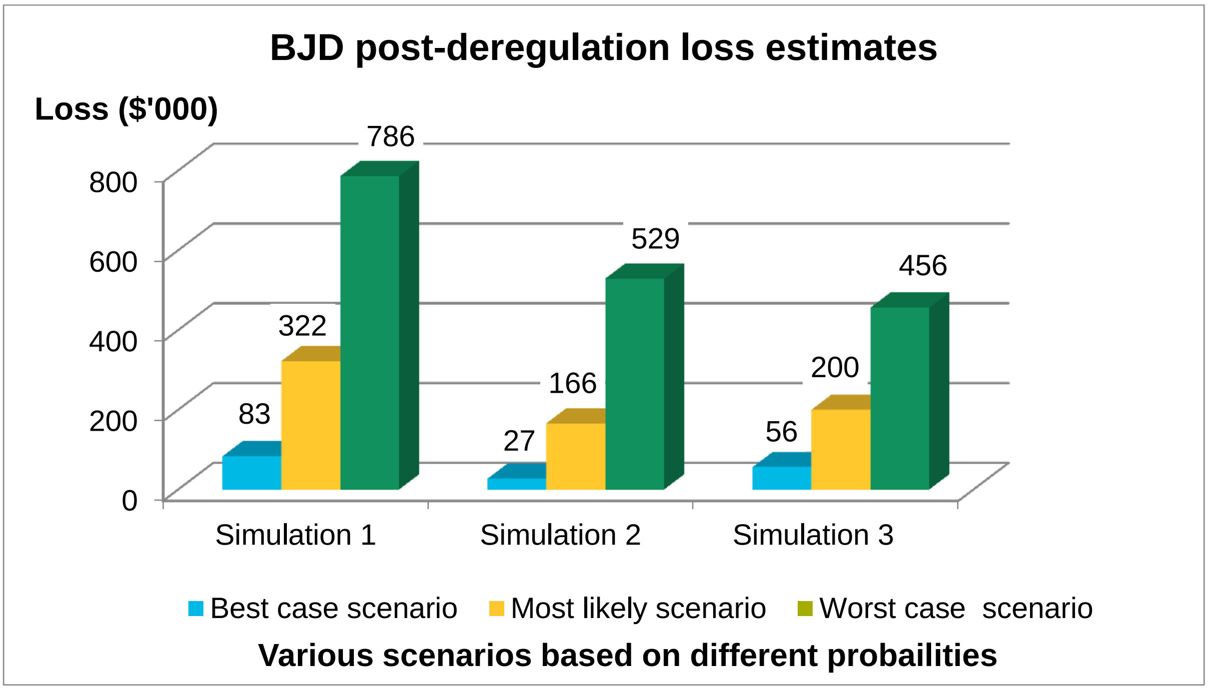

Figure 5 Production losses after deregulation (combined beef and dairy). These figures are based on the assumption that none of the infected properties are exporters and losses accrue due to production losses

Loss estimates – including export properties

Here the costs are calculated using the same epidemiological modelling for BJD-infected farms in 30 years' time but includes several properties (3–5) exporting to BJD-sensitive markets.

As above, these economic estimates depend on factors such as farm size and cattle price per head. In these simulations it is assumed that farm size varies in the range 3000–10 000 head per property, although this is likely an overestimate for exporting properties outside of the pastoral regions.

An infected property will suffer losses due to reduced production and deaths. Those that export may also suffer losses caused by reduced cattle prices for slaughter compared to export prices where they are unable to access JD-sensitive markets. Losses could vary in the range of $0.25M–$1.5M per year per exporting property depending on the farm size. Overall losses will depend on the number of exporting farms affected. Most likely (which indicates highest probability) export losses over 30 years are in the $11M–$14M range (NPV) if export properties are diagnosed with BJD. Table 2 below provides combined loss estimates when cattle, dairy and exporting farms are all affected by BJD.

Table 2 Cattle losses estimates after deregulation with exporting farms affected

Simulation	Simulation 1	Simulation 2	Simulation 3
Best case scenario ($M)	9.08	9.03	9.06
Most likely scenario ($M)	13.32	13.168	13.20
Worst case scenario ($M)	17.79	17.53	17.45

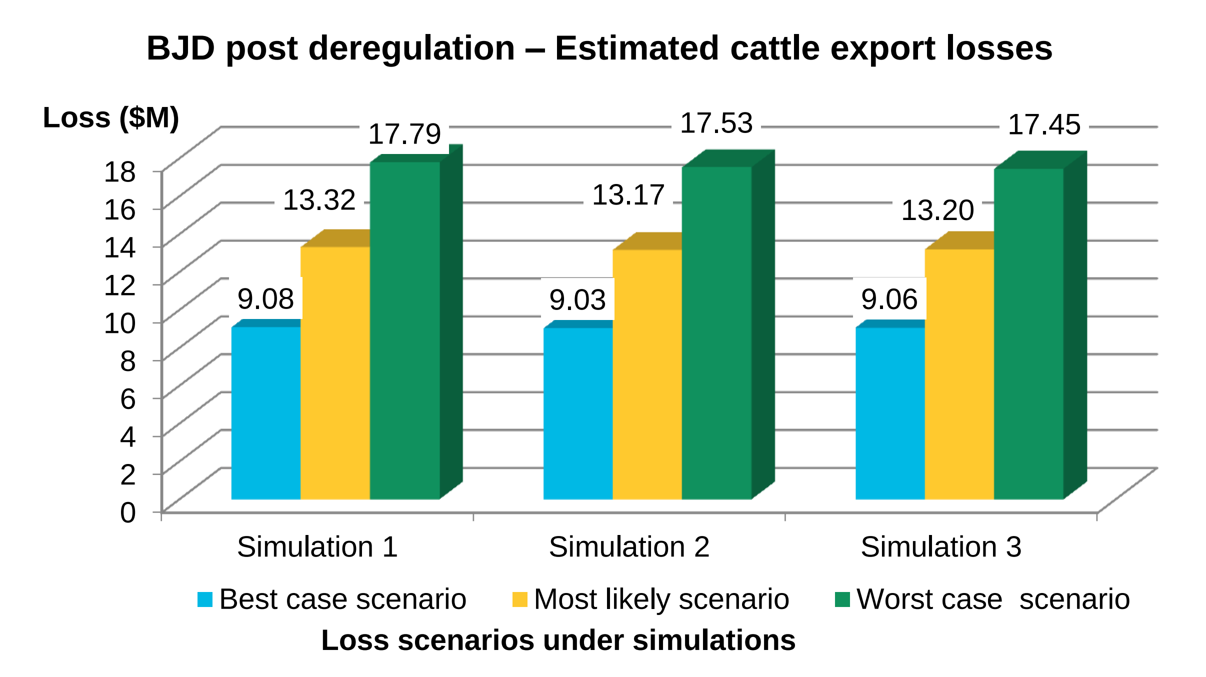

Figure 6 BJD production and export losses. BJD production and export losses. Above estimates are a combination of BJD post-deregulation production losses (nine scenarios) and potential export loss scenarios (nine scenarios)

Loss estimates – export trade in northern WA

Sixty beef cattle properties in the Kimberley region of WA are live animal exporters. If an exporting property becomes clinically infected with BJD, it is likely they will lose access to BJD-sensitive export market for at least five years based on current importing country requirements (see Table 19) plus time taken to manage the disease.

Currently, if BJD is found on a cattle-exporting farm and this finding affects access to BJD-sensitive markets, there are two major alternatives markets:

1. alternative export destinations that are not Johne's disease sensitive
2. domestic slaughter.

There is a distinct possibility that cattle intended for exports may lose 30–35% of their export value (Tim Wiley, pers. com.) if BJD is found on the farm due to lower domestic prices and oversupply of the domestic market. This formed the basis of the analysis. The other key parameter used is the turnoff rate (Verbrugge, Wiley, pers. com.), which is usually around 25–30%.

The potential impact of BJD on exporting properties under various simulated scenarios is calculated.

Export price and volume data

Table 3 Average price per bovine exported over the past 5 years

Countries	2010/11	2011/12	2012/13	2013/14	2014/15
Indonesia	$625.17	$658.87	$675.64	$781.59	$808.07
Israel	$653.95	$759.62	$700.09	$786.77	$903.40
Vietnam			$520.89	$721.77	$856.54
Malaysia	$518.75	$585.60	$598.62	$713.59	$909.70
Egypt	$759.81	$810.82	$675.00	$670.00	$690.00

Source: Katie Pritchett (DAFWA, ABS)

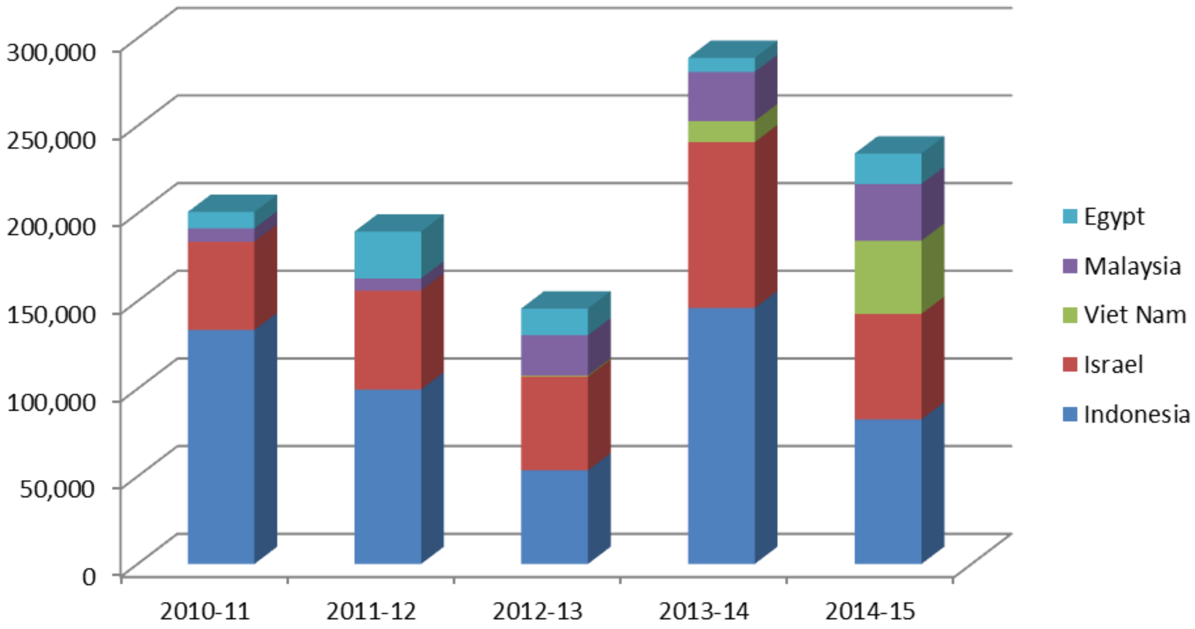

Figure 7 Live export cattle numbers to the top five countries

Based on the data for 2014-2015, cattle price for export is in the range $690–$910 per head. This price range has been used for the analysis.

In 2014/2015, WA properties exported to a total of 12 countries. The top five markets for WA cattle were Indonesia, Israel, Vietnam, Malaysia and Egypt. Other markets were Mauritius, Russian Federation, United Arab Emirates, Thailand, Turkey, Qatar and Jordan.

Total live cattle exports for 2014/2015 were 249 861 head worth approximately $213M. Export to Indonesia was of the highest value ($67M), followed by Israel ($54M), Vietnam ($36M), Malaysia ($29M) and Egypt (12M).

All of these markets have property-level requirements for BJD with the exception of Egypt, but they do not have a regional or state-based JD requirement. Therefore, there will not be a complete market loss as a result of BJD on WA properties.

Farms exporting to United Arab Emirates ($2.2M), Qatar ($0.4M) and Jordan ($0.2 M) are unlikely to be affected by on-farm BJD status as these markets do not have property-level requirements for JD. Other countries which do not have BJD restriction for imports are Bahrain, Kuwait and Singapore (see Table 19). Cattle were exported from WA to Bahrain and Kuwait until 2011/12.

Modelling the number of exporting properties in the Kimberley infected with BJD in 30 years

A number of hypothetical scenarios were simulated with single property outbreaks for exporting properties. Cattle numbers at exporting properties in the Kimberley are in the range of 1000–60 000. Results below are based on a sample of medium-sized properties with an average of 6 000 head per property and with the average cattle price for export being between $690 and $910. The model showed that if BJD established in the Kimberley in 30 years' time, on average seven properties would be BJD positive. Table 2 provides potential loss estimates in case of a BJD outbreak in a representative sample of exporting properties.

For this model, the following assumptions have been made:

- Only farms in northern WA (north of the 26th parallel) will become infected with BJD.
- There will be even spread between the Kimberley area and the Pilbara and northern Gascoyne regions
- Affected properties export to BJD-sensitive markets.
- Export to BJD-sensitive markets will completely stop from these properties and the animals on the property lose 30–40% value.
- Losses continue for at least five years (Tozer et al, 2010).
- Average number of cattle per property ranges from 3250–9450 head per property (range 1000–60 000). Medium cattle farm size in the Kimberley is therefore 6 350 head.
- At 30 years, number of farms infected with BJD is estimated to be between three and 13 with an average of seven.
- Additional fattening for domestic slaughter is likely to be cost neutral (Verbrugge, 2016).
- Transport costs to domestic slaughter are $20/head (Broome abattoir).

Loss estimates parameters for cattle exporting properties

- A combination of three different farm sizes are used for various simulations: 3250 (lower limit), 6 350 (most likely) and 9450 (upper limit).
- Turnoff rates vary in the range 25%, 30%, 35%.
- Loss due to lower price for cattle varies in the range 30%, 35% 40%.
- First infection occurs in year 6 post-deregulation.

Worst case scenario

- Up to 13 properties are infected.
- Over a 30-year period losses vary in the range of $30M–$56M.
- Losses in NPV terms over 30 years are in the range $17M–$26M.

Most likely scenario

- Up to seven properties are infected.
- Over a 30-year period losses vary in the range of $22M–$24M.
- Losses in NPV terms over 30 years are in the range of $11M–$14M.

Best case scenario

- Up to three properties are infected.
- Over a 30-year period losses vary in the range of $9M–$17M.
- Losses in NPV terms over 30 years are in the range $6M–$12M.

Summary of export loss estimates

The table and graph below represent the potential losses under the various scenarios.

Table 4 Export loss simulations in a deregulated situation

Deregulation	Loss estimates (30 years)	NPV
Worst case	$30M–$56M	$17M–$26M
Most likely case	$22M–$24M	$11M–$14M
Best case	$9M–$17M	$6M–$12M

Potential export losses are presented graphically below. Note that loss estimates do not account for extreme values (for example, if a cattle property with 40 000 head became infected with BJD, the losses will be a lot higher).

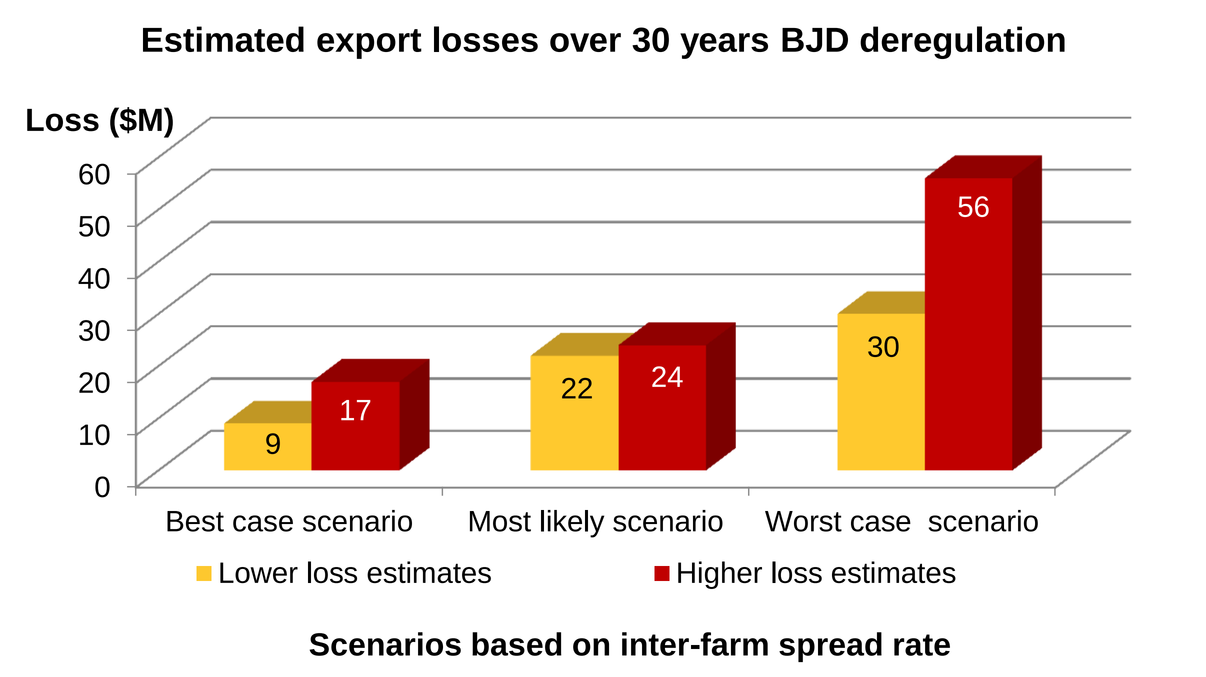

Figure 8 Export losses under deregulation. The above analysis covers losses for exporting properties should BJD be diagnosed on their property in a deregulated environment. While presented at an industry level, these losses are associated with export market loss for those individual infected properties

This modelling does not take into account other WA exporters increasing their export numbers to JD-sensitive markets in order to meet the resultant gap in supply. On an industry level this may reduce the overall losses, particularly over time.

Loss estimates – dairy industry

When estimating the losses due to a potential BJD outbreak in the WA dairy industry, losses due to decreased milk production of 4–6% have been taken into account[5] (Chaffer et al, 2002). Higher spread rates, both within and between farms, were applied for the dairy cattle industry according to literature review (Shepard, 2016) and practical experience in the Australian dairy industry. It is noted that losses due to BJD in these simulations are less than those caused by milk price[6] fluctuations over the past eight years.

Over a 30-year period the most likely scenario modelled is that 32 properties with 500 dairy cows each may be infected with 0.34% of animals showing clinical signs and 1.5% subclinically infected. This results in a total loss of $122 320 per year caused by a decreased milk production (4–6%) and removal and replacement of BJD-affected animals from the herd. Average NPV loss per infected farm in this case would be $2378 per year.

[5] It is assumed subclinical dairy cows would suffer 4–6% milk losses. On average dairy cows produce 6000L of milk per year and the current farm gate price is 0.49c/L.

[6] Milk prices fluctuated in the range of 42–49c/L between 2008 and 2015 (Dairy Australia).

Simulation 1

Best case: Over a 30-year period, 22 properties with 300 dairy cows may be infected showing clinical signs of 0.36% and subclinical of 1.6% resulting in a maximum total loss of $53 539 (NPV $33 301) per year with average loss per farm $1514 (NPV) per year.

Most likely: Over a 30-year period, 23 properties with 600 dairy cows may be infected with 0.34% of animals showing clinical signs and 1.5% subclinically infected resulting in a total loss of $100 809 (NPV $67 203) per year. Average loss per property may be $2726 per year per farm in NPV.

Worst case: Over a 30-year period, up to 57 properties with 1100 dairy cows may be infected showing clinical signs of 0.28% and subclinical signs of 1.2%, resulting in a maximum total loss of $391 498 per year (NPV $243 513). Average loss per property may be $4272 per farm per year.

Simulation 2

Best case: Over a 30-year period, 14 properties with 100 dairy cows may be infected with 0.38% showing clinical signs of and 1.7% subclinically infected, resulting in a maximum total loss of $12 010 (NPV $7 470) per year with average loss per farm $534 (NPV) per year.

Most likely: Over a 30-year period, it is estimated that 30 properties with 800 dairy cows each may be infected with 0.32% of animals showing clinical signs and 1.4% subclinically infected, resulting in a total loss of $164 592 (NPV 102 377) per year. Average NPV loss per farm per year is $3412.

Worst case: Over a 30-year period, 44 properties with 1200 dairy cows may be infected with 0.28% showing clinical signs and 1.2% subclinically infected, resulting in a maximum loss of $314 899 (NPV $195 868). Average loss per farm may be $4451 (NPV) per year.

Simulation 3

Best case: Over a 30-year period, 16 properties with 400 dairy cows may be infected with 0.36% showing clinical signs and 1.6% subclinically infected, resulting in a maximum total loss of $49 612 (NPV $30 589) per year with average loss per farm of $1928 (NPV) per year.

Most likely: Over a 30-year period, it is estimated that 40 properties with 700 dairy cows each may be infected with 0.32% of animals showing clinical signs and 1.4% sub-clinically infected, resulting in a total loss of $200 984 (NPV $125 013) per year. Average NPV loss per farm per year is $3125.

Worst case: Over a 30-year period, 48 properties with 900 dairy cows may be infected with 0.30% showing clinical signs of and 1.3% sub-clinically infected, resulting in a maximum total loss of $289 915 (NPV $180 328) per year with average loss per farm $3757 (NPV) per year.

Table 12 and Table 13 show alternative scenarios; farm size and different clinical prevalence (Appendix 1).

Table 5 Dairy industry production losses after BJD deregulation (30 years)

Simulations	Simulation 1	Simulation 2	Simulation 3
Best case scenario ($ '000)	53	12	49
Most likely scenario ($'000)	100	164	201
Worst case scenario ($'000)	391	314	289

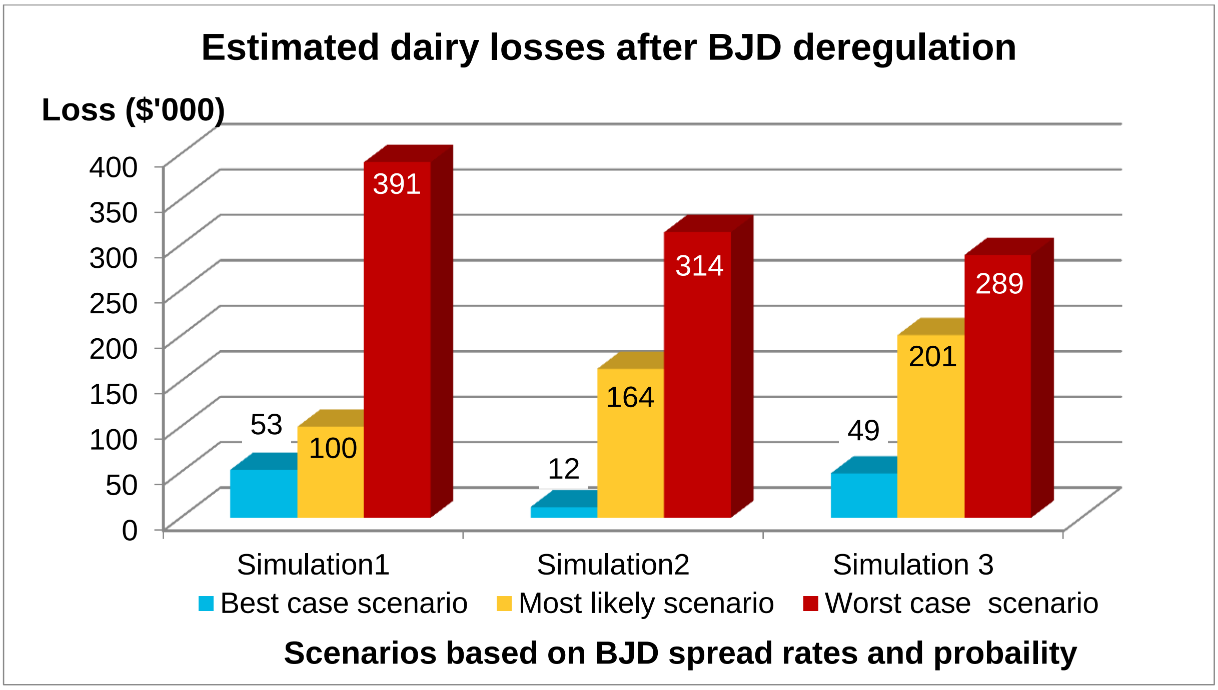

Figure 9 Dairy losses under various simulated scenarios

Loss estimates – cattle breeding properties

After 30 years, it is predicted that 18 properties will be infected with BJD, with 0.15% of the infected herd showing clinical signs. Assuming all 18 properties are seedstock producers, the most likely loss estimate for maximum total losses over 30 years are $146 000, with an NPV of $61 000 (or $3200 per farm) based on production losses.

These calculations do not take into account the potential loss in value of stock if a breeding property becomes infected and potential clients are therefore lost. Market loss is likely to be the significant factor for a breeding farm.

A number of different simulations was investigated over 30 years with the following variations in parameters:

1. Number of properties affected varies in the range 7–32.
2. Cattle numbers per property vary in the range 2000–3000 head (1.7 times slaughter or export value).
3. Rate of clinical disease varies in the range 0.14–0.24%
4. Breeder prices were considered to be in the range of $2000–$2500. Extreme prices, for example for some stud animals (e.g.>$10 000), are not reflected in the modelling.
5. Simulations assume that all infected properties are seedstock producers.

Simulation 1

Best case: Over a 30-year period, it is estimated that up to seven properties are infected (2000 head, $2000/ head) with 0.14% showing clinical signs resulting in a total loss of $39 200 (NPV $16 254) per year. Average NPV loss per farm per year is $2322.

Most likely: Over a 30-year period, it is estimated that up to 19 properties are infected (2400 head, $2000/head) with 0.16% showing clinical signs resulting in a total loss of $145 920 (NPV $60 503). Average NPV loss per farm per year is $3184.

Worst case: Over a 30-year period, it is estimated that up to 28 properties (2800 head, $2000/head) are infected with 0.21% showing clinical signs resulting in a total loss of $329 280 (NPV $136 531) per year. Average NPV loss per farm is per year is $4876.

Simulation 2

Best case: Over a 30-year period, it is estimated that up to 13 properties are infected (2200 head, $2000/ head) with 0.15% showing clinical signs resulting in a total loss of $85 800 (NPV $35 576) per year. Average NPV loss per farm per year is $2737.

Most likely: Over a 30-year period, it is estimated that up to 24 properties are infected (2600 head, $2000/head) with 0.19% showing clinical signs resulting in a total loss of $237 120 (NPV $98 318). Average NPV loss per farm per year is $4097.

Worst case: Over a 30-year period, it is estimated that up to 32 properties (3000 head, $2000/head) are infected with 0.24% showing clinical signs resulting in a total loss of $460 800 (NPV $191 064) per year. Average NPV loss per farm is per year is $5 971.

Table 6 Breeding property losses after BJD deregulation (30 years)

Simulations	Simulation 1	Simulation 2
Best case scenario ($ '000)	39	85
Most likely scenario ($'000)	145	237
Worst case scenario ($'000)	329	460

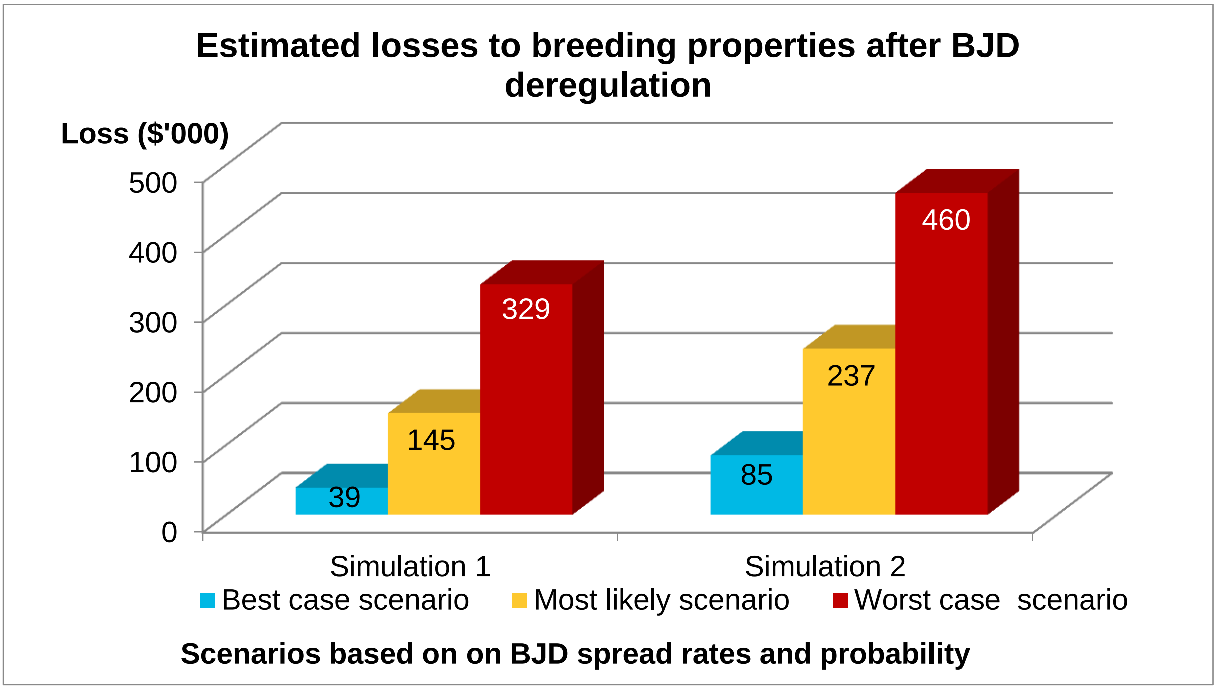

Figure 10 BJD losses to breeding properties

Note: It is assumed that in this scenario no exporting properties are involved. If necessary these values can be derived from Table 2: Cattle losses estimates after deregulation with exporting farms affected.

Maintaining current regulatory equivalence for BJD control in WA

This section looks at costs to industry of maintaining regulation for BJD within WA. It assumes a similar level of regulatory control to that applied under the National BJD Strategic Plan (2012–2020).

Annual passive surveillance and regulatory program costs

Current costs of the WA BJD annual surveillance program average around $86 000 per year. With the cessation of the National BJD Strategic Plan, management (regulatory or otherwise) of BJD in WA is to transition fully to an industry responsibility. For this reason, it is estimated that an annual surveillance and regulatory program equivalent to that currently in place will cost around $100 000 per year. The minimal rise takes into account that border controls are largely cost-recovered and so do not add significantly to overall cost. Border controls are one of the main components of the program that are currently government funded.

Over the modelled 30-year period, this will give a total cost of $3M with an NPV cost of $1 376 483, assuming these costs do not change significantly. If the cost goes up by 3% annually (assuming that is the approximate inflation rate) then total cost for the program over 30 years will be $4.75M with an NPV of $1.92M. This does not take into account any concurrent disease eradication programs or targeted surveillance.

Eradication of BJD following incursion

Despite previous regulatory import restrictions to prevent BJD incursion, there has been one incursion/outbreak of BJD in WA every 6–7 years over the past 60 years. Based on this evidence, it is estimated that 3–9 properties may be infected over the next 30 years even with the maintenance of regulatory border controls. Note, however, that this will likely increase due to changing disease prevalence elsewhere in Australia.

Maintenance of WA's negligible disease prevalence would require eradication of disease when incursions are detected. Eradication can be achieved by quarantining and culling all animals on the property, or quarantining, identifying and culling infected and in-contact animals, and conducting herd tests for a period until freedom from disease can be achieved (DAFF, 2014; DEPI, 2013).

Under both scenarios the cost to producers of disease eradication is estimated at an average $500 per head of cattle. Farm size varies from 1–75,000 head. The cost to eradicate BJD from an average WA cattle property is therefore $500 000 (95%CI 450 000–5 000 000). Assuming nine medium-sized properties become infected over the 30-year period (the upper value is taken to account for increasing disease prevalence in other jurisdictions over time), total eradication costs over a 30-year period may be as high as $4.5M.

In the case of destruction of livestock under regulation for BJD control purposes, compensation costs are payable under the Biosecurity and Agriculture Management Industry Funding Scheme (Cattle) Regulations 2010.

These costs do not take into account extreme values such as eradication of disease by destocking on a very large property (for example an extensive pastoral property) or multi-property outbreaks, and they do not take into account additional surveillance required post-eradication. These will both increase the estimated costs and could be significant.

Table 7 Eradication cost for BJD outbreak: single and dual farms

BJD outbreak	Best case scenario	Most likely scenario	Worst case scenario
Single outbreak cost (M$)	2	5	9
Multiple outbreak cost (M$)	5	8	12

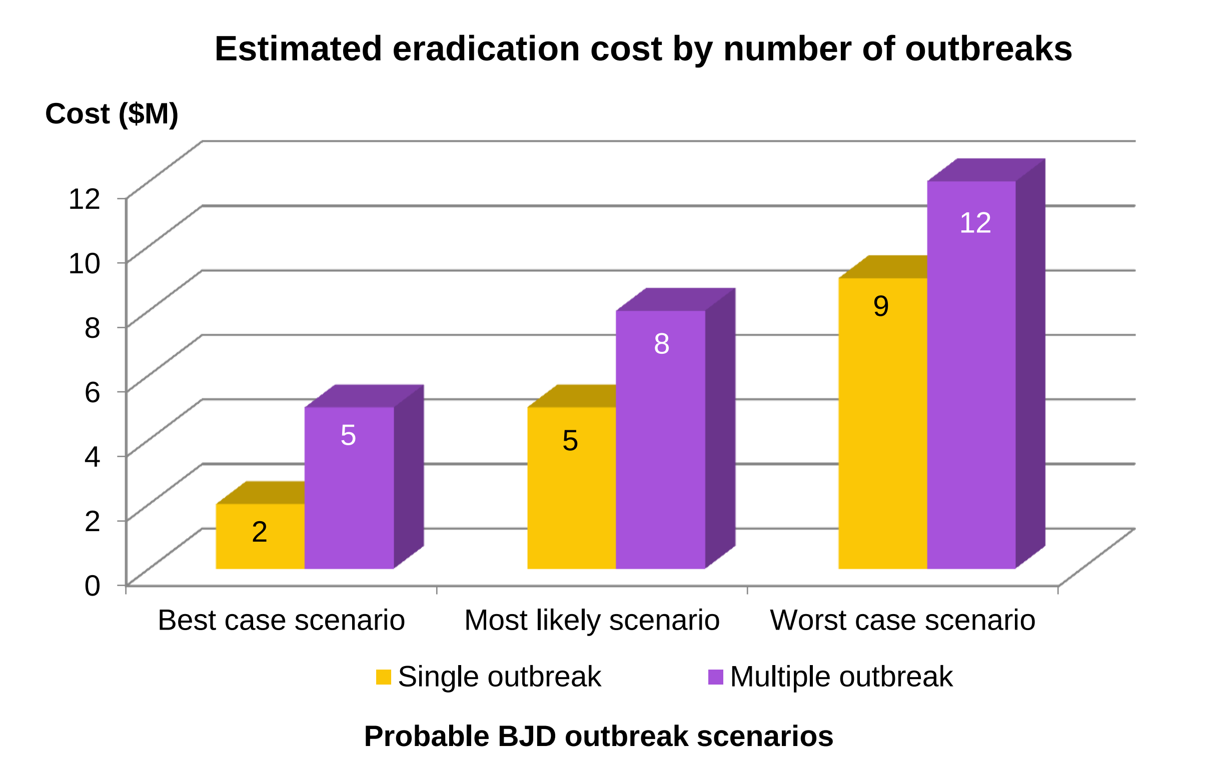

Figure 11 Eradication costs of BJD incursions

Proof of freedom – targeted surveillance

In addition to the annual passive surveillance program identified above, which focuses on investigation of suspect clinical disease and export test reactors, in order to continue with a regulatory control program for BJD within WA it will be necessary to prove that the disease is not present by undertaking a targeted surveillance program.

Proof of freedom surveillance will cost an estimated additional $100 000 per year (based on $500 000 every five years) to show that BJD is not present in WA with a 95% confidence level that the disease would be detected if it were present at 2% prevalence (Loth, 2015).

Should this surveillance show the presence of BJD in WA, the decision would have to be made as to whether significant additional funding should be applied to control and eradicate BJD in WA or not.

Total overall industry costs of a regulatory and surveillance program to control the entry and establishment of BJD within WA are presented below in Table 8. Note that, as above, eradication costs are conservative and do not take into account disease eradication on large, extensive, or multiple properties.

Table 8 Total cost of BJD regulatory control program in WA

Total cost	Cost breakdown	Over 30 years	NPV
Regulatory program	100 000/year	$3.0M	$1.37M
Targeted surveillance	100 000/year	$3.0M	$1.37M
Eradication costs	when applicable	$4.5M	$3.40M
Total		$10.5M	$6.14M

Individual producer costs

The industry costs given above do not include additional costs to individual producers of a statewide BJD regulatory program.

For some producers, the consequential costs will be greater than the potential cost of the disease in a deregulated environment where BJD is diagnosed or suspected on a property. These are the result of both regulatory and market-applied trade restrictions. This is applicable to producers who sell both into domestic market and export markets.

These include:

- costs associated with regulatory movement restrictions where disease is diagnosed on a property
- costs associated with regulatory movement restrictions where disease is suspected to be present on a property, for example after tracing animals from infected properties
- losses associated with not being able to access genetics from interstate.

Conclusion

Based on the existing epidemiological evidence from other states in Australia and overseas, a model was constructed to simulate scenarios for BJD entry and establishment in WA in a post-regulation environment. A number of 20-year and 30-year disease spread simulations were conducted and results presented.

These disease spread simulations were then used to explore various economic impact simulations at varying parameters such as different cattle numbers per property, within-herd clinical and subclinical infection rates, and value per head.

It appears from this modelling that, given the likely inter-herd and intra-herd spread rate of BJD, it is unlikely that the disease will cause significant production and associated economic losses in the WA cattle industries. This is particularly applicable to producers who sell into a domestic market and includes the dairy industry, and is supported by previous studies (Williams, 2014).

In NPV terms, production losses in beef cattle, breeder and dairy farms are estimated to be quite small on a per-property basis ranging from $900–$7 244 per infected farm per year once clinical signs are observed. These results are similar to recent findings in Victoria (Shephard et al, 2016).

Given the slow rate of inter-herd disease spread, these values are also small when applied on an industry level over the 30-year modelling period. At an industry level the costs of a regulatory program over 30 years are significantly greater than likely industry losses due to production impacts.

At an individual level, losses due to movement restrictions under a regulatory control program are likely to be far higher than production losses associated with presence of the disease.

Economic losses associated with the loss of access to BJD-sensitive markets, however, could be significant. This includes some export markets. Four of WA's main international trading partners have property-level requirements for Johne's disease freedom, and so access to these markets is lost to individual producers if BJD is found on their property.

It needs to be noted, however, that this does not impact the access of WA industry as a whole to these markets, as requirements are at a property level only. This analysis considers losses at an industry level based on numbers of predicted properties with disease, but does not consider that other exporters may increase supply and so reduce the overall economic impact.

In addition, while individual losses associated with a BJD diagnosis on an exporting property may be significant, losses of a similar magnitude may result from actions associated with a regulatory program that results in property-level restrictions for presence or suspicion of BJD.

The modelling demonstrates that it is not possible to assign the same level of cost or benefit of BJD regulation and disease across the WA cattle industry. The costs associated with the disease differ significantly depending on individual business models, as do potential costs of regulatory restrictions on individual business. Equally, the benefits of a regulated disease control program in WA cannot be assigned equally across individual businesses or even sub-industries.

While the modelling undertaken should be valid across the industry generally, individual businesses will need to undertake their own analysis based on their business requirements and individual risks. For example, farms which have more than 60 000 head of cattle are likely to have a completely different risk profile and biosecurity requirements compared to average size cattle farms, and producers who regularly bring cattle on to their property are at higher risk of BJD incursion.

Recommendations

Using the outcomes of this analysis, it is recommended that the WA cattle industry develops an options paper for control of BJD in WA. This will allow more accurate costing of potential regulatory options and further consideration by industry.

Acknowledgments

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Appendices

Appendix 1: Net present values calculation tables

Table 9 Beef cattle losses: 30-year projection for BJD impact for various scenarios with beef cattle price of $1000/head

Head	1000	1500	2000	2500	3000	3500
Year	11 properties 0.19% clinical	18 properties 0.21% clinical	24 properties 0.21% clinical	32 properties 0.23% clinical	40 properties 0.25% clinical	45 properties 0.27% clinical
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$353	$958	$1704	$3,381	$5 477	$7 721
6	$375	$1016	$1806	$3,584	$5 806	$8 184
7	$397	$1077	$1915	$3,799	$6 154	$8 675
8	$421	$1142	$2029	$4,027	$6 523	$9 196
9	$446	$1210	$2151	$4,268	$6 915	$9 748
10	$473	$1283	$2280	$4,524	$7 329	$10 333
11	$501	$1360	$2417	$4,796	$7 769	$10 952
12	$531	$1441	$2562	$5 084	$8 235	$11 610
13	$563	$1528	$2716	$5 389	$8 730	$12 306
14	$597	$1619	$2879	$5 712	$9 253	$13 045
15	$633	$1716	$3052	$6 055	$9 808	$13 827
16	$671	$1819	$3235	$6 418	$10 397	$14 657
17	$711	$1929	$3429	$6 803	$11 021	$15 536

Head	1000	1500	2000	2500	3000	3500
Year	11 properties 0.19% clinical	18 properties 0.21% clinical	24 properties 0.21% clinical	32 properties 0.23% clinical	40 properties 0.25% clinical	45 properties 0.27% clinical
18	$754	$2044	$3634	$7 211	$11 682	$16 468
19	$799	$2167	$3852	$7 644	$12 383	$17 457
20	$847	$2297	$4084	$8 102	$13 126	$18 504
21	$898	$2435	$4329	$8 589	$13 914	$19 614
22	$951	$2581	$4588	$9 104	$14 748	$20 791
23	$1008	$2736	$4864	$9 650	$15 633	$22 039
24	$1069	$2900	$5 155	$10 229	$16 571	$23 361
25	$1133	$3074	$5 465	$10 843	$17 566	$24 762
26	$1201	$3258	$5 793	$11 493	$18 619	$26 248
27	$1273	$3454	$6 140	$12 183	$19 737	$27 823
28	$1350	$3661	$6 509	$12 914	$20 921	$29 493
29	$1430	$3881	$6 899	$13 689	$22 176	$31 262
30	$1516	$4114	$7 313	$14 510	$23 507	$33 138
Total	$20 900	$56 700	$100 800	$200 000	$324 000	$456 750
NPV	$8 666	$23 510	$41 795	$82 927	$134 342	$189 384
Loss/property	$788	$1306	$1741	$2591	$3359	$4209

Note: Estimates are based on various farm sizes ranging from 1000–3500 head. Intra-farm spread range is 0.19%–0.27%. Properties infected over 30 years vary in the range 11–45. The table represents six different case studies from which more combinations can be derived. Maximum total loss over 30 years is $456,750. This is the last column where 45 infected properties are showing clinical signs to the extent of 0.27%. Losses per property in NPV terms are $4209.

Table 10 30-year projection for BJD impact with beef cattle price of $1200/head (part 1)

Head	800	1200	1600
Year	11 properties clinical 0.14%	18 properties clinical 0.15%	24 properties clinical 0.19%
1	$0	$0	$0
2	$0	$0	$0
3	$0	$0	$0
4	$0	$0	$0
5	$246	$659	$1486
6	$261	$699	$1575
7	$276	$740	$1670
8	$293	$785	$1770
9	$311	$832	$1876
10	$329	$882	$1989
11	$349	$935	$2108
12	$370	$991	$2235
13	$392	$1050	$2369
14	$416	$1113	$2511
15	$441	$1180	$2662
16	$467	$1251	$2821
17	$495	$1326	$2991
18	$525	$1406	$3170

Head	800	1200	1600
Year	11 properties clinical 0.14%	18 properties clinical 0.15%	24 properties clinical 0.19%
19	$556	$1490	$3360
20	$590	$1579	$3562
21	$625	$1674	$3776
22	$662	$1775	$4002
23	$702	$1881	$4242
24	$744	$1994	$4497
25	$789	$2113	$4767
26	$836	$2240	$5 053
27	$886	$2375	$5 356
28	$940	$2517	$5 677
29	$996	$2668	$6 018
30	$1056	$2828	$6 379
Total loss	$14 552	$38 984	$87 921
NPV loss	$6 034	$16 164	$36 455
Loss/property	$549	$898	$1519

Note: Estimates are based on various farm sizes ranging from 800–1600. Intra-farm spread range is 0.14%–0.19%. Numbers of properties affected vary in the range 11–24.

Table 11 30-year projection for BJD impact with beef cattle price of $1200/head (part 2)

Head	800	1200	1600	2000	2400	2800
Year	11 properties 0.26% clinical	18 properties 0.32% clinical	24 properties 0.36% clinical	32 properties 0.42% clinical	40 properties 0.46% clinical	45 properties 0.52% clinical
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$464	$1402	$2804	$5 454	$8 958	$13 291
6	$492	$1486	$2972	$5 781	$9 495	$14 088
7	$521	$1575	$3151	$6 128	$10 065	$14 934
8	$553	$1670	$3340	$6 496	$10 669	$15 830
9	$586	$1770	$3540	$6 886	$11 309	$16 779
10	$621	$1876	$3753	$7 299	$11 988	$17 786
11	$658	$1989	$3978	$7 737	$12 707	$18 853
12	$698	$2108	$4217	$8 201	$13 469	$19 985
13	$740	$2235	$4470	$8 693	$14 278	$21 184
14	$784	$2369	$4738	$9 215	$15 134	$22 455
15	$831	$2511	$5 022	$9 768	$16 042	$23 802
16	$881	$2662	$5 323	$10 354	$17 005	$25 230
17	$934	$2821	$5 643	$10 975	$18 025	$26 744
18	$990	$2991	$5 981	$11 633	$19 107	$28 348

Head	800	1200	1600	2000	2400	2800
Year	11 properties 0.26% clinical	18 properties 0.32% clinical	24 properties 0.36% clinical	32 properties 0.42% clinical	40 properties 0.46% clinical	45 properties 0.52% clinical
19	$1049	$3170	$6 340	$12 331	$20 253	$30 049
20	$1112	$3360	$6 721	$13 071	$21 468	$31 852
21	$1179	$3562	$7 124	$13 856	$22 756	$33 763
22	$1250	$3776	$7 551	$14 687	$24 122	$35 789
23	$1325	$4002	$8 004	$15 568	$25 569	$37 937
24	$1404	$4242	$8 484	$16 502	$27 103	$40 213
25	$1489	$4497	$8 994	$17 492	$28 729	$42 626
26	$1578	$4767	$9 533	$18 542	$30 453	$45 183
27	$1672	$5 053	$10 105	$19 654	$32 280	$47 894
28	$1773	$5 356	$10 711	$20 834	$34 217	$50 768
29	$1879	$5 677	$11 354	$22 084	$36 270	$53 814
30	$1992	$6 018	$12 035	$23 409	$38 446	$57 043
Total loss	$27 456	$82 944	$165 888	$322 650	$529 920	$786 240
NPV loss	$11 384	$34 391	$68 783	$133 782	$219 723	$326 002
Loss/property	$1035	$1911	$2866	$4181	$5 493	$7 244

Note: Estimates are based on various farm size ranging from 800–2800 head. Intra-farm spread range is 0.26%–0.52%. Number of properties infected over 30 years varies in the range 11–45. Table 11 represents six different case studies from which more combinations can be derived. Maximum loss is $786,000 over 30 years. Loss per property in NPV terms is $7244.

Table 12 Dairy losses over 30 years (200–1200 head per property)

Cows	200	400	600	800	1000	1200
Year	12 properties clinical 0.38% subcl 1.7%	16 properties clinical 0.36% subcl 1.6%	23 properties clinical 0.34% subcl 1.5%	30 properties clinical 0.32 subcl 1.4%	37 properties clinical 0.30 subcl 1.3%	44 properties clinical 0.28% subcl 1.2%
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$323	$839	$1704	$2782	$4010	$5 323
6	$362	$889	$1806	$2950	$4250	$5 643
7	$374	$942	$1915	$3126	$4505	$5 981
8	$396	$999	$2030	$3314	$4776	$6 340
9	$420	$1059	$2151	$3513	$5 062	$6 720
10	$445	$1122	$2280	$3723	$5 366	$7 124
11	$472	$1190	$2417	$3947	$5 688	$7 551
12	$500	$1261	$2562	$4184	$6 029	$8 004
13	$530	$1337	$2716	$4435	$6 391	$8 484
14	$562	$1417	$2879	$4701	$6 775	$8 993
15	$596	$1502	$3052	$4983	$7 181	$9 533
16	$631	$1592	$3235	$5 282	$7 612	$10 105
17	$669	$1688	$3429	$5 599	$8 069	$10 711

Cows	200	400	600	800	1000	1200
Year	12 properties clinical 0.38% subcl 1.7%	16 properties clinical 0.36% subcl 1.6%	23 properties clinical 0.34% subcl 1.5%	30 properties clinical 0.32 subcl 1.4%	37 properties clinical 0.30 subcl 1.3%	44 properties clinical 0.28% subcl 1.2%
18	$709	$1789	$3635	$5 934	$8 553	$11 354
19	$752	$1896	$3853	$6 291	$9 066	$12 035
20	$797	$2010	$4084	$6 668	$9 610	$12 757
21	$845	$2130	$4329	$7 068	$10 186	$13 523
22	$896	$2258	$4589	$7 492	$10 798	$14 334
23	$949	$2394	$4864	$7 942	$11 445	$15 194
24	$1006	$2537	$5 156	$8 418	$12 132	$16 106
25	$1067	$2690	$5 465	$8 923	$12 860	$17 072
26	$1131	$2851	$5 793	$9 459	$13 632	$18 096
27	$1199	$3022	$6 141	$10 026	$14 450	$19 182
28	$1271	$3203	$6 509	$10 628	$15 317	$20 333
29	$1347	$3396	$6 900	$11 265	$16 236	$21 553
30	$1428	$3599	$7 314	$11 941	$17 210	$22 846
Total	$19 677	$49 612	$100 809	$164 592	$237 207	$314 899
NPV	$12 239	$30 859	$62 703	$102 377	$147 543	$195 868
Loss/property	$1019.89	$1928.67	$2726.24	$3412.55	$3987.66	$4451.54

Note: Table is designed to address queries regarding numerous different situations. Over 30 years without intervention, 12–44 dairies may be infected by the BJD. Maximum loss that may occur is $314,899 over 30 years (6th column). Losses (NPV) per property are $4451.

Table 13 Dairy losses over 30 years (100–1100 head per property)

Cows	100	300	500	700	900	1100
Year	14 properties 0.38% clinical 1.7% subcl	22 properties 0.36% clinical 1.6% subcl	32 properties 0.34% clinical 1.5% subcl	40 properties 0.32% clinical 1.4% subcl	48 properties 0.30% clinical 1.3% subcl	57 properties 0.28% clinical 1.2% subcl
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$203	$905	$2068	$3398	$4901	$6 618
6	$215	$959	$2192	$3601	$5195	$7 015
7	$228	$1017	$2323	$3817	$5 507	$7 436
8	$242	$1078	$2463	$4046	$5 837	$7 882
9	$256	$1143	$2610	$4289	$6 187	$8 355
10	$272	$1211	$2767	$4547	$6 558	$8 856
11	$288	$1284	$2933	$4819	$6 952	$9 388
12	$305	$1361	$3109	$5 109	$7 369	$9 951
13	$324	$1443	$3296	$5 415	$7 811	$10 548
14	$343	$1529	$3493	$5 740	$8 280	$11 181
15	$364	$1621	$3703	$6 084	$8 777	$11 852
16	$385	$1718	$3925	$6 449	$9 303	$12 563
17	$409	$1821	$4161	$6 836	$9 861	$13 317

Cows	100	300	500	700	900	1100
Year	14 properties 0.38% clinical 1.7% subcl	22 properties 0.36% clinical 1.6% subcl	32 properties 0.34% clinical 1.5% subcl	40 properties 0.32% clinical 1.4% subcl	48 properties 0.30% clinical 1.3% subcl	57 properties 0.28% clinical 1.2% subcl
18	$433	$1930	$4410	$7 247	$10 453	$14 116
19	$459	$2046	$4675	$7 681	$11 080	$14 963
20	$487	$2169	$4955	$8 142	$11 745	$15 860
21	$516	$2299	$5 253	$8 631	$12 450	$16 812
22	$547	$2437	$5 568	$9 149	$13 197	$17 821
23	$579	$2583	$5 902	$9 698	$13 989	$18 890
24	$614	$2738	$6 256	$10 279	$14 828	$20 023
25	$651	$2903	$6 632	$10 896	$15 718	$21 225
26	$690	$3077	$7 029	$11 550	$16 661	$22 498
27	$732	$3261	$7 451	$12 243	$17 660	$23 848
28	$775	$3457	$7 898	$12 978	$18 720	$25 279
29	$822	$3664	$8 372	$13 756	$19 843	$26 796
30	$871	$3884	$8 874	$14 582	$21 034	$28 404
Total	$12 010	$53 539	$122 320	$200 984	$289 915	$391 498
NPV	$7 470	$33 301	$76 083	$125 013	$180 328	$243 513
Loss/property	$534	$1514	$2378	$3125	$3757	$4272

Note: Table is designed to address queries regarding numerous different situations. Over 30 years without intervention 14–57 dairies may be infected by BJD. Maximum loss that may occur is $391,498 over 30 years (6th column). Losses (NPV) per property are $4272.

Table 14 BJD impact on cattle breeding farms over 30 years with cattle price per head of $2000

Head	2000	2200	2400	2600	2800	3000
Year	7 properties clinical 0.14%	13 properties clinical 0.15%	19 properties clinical 0.16%	24 properties clinical 0.19%	28 properties clinical 0.21%	32 properties clinical 0.24%
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$663	$1450	$2467	$4008	$5 566	$7 790
6	$702	$1537	$2615	$4249	$5 900	$8 257
7	$745	$1630	$2772	$4504	$6 254	$8 752
8	$789	$1727	$2938	$4774	$6 630	$9 277
9	$837	$1831	$3114	$5 060	$7 027	$9 834
10	$887	$1941	$3301	$5 364	$7 449	$10 424
11	$940	$2057	$3499	$5 686	$7 896	$11 050
12	$996	$2181	$3709	$6 027	$8 370	$11 713
13	$1056	$2312	$3932	$6 389	$8 872	$12 415
14	$1120	$2450	$4167	$6 772	$9 404	$13 160
15	$1187	$2597	$4417	$7 178	$9 968	$13 950
16	$1258	$2753	$4683	$7 609	$10 566	$14 787
17	$1333	$2918	$4963	$8 066	$11 200	$15 674
18	$1413	$3094	$5 261	$8 550	$11 872	$16 614

Head	2000	2200	2400	2600	2800	3000
Year	7 properties clinical 0.14%	13 properties clinical 0.15%	19 properties clinical 0.16%	24 properties clinical 0.19%	28 properties clinical 0.21%	32 properties clinical 0.24%
19	$1498	$3279	$5 577	$9 063	$12 585	$17 611
20	$1588	$3476	$5 912	$9 606	$13 340	$18 668
21	$1683	$3685	$6 266	$10 183	$14 140	$19 788
22	$1784	$3906	$6 642	$10 794	$14 989	$20 975
23	$1891	$4140	$7 041	$11 441	$15 888	$22 234
24	$2005	$4388	$7 463	$12 128	$16 841	$23 568
25	$2125	$4652	$7 911	$12 855	$17 852	$24 982
26	$2253	$4931	$8 386	$13 627	$18 923	$26 481
27	$2388	$5 227	$8 889	$14 444	$20 058	$28 070
28	$2531	$5 540	$9 422	$15 311	$21 262	$29 754
29	$2683	$5 873	$9 987	$16 230	$22 537	$31 539
30	$2844	$6 225	$10 587	$17 203	$23 890	$33 432
Total	$39 200	$85 800	$145 920	$237 120	$329 280	$460 800
NPV	$16 254	$35 576	$60 503	$98 318	$136 531	$191 064
Loss/property	$2322	$2737	$3184	$4097	$4876	$5 971

Note: Table is designed to address queries regarding numerous different situations. Over 30 years without intervention, 7–32 breeding properties may be infected by BJD. Impact varies based on the number of cattle on each property. Maximum loss under this scenario is estimated to be $460,888 with NPV losses per farm $5791.

Table 15 BJD impact on cattle breeding farms over 20 years with cattle price per head of $2000

Head	2000	2200	2400	2600	2800	3000
Year	8 properties clinical 0.14%	12 properties clinical 0.15%	16 properties clinical 0.16%	18 properties clinical 0.17%	20 properties clinical 0.18%	24 properties clinical 0.19%
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$1745	$3085	$4786	$6 198	$7 853	$10 657
6	$1850	$3270	$5 074	$6 570	$8 324	$11 297
7	$1961	$3466	$5 378	$6 964	$8 823	$11 975
8	$2078	$3674	$5 701	$7 382	$9 353	$12 693
9	$2203	$3895	$6 043	$7 825	$9 914	$13 455
10	$2335	$4128	$6 405	$8 294	$10 509	$14 262
11	$2475	$4376	$6 790	$8 792	$11 139	$15 118
12	$2624	$4639	$7 197	$9 320	$11 808	$16 025
13	$2781	$4917	$7 629	$9 879	$12 516	$16 986
14	$2948	$5 212	$8 087	$10 472	$13 267	$18 005
15	$3125	$5 525	$8 572	$11 100	$14 063	$19 086
16	$3313	$5 856	$9 086	$11 766	$14 907	$20 231
17	$3511	$6 208	$9 631	$12 472	$15 801	$21 445
18	$3722	$6 580	$10 209	$13 220	$16 749	$22 731

Head	2000	2200	2400	2600	2800	3000
Year	8 properties clinical 0.14%	12 properties clinical 0.15%	16 properties clinical 0.16%	18 properties clinical 0.17%	20 properties clinical 0.18%	24 properties clinical 0.19%
19	$3945	$6 975	$10 822	$14 013	$17 754	$24 095
20	$4182	$7 393	$11 471	$14 854	$18 820	$25 541
Total	$44 800	$79 200	$122 880	$159 120	$201 600	$273 600
NPV	$26 340	$46 566	$72 248	$93 556	$118 532	$160 865
Loss/property	$3293	$3881	$4 516	$5 198	$5 927	$6 703

Note: Table is designed to address queries regarding numerous different situations. Over 20 years without intervention, 8–24 breeding properties may be infected by BJD. Impact varies based on the number of cattle on each property. Maximum loss under this scenario is estimated to be $273,600 with NPV losses per farm $6703.

Table 16: Alternative scenario for breeding farms over 30 years with cattle price at $2500 per head – maximum loss estimates

Head	**3000**	**3200**	**3400**	**3600**	**3800**	**4000**
Year	8 properties clinical 0.19%	18 properties clinical 0.22%	24 properties clinical 0.28%	28 properties clinical 0.34%	32 properties clinical 0.36%	36 properties clinical 0.38%
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$1927	$5 355	$9 656	$14 484	$18 500	$23,125
6	$2043	$5 677	$10 235	$15 353	$19 610	$24,513
7	$2165	$6 017	$10 849	$16 274	$20 787	$25,983
8	$2295	$6 378	$11 500	$17 250	$22 034	$27,542
9	$2433	$6 761	$12 190	$18 285	$23 356	$29,195
10	$2579	$7 167	$12 922	$19 382	$24 757	$30,947
11	$2734	$7 597	$13 697	$20 545	$26 243	$32,803
12	$2898	$8 052	$14 519	$21 778	$27 817	$34,772
13	$3072	$8 536	$15 390	$23 085	$29 486	$36,858
14	$3256	$9 048	$16 313	$24 470	$31 256	$39,069
15	$3451	$9 591	$17 292	$25 938	$33 131	$41,414
16	$3658	$10 166	$18 330	$27 494	$35 119	$43,898
17	$3878	$10 776	$19 429	$29 144	$37 226	$46,532
18	$4110	$11 422	$20 595	$30 893	$39 459	$49,324

Head	**3000**	**3200**	**3400**	**3600**	**3800**	**4000**
Year	8 properties clinical 0.19%	18 properties clinical 0.22%	24 properties clinical 0.28%	28 properties clinical 0.34%	32 properties clinical 0.36%	36 properties clinical 0.38%
19	$4357	$12 108	$21 831	$32 746	$41 827	$52,284
20	$4618	$12 834	$23 141	$34 711	$44 337	$55,421
21	$4896	$13 604	$24 529	$36 794	$46 997	$58,746
22	$5 189	$14 421	$26 001	$39 001	$49 817	$62,271
23	$5 501	$15 286	$27 561	$41 341	$52 806	$66,007
24	$5 831	$16 203	$29 214	$43 822	$55 974	$69,967
25	$6 180	$17 175	$30 967	$46 451	$59 332	$74,165
26	$6 551	$18 206	$32 825	$49 238	$62 892	$78,615
27	$6 944	$19 298	$34 795	$52 192	$66 666	$83,332
28	$7 361	$20 456	$36 883	$55 324	$70 666	$88,332
29	$7 803	$21 683	$39 096	$58 643	$74 906	$93,632
30	$8 271	$22 984	$41 441	$62 162	$79 400	$99,250
Total	$114 000	$316 800	$571 200	$856 800	$1 094 399	$1,367,999
NPV	$47 268	$131 356	$236 839	$355 259	$453 776	$567,220
Loss/property	$5 909	$7 298	$9 868	$12 688	$14 181	$15,756

Note: Table is designed to address queries regarding numerous different situations. Over 30 years, without intervention, 8–36 dairies may be infected by the BJD. Maximum loss that may occur is$ 1367,999 over 30 years (6th column). Losses (NPV) per property are $15,756. This is an extreme scenario.

Table 17 Alternative scenario for breeding farms over 20 years with cattle price at $2500 per head – maximum loss estimates

Head	2000	2200	2400	2600	2800	3000
Year	8 properties clinical 0.14%	12 properties clinical 0.15%	16 properties clinical 0.16%	18 properties clinical 0.17%	20 properties clinical 0.18%	24 properties clinical 0.19%
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$4996	$8 227	$14 303	$23 558	$29 826	$37 082
6	$5 295	$8 720	$15 161	$24 972	$31 615	$39 307
7	$5 613	$9 244	$16 071	$26 470	$33 512	$41 666
8	$5 950	$9 798	$17 035	$28 058	$35 523	$44 166
9	$6 307	$10 386	$18 058	$29 742	$37 654	$46 816
10	$6 685	$11 009	$19 141	$31 526	$39 913	$49 625
11	$7 086	$11 670	$20 289	$33 418	$42 308	$52 602
12	$7 512	$12 370	$21 507	$35 423	$44 847	$55 758
13	$7 962	$13 112	$22 797	$37 548	$47 538	$59 104
14	$8 440	$13 899	$24 165	$39 801	$50 390	$62 650
15	$8 946	$14 733	$25 615	$42 189	$53 413	$66 409
16	$9 483	$15 617	$27 152	$44 721	$56 618	$70 394
17	$10 052	$16 554	$28 781	$47 404	$60 015	$74 617
18	$10 655	$17 547	$30 508	$50 248	$63 616	$79 094

Head	**2000**	**2200**	**2400**	**2600**	**2800**	**3000**
Year	8 properties clinical 0.14%	12 properties clinical 0.15%	16 properties clinical 0.16%	18 properties clinical 0.17%	20 properties clinical 0.18%	24 properties clinical 0.19%
19	$11 295	$18 600	$32 338	$53 263	$67 433	$83 840
20	$11 972	$19 716	$34 279	$56 459	$71 479	$88 870
Total loss	$128 250	$211 200	$367 200	$604 800	$765 700	$952 000
NPV	$69 686	$114 758	$199 523	$328 626	$416 053	$517 281
Loss/property	$8 711	$9 563	$12 470	$18 257	$20 803	$21 553

Note: Maximum loss under this scenario is $952,000 based on 24 infected properties showing clinical signs of 0.19%. Loss estimates are relatively high because of the assumption of 3000 breeder cattle per property.

Table 18: BJD losses for beef and dairy farms in southern WA

Year	5 properties clinical 0.14%	11 properties clinical 0.15%	18 properties clinical 0.19%	4 properties clinical 0.19%	12 properties Clinical 0.2%	25 properties clinical 0.25%
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0
5	$1117	$2603	$5,395	$1213	$3831	$11 362
6	$1184	$2759	$5,719	$1286	$4061	$12 044
7	$1255	$2925	$6,062	$1363	$4305	$12 767
8	$1331	$3100	$6,426	$1445	$4563	$13 533
9	$1411	$3286	$6,811	$1531	$4837	$14 345
10	$1495	$3483	$7,220	$1623	$5 127	$15 205
11	$1585	$3692	$7,653	$1721	$5 434	$16 118
12	$1680	$3914	$8,112	$1824	$5 760	$17 085
13	$1781	$4149	$8,599	$1933	$6 106	$18 110
14	$1888	$4398	$9,115	$2049	$6 472	$19 196
15	$2001	$4662	$9,662	$2172	$6 861	$20 348
16	$2121	$4941	$10,242	$2303	$7 272	$21 569
17	$2248	$5,238	$10,856	$2441	$7 709	$22 863
18	$2383	$5,552	$11,508	$2587	$8 171	$24 235
19	$2526	$5,885	$12,198	$2742	$8 662	$25 689

Year	5 properties clinical 0.14%	11 properties clinical 0.15%	18 properties clinical 0.19%	4 properties clinical 0.19%	12 properties Clinical 0.2%	25 properties clinical 0.25%
20	$2678	$6 238	$12 930	$2907	$9 181	$27 230
Total loss	$28 686	$66 825	$138 510	$31 140	$98 352	$291 698
NPV loss	$16 866	$39 290	$81 437	$18 308	$57 826	$171 505
Loss/property	$3373	$3571	$4524	$4577	$4818	$6 860

1. The results are based on epidemiological modelling. Infected cattle are likely to show clinical signs in those properties in the 5th year only. Hence losses are calculated from 5th year onwards.
2. Up to 25 properties are infected with an intra-farm spread rate of maximum 25%. Minimum spread rate for the modelling purpose is 0.14%
3. Number of head on a cattle farm is assumed to be 2732 — this is the number arrived at by taking averages of class-intervals in cattle data.
4. Price per head is $1500.
5. Maximum total loss over 20 years is $291,698. This is the last column where 25 infected properties are showing clinical signs to the extent of 0.25%. Losses per property in NPV terms are $6860.

Table 19: The value of live cattle exports to various countries

	2010/11	2011/12	2012/13	2013/14	2014/15
Sum of value	($A)	($A)	($A)	($A)	($A)
Indonesia	83 424 763	65 592 414	36 121 015	114 089 540	66 654 889
Israel	32 969 370	42 863 159	37 389 558	74 504 174	54 357 746
Vietnam			356 291	8 670 664	35 785 262
Malaysia	3 942 500	4 062 283	13 709 551	20 029 719	29 442 446
Egypt	7 096 599	21 678 075	10 327 500	5 360 000	12 006 000
Mauritius	1 080 000	4 783 000	2 440 000	5 504 000	4 101 985
Russian Federation	248 374			2 460 874	3 659 625
Thailand					2 524 405
United Arab Emirates		313 166		896 000	2 187 200
Turkey	67 325 570	11 818 820	16 608 570		1 632 000
Qatar	1 509 205	723 357	1 682 278	755 500	379 500
Jordan	4 781 680	237 010	5 310 000	1 468 000	196 000
Philippines	3 569 166			2 016 151	
Libya			4 209 000		
Saudi Arabia	16 000 592		2 837 817		
Bahrain	1 146 260	1 522 673			
Kuwait	374 500	159 000			
Japan	731 700	400 560			

Appendix 2: Terms of Reference (TOR) for this consultancy

The proposed evaluation will cover a number of economic impact analyses based on epidemiological assessments. Simulation and sensitivity analyses will be undertaken to assess a range of potential economic impacts.

Epidemiological assessments will take into account 20- and 30-year horizons. The standard economic assessment projection is 20 years, however, the epidemiology of BJD and previous experience from OJD deregulation analysis indicate that a 20-year projected scenario may not be able to capture the real impact of BJD-related production loss. Variables that will be taken into consideration:

1. North and south analysis for cattle industries will be different. The rate of inter-farm spread is assumed to be a lot faster in the South-Weest compared to the North due to environmental conditions.
2. Export market analysis: potential impact of BJD on export markets[7]. Export protocols and data analysis will be required to estimate losses if any.
3. The current rate of BJD incursion in WA is one incursion every 6 years (In WA, prior to 2013, there have been nine cases of BJD in cattle and one in an alpaca. These cases occurred between 1952 and 2006; DAFWA website). New probabilities will require estimation under various scenarios.
4. Production losses at varying realistic disease prevalence need to be factored in.

Scenarios

a. Deregulation of BJD control in WA

Existing border and intrastate regulatory controls will be abolished. It can be assumed over time BJD will enter WA and the disease will spread. The rate of disease spread is likely to be different in the north and south of WA. Over time the disease may become endemic in some areas of WA.

- The risk of infection and resultant production losses on property will depend on the effectiveness of individual on-farm biosecurity and management practices.
- The costs of individual farmer losses through restricted market access need to be factored in.

b. Maintain current regulatory equivalence for BJD control in WA

Under this scenario, the WA cattle industry will put in place a program with regulatory restrictions similar to current levels. It needs to be noted, however, that it will be very difficult to achieve equivalence to current risk levels in the case of deregulation on other jurisdictions.

Consideration will need to be given to the likelihood that BJD will enter WA with a frequency similar to current BJD detections.

- The costs to individual farmers and the industry as a whole due to regulatory restrictions, including compensation for disease control activities, need to be factored in.

[7] Market access requirements for BJD need to be met at the property level.

Appendix 3: Formulae and details of the intra- and inter-herd spread models

Intra-herd spread modelling

Intra-herd BJD spread is calculated by using a simplified deterministic SIR model, a system of coupled differential equations for modelling the growth of an epidemic or steady state in a population within which all cattle interact equally with all other cattle. The model describes a population of *N* cattle divided into three classes, susceptible **S**, infected **I**, and recovered **R**:

$$d\mathrm{S}(t)dt = -\beta \mathrm{S}(t)\mathrm{I}(t); \qquad (1)$$

$$d\mathrm{I}(t)dt = \beta \mathrm{S}(t)\mathrm{I}(t) - \gamma \mathrm{I}(t); \qquad (2)$$

$$d\mathrm{R}(t)dt = \gamma \mathrm{I}(t) \qquad (3)$$

We omit the equation for the recovered class (as BJD is fatal).

The continuous variables **S**(t) and **I**(t) are the average values (over many iterations) of two discrete integer-valued variables *S* and *I*. At any time then, the system can be characterised as being in a state (S, I), which can undergo one of two transitions:

$$(\mathrm{S}, \mathrm{I}) \rightarrow (\mathrm{S}-1, \mathrm{I}+1) \text{ at rate } \beta \mathrm{SI};$$

$$(\mathrm{S}, \mathrm{I}) \rightarrow (\mathrm{S}, \mathrm{I}-1) \text{ at rate } \gamma \mathrm{I}.$$

The parameters β and γ are defined in terms of physical observables, the average number of contacts per year c, the probability of infection through contact p, and the characteristic duration of the infection T:

β = (rate at which each individual makes contacts) × (probability of infection from contact)(total population size N)

$$\beta = c \times p/N; \qquad (4)$$

Γ = 1/characteristic duration of infection

$$\Gamma = 1/T. \qquad (5)$$

For each set of parameters β and γ, the reproductive number, r_0 is defined to be:

$$r_0 = \beta/\mathrm{S0}\gamma = c \times p \times T \times \mathrm{S0}/N, \qquad (6)$$

Where $\mathbf{S}_0$ is the initial number of susceptible individuals, **S**(t = 0). Here r_0 can be interpreted as the average number of new infections a single infected individual will produce in a completely susceptible population. Initially $r_0 > 1$, in the deterministic model $d\mathbf{I}/dt > 0$, the number of infected individuals will slowly increase till a steady infection rate in the herd occurs (after 20 years) by the number of newly infected animals and the number of BJD shedding animals remains constant. In this numerical simulation, the value of r_0 is tuned by varying β. Because β is inversely proportional to N, transmission is frequency dependent, and the rate at which each animal makes contacts with others, c, is independent of the population size N.

Different variables were used to calculate the difference between dairy and beef herds.

The model assumes that I is the infectious state of BJD (shedding animals). The percentages of subclinical infected animals are calculated by looking at average incubation periods (anywhere from 2 to 12 years).

Modelling BJD incursions and spread in WA

Number of BJD-infected farms over the next 30 years with remaining current BJD regulations:

$$N_t = f_t (\mathrm{I} * t)$$

N_t = Number of BJD-infected farms in WA in year t
I = Number of current (probability of) BJD incursions into WA per year
t = (calendar year – 2016)

Number of BJD-infected farms with lifting current BJD regulations (with inter-herd spread)

$$N_t = f_t (\alpha \mathrm{I} * t) + \beta [\{(\alpha \mathrm{I} * (t - n)\} + \{(\alpha \mathrm{I} * (t - 2n)\} + \{(\alpha \mathrm{I} * (t - 3n)\} +........]$$

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.

Overall confidence intervals where calculated using 95% confidence intervals for I using binomial calculations, assuming a normal distribution of I.

Appendix 4: Johne's disease requirements for main trading partners

Table 18: Johne's disease requirements of cattle markets

Importing country	Commodity	Property of origin certification requirements for Johne's disease	Testing requirements for Johne's disease
Brunei	Feeder/ slaughter	Not specified	
China	Breeder	No clinical cases of paratuberculosis for one year	ELISA
Egypt	Feeder/ slaughter	Not specified	
Indonesia	Feeder/ slaughter	No clinical evidence of bovine Johne's disease for 5 years	nil
Indonesia	Productive	No clinical signs or abattoir evidence or cases of bovine Johne's disease for 2 years	ELISA or PCR
Israel	Feeder	Herds of origin free from paratuberculosis and no clinical case in herds of origin for 3 years	ELISA (female cattle)
Jordan	Slaughter	Not specified	
Kuwait	Breeder	Not specified	
Kuwait	Slaughter	Not specified	
Malaysia	Feeder/ slaughter	Derived from herds clinically free from Johne's disease for 2 years	nil
Oman	Breeder	Free for the previous 24 months from clinical evidence of paratuberculosis (Johne's disease)	nil
Pakistan	Breeder	Not under restriction due to officially controlled infectious/contagious disease of cattle; animals examined by AQIS vet within 72 hours of export and showed no clinical signs paratuberculosis	ELISA or CFT
Philippines	Feeder	Free from clinical evidence of paratuberculosis (Johne's disease) for 1 year	nil
Qatar	Slaughter	Not specified	

Importing country	Commodity	Property of origin certification requirements for Johne's disease	Testing requirements for Johne's disease
Qatar	Breeder	Animals examined within 48 hours of export and were free from evidence of paratuberculosis	nil
Russia	Feeder	Free of paratuberculosis for 3 years	nil
Thailand	Feeder/ slaughter	Animals resided on properties for the last 6 months that have had no clinical cases of BJD for 2 years	nil
Turkey	Feeder/ slaughter	Not subject to official quarantine restrictions on animal health grounds for paratuberculosis; herds of origin free from Johne's disease for 5 years (feeder only)	nil
UAE	Slaughter	Not specified	
UAE	Breeder	Examined 48 hrs prior to loading – free from evidence of Johne's disease	nil
Vietnam	Feeder/ slaughter	Free from paratuberculosis for 3 years	nil
Vietnam	Breeder	Free from paratuberculosis for 3 years	DTH or ELISA

Note that these requirements are accurate as of 17 October 2016 and are subject to change. Up to date and complete requirements can be found at micor.agriculture.gov.au/Pages/default.aspx

It is the responsibility of the exporter to ensure that current requirements are known and met.