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Review

A review of bovine Johne's disease control activities in 6 endemically infected countries

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ABSTRACT

Mycobacterium avium subspecies *paratuberculosis* (MAP) is endemic in the bovine populations of many countries and can cause a significant reduction in animal welfare and production efficiency making control desirable. Effective control has proved very difficult to achieve despite multiple regionally coordinated programmes being in existence since the 1920s. The international community increasingly recognises the value in learning from the collective experiences of existing programmes to improve the effectiveness of control. The aim of this review is to outline key aspects of bovine Johne's disease control activities across 6 endemically infected countries to facilitate comparison of current international practice. The background, control activities and monitoring components of programmes in Australia, Canada, Denmark, the Netherlands, the United Kingdom and the United States of America were individually reviewed. Factual accuracy of each review was checked by individuals involved in the respective programmes before the reviews were condensed and combined into a single document presented here, with the complete reviews of each programme available as supplementary material. There was considerable heterogeneity in key aspects of control activity design including goals, responses to declining participation, herd classification, recommended control measures and associated test requirements. The data presented will be of interest to organisations that are involved in developing new or existing regionally coordinated BJD control activities.

1. Introduction

Mycobacterium avium subspecies *paratuberculosis* (MAP), the infectious cause of bovine Johne's disease (BJD), is endemic in the bovine populations of many countries (Nielsen and Toft, 2009). The disease is recognised internationally as causing a significant reduction in animal welfare and production efficiency, making control desirable. The potential association between exposure to MAP and Crohn's disease in humans increases the importance of reducing human exposure to this organism (FSAI, 2009).

Regionally coordinated BJD control activities have been in existence since the 1920s (Benedictus et al., 2000) although most still active today were initiated within the last 30 years. Control activities within countries are not uniformly coordinated at a national level, and vary from small, independent programmes targeting limited

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production systems within a defined geographical region to single 'national' programmes that include all cattle in a given country (Nielsen, 2009d). Regardless of the level of national coordination, effective control (measurable and sustained reduction in clinical or economic impact, or MAP prevalence) has proved very hard to achieve.

In 2006, in recognition of the significant challenges of achieving effective control, the International Dairy Federation initiated a forum to facilitate the sharing of ideas and experiences between organisations involved in delivering control activities (Kennedy and Nielsen, 2007). This forum was preceded by (and runs in parallel to) other international knowledge transfer initiatives (e.g. the International Colloquium on Paratuberculosis) but was unique in focussing specifically on the design and delivery of control activities. The proceedings from these meetings (Kennedy and Nielsen, 2007; Nielsen, 2009a; Kennedy and Wall, 2012) give some insight into international practice, but do not facilitate a direct comparison between different control activities. The ability to directly compare existing control activities provides the best opportunity to learn from past, collective experiences of BJD control and to design and implement improved control activities in the future.

The aim of this review is to outline key aspects of bovine Johne's disease control activities across 6 endemically infected countries to facilitate comparison of current international practice.

2. Materials and methods

Six endemically infected countries that had active control activities starting in or before 2007 were identified for inclusion in the review. These countries were chosen purposively, representing regionally coordinated BJD control activities across three continents. To avoid significant errors arising from mistranslation, these countries each had programme material published predominantly in English or with extensive programme details published in the international literature. For each country, an individual review of BJD control activities was performed between February and July 2012, with a focus on the following three areas:

- Programme background (history and development, current structure, aims, organisations involved, funding, voluntary or compulsory participation)
- Programme components: Surveillance and control (testing and classification for low and high risk herds and recommended control activities, distinguishing bio-exclusion activities as those designed to reduce the risk of introduction of MAP into a herd, and bio-containment as those designed to reduce spread of MAP within an infected herd)
- Monitoring and review (participation, surveillance monitoring, programme review and current areas of concern)

Following completion, each country review was sent for external validation of factual accuracy to appropriate individuals involved in the respective programmes. The reviews were sent in July 2012 and completed in July 2013. Information from each review was then summarised to allow comparisons to be made easily in a single document.

3. Results

The BJD control programmes of Australia, Canada, Denmark, the Netherlands, the United Kingdom and the United States of America were selected for inclusion in this review. Each complete review is included as supplementary material to this publication so that readers can access more detail of all programmes as required.

3.1. Programme background

Herd level prevalence and aims of control activities are shown in Table 1. Sources of funding for control activities are shown in Table 2 (USDA-APHIS-VS, 1999, 2010; Muskens et al., 2000; CVJDPCP, 2006; Tiwari et al., 2006; Nielsen et al., 2007; Scott et al., 2007; Weber and Schaik, 2007; VS, 2008; Anon, 2009; CJDI, 2009; Nielsen, 2009c; AHA, 2012; CHeCS, 2012).

3.1.1. Australia

BJD control activities are coordinated by Animal Health Australia within the National Bovine Johne's Disease Strategic Plan (NBJDSP, initiated in 1996) (AHA, 2012). It includes prevalence-based geographical zoning, legally required controls, multiple herd scoring systems ('*CattleMAP*', '*National Dairy Bovine Johne's Disease Assurance Score (NDBJDAS)* and '*Beef only*'), and technical notes for best practice (Citer and Kennedy, 2009). Additional control activities are also provided within endemically infected states that are consistent with the NBJDSP (Rogers et al., 2012; Spence, 2012).

3.1.2. Canada

BJD control activities are delivered through multiple provincial programmes (Barker et al., 2012). These are largely independent of one another and in various stages of development but include producer (farmer) education and herd risk assessment (RA)/testing. Guidelines to improve inter-provincial coordination were produced in 2006 within a proposed Canadian Voluntary Johne's Disease Prevention and Control Programme (CVJDPCP) but these were not adopted (CVJDPCP, 2006). The Canadian Johne's Disease Initiative (CJDI) was formed in 2006 to highlight the importance of national control and improve inter-provincial coordination (CJDI, 2009).

3.1.3. Denmark

BJD control activities are delivered within a single, dairy only programme termed '*Operation Paratuberculosis*' (OP, initiated in 2006). This programme is coordinated by the Knowledge Centre for Agriculture (Nielsen et al., 2007) and includes standard educational and on farm RA material plus quarterly individual animal testing and herd classification (Krogh et al., 2012).

3.1.4. The Netherlands

BJD control activities have been delivered via the 'Intensive Paratuberculosis Programme' (IPP) since 1998. This

Table 1
Estimated true or apparent herd-level prevalence of bovine Johne's disease (BJD) and aims of control activities in 6 endemically infected countries. MAP = *Mycobacterium avium* subspecies *paratuberculosis*.

Country	Herd prevalence overview	Specific aim(s) of control activities
Australia	Endemic in South East dairy and beef (lower prevalence) farms; rare or absent elsewhere	*National Bovine Johne's Disease Strategic Plan* (initiated 1996): to minimise contamination of farms/farm products by MAP and to protect non-infected herds while minimising disruption to trade and the social, economic and trade impact of BJD at herd, regional and national level (AHA, 2012)
Canada	Infected dairy (9.8–43.1%[a]) and beef (7.9%[a]) herds present in all provinces (Tiwari et al., 2006; Scott et al., 2007)	*Canadian Johne's Disease Initiative* (initiated 2006): to reduce the prevalence of BJD (CJDI, 2009) *Canadian Voluntary Johne's Disease Prevention and Control Programme* (initiated 2006): to reduce prevalence, reduce impact on animal health and economics, to reduce or eliminate MAP in milk, beef cattle and the environment and to provide certification of herds as low risk for BJD (CVJDPCP, 2006) Provincial programmes: vary with province
Denmark	Endemic in national dairy herd (80–86%[b]); present in beef herd at a lower prevalence (Nielsen, 2009a,b,c,d)	*Operation paratuberculosis* (initiated 2006): To provide tools to dairy farmers that wish to control BJD; to reduce the over-all prevalence of BJD (Nielsen et al., 2007)
Netherlands	Endemic in the national dairy herd (20–71%[b]) (Muskens et al., 2000); no published reports in small national beef herd	*Intensive Paratuberculosis Programme* (initiated 1998): to enable low-risk trade of cattle between herds and to facilitate eradication of paratuberculosis from known infected herds *Milk Quality Assurance Programme* (initiated 2006): to reduce the concentration of MAP in milk delivered to processing units (Weber and Schaik, 2007)
UK	Endemic in national dairy (27.6–42.5%[b]) and beef herd (Anon, 2009)	*Cattle Health Certification Standards (CHeCS) accreditation schemes* (initiated 1998): to provide a graded system of accreditation which enables herds to maintain or move towards clear herd tests (CHeCS, 2012) *CheCS control schemes*: Implement a control programme to reduce the detrimental effects on herd productivity (CHeCS, 2012)
USA	Endemic in national dairy (68%[a]) and beef (7.9%[a]) herd (USDA-APHIS-VS, 1999; VS, 2008)	*Voluntary Bovine Johne's Disease Control Plan* (initiated 2002): To provide national standards for the control of BJD and to reduce prevalence, impact and risk of introducing BJD to non-infected herds (USDA-APHIS-VS, 2010)

[a] Apparent herd prevalence based on at least one or two sero-positive animals or environmental culture.
[b] Estimated true herd prevalence (various methods).

Table 2
Funding for control activities in 6 countries with endemic bovine Johne's disease infection.

Region	Funding for coordination activity	Funding for farm level participation
Australia	Animal Health Australia (a not-for-profit company) with government, producer, veterinary and academic representation is funded principally by national dairy and beef industry subscription	Surveillance testing in Free/Protected zones is state/national industry funded; participation in accreditation scheme (CattleMAP) is paid by participant producers (some funding available for beef herds); in Victoria and South Australia some state funding is available for risk assessment and testing
Canada	Provincial programmes and the Canadian Johne's Disease Initiative are funded by provincial government and industry bodies (Dairy Farmers of Canada, Canadian Cattlemen's Association)	All provincial programmes offer some financial subsidy to participant producers (amount varies).
Denmark	Most costs met through testing and admin fees to participant producers; limited funding from producer levy boards; supportive research received public funding	All costs met by participant producers
Netherlands	All coordination activities are funded by an annual subscription fee of participating producers. Public funds and funds from the Dairy Commodity Board have been made available for research activities such as the development of the Milk Quality Assurance Programme	Costs associated with the Milk Quality Assurance Programme and Intensive Paratuberculosis Programme are covered by participant producers (although dairy processors funded testing in the Milk Quality Assurance Programme initially)
UK	Providers of Cattle Health Certification Standards accreditation/control programmes pay a subscription fee to fund central coordination; engagement programmes have variable public and private funding	Costs associated with licensed accreditation/control programmes are met by participant producers; costs and funding associated with engagement programmes are variable
USA	State and federally funded in the past, now significantly reduced with the aim to adopt a shared public/private model	Subsidised by federal funds in many states; exact amount varies; reducing as federal funding reduces

Table 3
Tests utilised for surveillance/control activities for bovine Johne's disease in 6 endemically infected countries.

Country	Direct tests used for surveillance/control	Indirect tests used for surveillance/control
Australia	Faecal culture (individual following positive ELISA, pooled from over 2 year olds and environmental for maintenance in dairy herds). Post-mortem with histology can also follow positive ELISA.	Three commercial serum ELISAs: Parachek™ (PRIONICS); Pourquier Paratuberculosis Screening Test (IDEXX); and ID Screen® (IDVET) (over two year olds with defined proportional sample size for screening; 50 animals over four years old for maintenance)
Canada (surveillance not performed in all provincial programmes)	Faecal culture (environmental in the Atlantic Johne's disease initiative) and individual samples (proposed in the Canadian Voluntary Johne's Disease Prevention and Control Programme) from all over 2 year old in pools of 10 for screening	Proposed in the Canadian Voluntary Johne's Disease Prevention and Control Programme: Unspecified milk/serum ELISA (up to 100 over 2 year olds or all animals in herds of under 100 for screening)
Denmark	None	Milk ELISA ID Screen®, (IDVET) (all milking cows quarterly for screening; in infected herds after 2 years participation test negative cows over 150 days from next calving can be skipped)
Netherlands (MQAP and IPP considered separately)	Intensive Paratuberculosis Programme: Individual or pooled (5 per pool) faecal culture of PCR of all cattle of 2 years and older for screening. Follow up positive pools by individual faecal culture. Milk Quality Assurance Programme: Faecal culture or PCR as confirmatory test following positive ELISA	Intensive Paratuberculosis Programme (IPP): Serum ELISA (IDEXX Paratuberculosis Screening Ab Test) of all cattle 3 years and older. Milk Quality Assurance Programme: As IPP or milk ELISA (IDEXX Paratuberculosis Screening Ab Test) of all milking animals for screening annually (status 'B' and 'C') or biennially (status 'A')
UK (CHeCS licensed accreditation schemes only)	Faecal culture/PCR on individual animal samples (all animals over 2 years old for screening; individual confirmatory test following positive ELISA)	Unspecified milk/serum ELISA (all animals over two years old for screening – quarterly for milk, annually for serum; reduced frequency for maintenance test)
USA	Faecal or post-mortem tissue culture/PCR as confirmatory test following positive ELISA.	Unspecified milk ELISA and serum ELISA (all females over 36 months and males over 24 months for screening; 60 animals for minimum maintenance test)
	Faecal culture/PCR of all females over 36 months/males over 24 months for screening, of 30 samples in pools of 5 or of environmental sample for maintenance	

PCR = polymerase chain reaction; ELISA = enzyme-linked immunosorbent assay.

provides certification of test-negative herds and guidelines for control of MAP in infected herds. A Milk Quality Assurance Programme (MQAP) was initiated in 2006 with the aim to reduce MAP contamination of bulk milk (Weber and Schaik, 2007; Weber et al., 2008). Dairy producer participation (in either programme) has been a requirement of dairy processors (through terms of delivery) since 2010. Most milk processors do not collect milk from herds containing test positive cattle (Weber, 2012).

3.1.5. United Kingdom

BJD control activities in the UK are delivered via multiple, independent groups. Ten separate programmes are run by breed societies and laboratories, each of which is licensed by the Cattle Health Certification Standards (CHECS, established in 1998) and operates to a common Technical Standard (CHeCS, 2012) regarding herd certification and control guidelines. In addition, there are multiple engagement programmes that aim to increase awareness and uptake of control run by levy-funded industry organisations, veterinary practices, animal health and milk processing companies (SRUC, 2010; Orpin et al., 2012). Some milk retailers require regular testing of suppliers' herds.

3.1.6. USA

BJD control activities are delivered via state programmes that adhere to minimum standards and utilise a standard herd RA produced by the Voluntary Bovine Johne's Disease Control Programme (VBJDCP, initiated in 2002). The level of producer engagement can increase from education to management and finally to herd testing/classification. Each state programme has a Designated Johne's Coordinator to facilitate activities (USDA-APHIS-VS, 2010; Carter, 2011).

3.2. Programme components

3.2.1. a) Testing and classification of low risk herds

'Low risk' herds are considered unlikely to contain infected cattle (with variable confidence in prevalence being below a variable cut-off). These herds typically obtain no positive test results after an initial screen or are located within a known low prevalence geographical area. The testing outlined below requires all negative results unless otherwise stated. Specific details of the direct and indirect tests used are presented in Table 3.

3.2.1.1. Australia. Classifications are defined within the NBJDSP, with herds classified as low risk (with three different levels of confidence) either by being in a low prevalence zone or by participation in CattleMAP, *Beef Only* or the NDBJDAS. Most herds from Free, Protected or Beef Protected zones require no testing other than follow up of suspicious clinical signs. This also applies to Beef herds in high prevalence 'Management' zones that have no dairy contact (*Beef Only*). Biennial testing is required for dairy herds (and beef herds with dairy contact) within Beef Protected/Management zones to be classified as low risk. In each herd, up to 300 cattle >2 years old are tested by ELISA (plus follow up faecal culture on positives). Biennial repeat testing allows progress to lower risk classifications but testing reduced numbers of older cattle allows maintenance of status (AHC, 2012).

3.2.1.2. Canada. Herd classification is not uniform across provincial programmes, and has not been defined in most. The Atlantic Johne's Disease Initiative (AJDI) lists herds with either one (EC Negative Level 1) or more than one (EC Negative Level 2) negative environmental culture (>10 month test interval) (AJDI, 2012). The CVJDPCP defined two low risk classifications but these have not been implemented in provincial programmes (CVJDPCP, 2006). It was proposed that herds complete an RA and have negative results from either an environmental culture or milk/serum ELISA on up to 100 cattle >2 years old to be 'Stage One' (maintained by annual RA review and biennial environmental culture). Progress to 'Stage Two' would require annual culture of pooled faecal samples collected from all >2 year olds (pools of 10).

3.2.1.3. Denmark. Herd classifications are defined within the OP. The classification is based on a combination of within-herd prevalence and purchase behaviour. The lowest risk herds must have no introduced (purchased) cattle and all milking cattle tested quarterly. The lowest risk classification (score 1) requires a 95% probability that true prevalence is less than 0.5% using a model described by Sergeant et al. (2008) with sensitivity and specificity estimates that have been published recently (Krogh et al., 2012; Nielsen et al., 2013). It is a minimum requirement that 75% of the herd has been tested within the past year or the herd will be classified as 'non-tested'. The second lowest risk classification (score 2) is defined for herds with no introduced cattle and apparent prevalence of 0%, but with a true prevalence not less than 0.5% in the model described above.

3.2.1.4. The Netherlands. Within the MQAP herds are considered to be at low risk (of having an estimated $>10^3$ MAP bacteria per litre in delivered milk) when all milking cattle are negative on milk ELISA (or >3 year olds on serum ELISA) and maintenance is by biennial repeat testing (Weber and Schaik, 2007). These herds are assigned status 'A'. In the IPP, herds can obtain 'MAP-free' status following five annual herd examinations for which all results are negative. The first herd examination consists of serial testing of all cattle >3 years old by serology (ELISA) and individual faecal culture or PCR of seropositive animals. The second to fifth herd examinations each consist of serial testing of all cattle >2 years old by pooled faecal culture or PCR (pools of 5) and individual animal faecal culture or PCR of positive pools. Herds move from Level 6–10 with each negative result, and the status of 'MAP-free' (level 10) herds is then monitored by biennial herd faecal examinations (Benedictus et al., 2000; Weber et al., 2006).

3.2.1.5. United Kingdom. CHeCS licensed programmes accredit herds according to standards defined within the technical document. These require screening of all cattle >2 years old by (quarterly) milk or (annual) serum ELISA or individual faecal culture/PCR. Test negative herds gain 'Level 2, one year clear' classification then progress annually for 3 years to level 1 (only a positive direct test result performed in follow-up to a positive indirect test result will remove low risk status). After maintaining level 1 status for 2 years, the test interval for home-bred cattle (serum ELISA or faecal culture/PCR) is biennial provided all cull cattle are tested (CHeCS, 2012).

3.2.1.6. USA. In the VBJDCP, low risk herds must have a RA and up to 300 cows >36 months and males >24 months are tested by milk/serum ELISA or faecal culture/PCR for 'level 3' classification. Levels 4–6 are obtained by annual repeat testing and are considered the lowest risk herds. Maintenance testing requires lower numbers or pooled/environmental faecal culture (USDA-APHIS-VS, 2010).

3.2.2. b) Testing and classification for control in high risk herds

Classifications used for herds considered at high risk of containing infected cattle often form part of the scale used for low risk herds. Typically these herds contain at least one test positive bovine animal but they may also be untested herds that are located within a geographical region with known high prevalence or herds that have bought cattle into the herd (regardless of any test results).

3.2.2.1. Australia. Strict testing and control of suspect herds is compulsory except in Management zones and dairy herds in Beef Protected zones (AHC, 2012). Within these zones, the NDBJDAS describes 7 classifications for non-low risk herds: 0 and 1 are for non-tested/suspect herds (highest risk); 3–5 following annual ELISA testing of cattle >2 years old with test-prevalence based classifications (>3% to <1.5%); 6 then 7 with 0% test prevalence repeated annually. Cattle that are protected from potential exposure as calves (using an approved calf rearing programme) are eligible for up to an additional 3 points on their classification (Citer and Kennedy, 2009).

3.2.2.2. Canada. No classification system for infected herds is used in any provincial programme and testing is not compulsory. The CVJDPCP guide recommended that herds should be classified by the number of consecutive years they had implemented RA but this has not yet been adopted by provincial programmes (CVJDPCP, 2006).

3.2.2.3. Denmark. There are 8 classifications for high risk herds based on test prevalence and cattle introduction (purchase) history within the OP (Krogh et al., 2012). Score 3 is for herds with no introduced stock but with test prevalence greater than zero and up to 5%. Herds with introduced cattle cannot gain score 1–3 even with a test prevalence of 0% so would be score 4. Scores 5–9 are test prevalence based with score 10 for non-tested herds (highest risk). Herds participating for >2 years can exclude test negative cows

Table 4
Requirement for written bio-containment risk assessment and selected bio-containment measures for infected herds as part of bovine Johne's disease control programmes in 6 endemically infected countries (mandatory/optional status may differ for accredited low risk herds in respective country).

Country	Written bio-containment plan	External auditing of compliance	Whole herd destocking	Immediate cull of clinical cases	Regular whole herd testing (with separate management/preferential culling of test positive animals)	Protective calf management
Australia	O	Yes (protective calf management)	O[b]	O	O	O
Canada	O[a]	No	O	O	O	O
Denmark	O[a]	No	O	O	M	O
Netherlands	O[a]	No	O	M	M	O
UK (CHeCS licensed control schemes only)	O	No	O	O	M	O
USA	M[a]	No	O	O	M (classified low risk herds only)	O

M = mandatory for participating herds; O = optional for participating herds though may be strongly advised.
[a] As part of a combined bio-exclusion and bio-containment risk assessment.
[b] This is a legal requirement in Free zones.

that are >150 days from next calving from the herd test protocol.

3.2.2.4. The Netherlands. In the MQAP, herds with test-positive cattle are assigned classification 'B' (if all test-positive cattle are culled) or 'C' (if any test-positive cattle are retained in the herd). Herds with status B or C are tested by annual herd examinations consisting of a milk-ELISA of all lactating cattle or a serum-ELISA of all cattle ≥ 3 years of age. If an annual herd examination in a herd with status B yields negative results only, then the herd progresses to status A (Weber and Schaik, 2007). In the IPP, levels 1–4 are designated for infected/suspect herds but only 3 and 4 are currently used. Known infected herds are Level 3 and tested by annual individual faecal culture/PCR of adult cattle (test protocol can be altered after veterinary consultation). Pooled faecal sampling is used in herds with <10% individual cattle positive (pools of 5). Young-stock can be included in herd tests at the discretion of the farmer. Level 4 is used for low risk herds (level 6 or higher) that introduce high risk cattle or have inconclusive test results (Benedictus et al., 2000).

3.2.2.5. United Kingdom. There are 3 classifications for infected herds defined in the CHeCS technical document for licensed programmes. Testing requirements are as for low risk herds with score 3 and 4 for herds below and above 3% prevalence, respectively. Herds not participating in a CHeCS licensed control scheme are level 5 (highest risk) (CHeCS, 2012).

3.2.2.6. USA. Levels 1 and 2 represent low prevalence (test positive) herds in the VBJDCP, although most infected herds choose to engage only at the management level rather than progressing to herd classification (USDA-APHIS-VS, 2010). Testing to aid management using environmental culture and prevalence directed individual faecal culture or serum ELISA is advised but not compulsory (Collins et al., 2006).

3.2.3. c) Recommended control measures for infected herds

Common control measures are presented in Tables 4 and 5. Additional information is provided below. Stock introduction refers to any bovine animal that is brought into a herd (regardless of whether the animal originated from the same country or from outside the country).

3.2.3.1. Australia. In Free zones, destocking of confirmed infected herds is a legal requirement and subsequent cattle sourcing for re-stocking is strictly regulated (AHC, 2012). The alternative bio-containment measures (Table 4) are predominantly optional for most other herds, but may be required in some specific situations (e.g. following detection of infection in a Protected Zone) (AHC, 2012).

3.2.3.2. Canada. Risk assessment and management planning is more coordinated than testing or classification as a national standard veterinary RA (bio-exclusion and bio-containment) was developed by the CJDI and is available to all provincial programmes (Barker et al., 2012). Delivery of the RA varies between provinces and any recommended control activities are always voluntary. In Ontario, completion of the RA was required to be eligible for financial assistance for herd testing (OJEMAP, 2012).

3.2.3.3. Denmark. Control measures are implemented following RA by a trained consultant. Individual cows are classified as high, moderate or low risk, based on quarterly milk testing, and preferential culling or separate management (to minimise potential exposure of multiple calves) is advised. Introduction of cattle increases risk score (Nielsen et al., 2007; Krogh et al., 2012).

3.2.3.4. The Netherlands. In both the IPP and MQAP test positive cattle must be culled (Weber and Schaik, 2007). Preventative control measures are farm specific with veterinary input using a standard RA (Para-planner/Para-Informer). Bio-containment controls are focussed on calf management following modelling research (Groenendaal

Table 5
Requirement for written bio-exclusion risk assessment and specific cattle introduction (purchase) guidelines defined by bovine Johne's disease control programmes in 6 endemically infected countries.

Country	Written bio-exclusion plan	External auditing of compliance	Introduce cattle from lower/equivalent risk classified herds only (other introductions may increase risk classification)	Post movement testing of introduced cattle (no affect on risk classification if negative)	Avoid introducing specifically high risk cattle only
Australia	LR	Yes	ALL	–	–
Canada	ALL[a] (province dependent)	No	–	–	ALL
Denmark	ALL[a] (optional)	No	ALL	–	–
Netherlands	ALL[a] (optional)	No	ALL in the Intensive Paratuberculosis Programme	LR in the Milk Quality Assurance Programme (if animal is over 2 years old)	–
UK (Cattle Health Certification Standards licensed control schemes only)	ALL	No	–	ALL	–
USA	ALL[a]	No	LR	ALL	–

ALL = applies to all herds participating in a control/accreditation programme; LR = applies to herds accredited in lowest risk categories only.
[a] As part of a combined bio-exclusion and bio-containment risk assessment plan.

et al., 2003). Stock must not be introduced from higher risk herds in the IPP. In herds with status A in the MQAP, testing of stock introduced from higher risk herds is obligatory for cattle aged ≥ 2 years, and advised for cattle aged 1–2 years.

3.2.3.5. United Kingdom. In addition to the information in Tables 4 and 5, CHeCS licensed programmes are required to complete an annual veterinary plan, remove recent off-spring of test-positive cattle quickly (do not retain or sell for breeding), minimise faecal contamination of feed/water, prevent co-grazing with sheep, provide an isolation facility, move cattle off-site for <7 days only, prevent grazing of potentially contaminated pasture, supply mains water only, disinfect shared equipment and load/unload cattle away from main herd. Vaccination is advised for herds with high clinical prevalence (CHeCS, 2012).

3.2.3.6. USA. A veterinary RA and individual cattle identification must be implemented in herds participating in the VBJDCP (USDA-APHIS-VS, 2011). In addition to practices in Table 4 herds must minimise faecal contamination of feed, water, equipment and vehicles, minimise the density of cow-calf pairs (beef) and house weaned young-stock separately from adults (beef and dairy).

3.3. Programme monitoring and review

3.3.1. Australia

The number of infected/low risk herds is published biannually (AHA, 2012) and indicates CattleMAP participation is low and declining (*Beef Only* is cheaper to maintain) and that uptake of some state control activities in the south east (South Australia) is increasing. The increase is thought to be due to compulsory declaration of risk score at sale in some states, funding from some state producer levies and national industry, promotion by stakeholders, support from dairy processors and reduced 'stigma' of infection (Rogers et al., 2012). Factors likely to threaten progress include misplaced reliance on 'individual business risk', over estimating stakeholder education and a reliance on limited control tools (Citer and Kennedy, 2012). Risk-based trading removes trade barriers in endemic areas (Citer and Kennedy, 2009).

3.3.2. Canada

Participation in the Ontario programme (with funding) varied regionally between 38 and 70% (Kelton et al., 2012). Around 20% of dairy herds enrolled in the Quebec programme in 2012 but 20% of these dropped out (CAHC, 2012; G. Cote, personal communication). An inter-province investigation of producer attitudes to control indicated that compliance was poor with recommendations considered unnecessary or impractical (Sorge et al., 2010). Other concerns include a lack of education of stakeholders regarding test sensitivity and risks of cattle movement, over-reliance on 'test and cull' and a lack of an inexpensive, effective herd test to attract/maintain participation (Kelton et al., 2012; G. Cote, personal communication).

3.3.3. Denmark

The within-herd apparent prevalence for participating herds has dropped by approximately 1% annually since 2006 (Nielsen, personal communication). Significant challenges are reduced funding, a high rate of false positive ELISA results (estimated that most positives in participant herds are now false positives) and the low sensitivity of live cattle direct testing (Nielsen, 2009b; Krogh and Nielsen, 2012).

3.3.4. The Netherlands

Almost all Dutch herds participate in either the MQAP (95% of dairy herds) or the IPP (2% of dairy herds) (Weber, 2012). In 711 herds that joined the MQAP in 2006/2007, there is an increasing proportion of status 'A' herds. 30% of these 711 herds have always had 'A' status; 15% have always have had 'B' or 'C' status and 54% have changed status (Weber, 2012).

3.3.5. United Kingdom

Few providers of CHECS licensed programmes publish details of participating herds. The CHeCS technical document is reviewed annually. One independent voluntary dairy engagement programme (supported by public funding) reported 2500 participant herds in 2012 (16% of UK dairy farms) with 50% and 80% having poor bio-exclusion and bio-containment RA, respectively (Orpin et al., 2012).

3.3.6. USA

Participation in the VBJDCP peaked in 2007 (9% of dairy herds) then rapidly declined, with several states terminating programmes (Olson, 2010; Patton and Wheeler, 2010; Carter, 2012; Roussel, 2012). Suggested reasons included the removal of federal funding and a lack of perceived economic benefits for participants. Low-risk classifications were less valuable than anticipated. Many herds in Minnesota lost low-risk status due to detection of infection (Roussel, 2012). Future ambitions include increased education of the economic benefits of participation, to develop low cost 'self assessment' RA, to build market incentives for low risk herds and to develop shared state/private funding.

4. Discussion

In this review we outline key aspects of bovine Johne's disease control activities across 6 endemically infected countries, to facilitate comparison of current international practices. The greatest challenge in completing the review was ensuring accuracy of the data compiled, given the limited information available in the peer-reviewed literature. Many of the documents used to compile the original review chapters were drawn from non-peer reviewed sources including conference proceedings and websites associated with the control activities. In an effort to ensure accuracy of the compiled information, each original review was sent to between 2 and 5 individuals that were active in coordinating BJD control in their respective countries (18 external reviewers in total). We believe that the data presented is as accurate as could have been obtained for the period considered (February–July 2012). The inevitable delay associated with this review process means that any developments since July 2012 are not presented in this review.

A second significant challenge lay in presenting the results in a uniform format to allow direct comparisons to be made while accommodating for marked heterogeneity in key aspects of control activity design. In Australia there is a single, national programme for all bovine production systems; in Denmark there is a single dairy-only programme and in the Netherlands there are two active programmes, the MQAP and the IPP, with different goals. In Canada there are multiple provincial programmes with minimal coordination, while in the USA multiple state programmes operate to a defined standard. Finally, in the UK there are multiple independent control activities, where the longest established is itself made up of 10 different programmes operating to a defined standard (CHeCS licensed schemes). These differences between countries were not the primary focus of the review, though we hope the format of the review provides a sufficient understanding of them to allow direct comparisons of control activity goals, reported challenges, herd certification methods, recommended control measures and all associated testing requirements to be made in context.

There is considerable heterogeneity between the stated goals of the BJD control activities, which include improving food quality assurance (Australia, the Netherlands MQAP), protecting free herds/areas (Australia, IPP in The Netherlands), reducing the number of infected herds (Canada, Denmark, IPP in The Netherlands, USA), providing tools to help producers implement control (Denmark and the UK), providing accreditation of low risk herds (Canada, Denmark, MQAP and IPP in The Netherlands and the UK) and reducing the negative financial, regulatory, social and/or animal welfare impact of infection (Australia, Canada, the Netherlands, UK, the USA) (CVJDPCP, 2006; Nielsen et al., 2007; Weber and Schaik, 2007; CJDI, 2009; USDA-APHIS-VS, 2010; AHA, 2012; CHeCS, 2012). Eradication is a long term goal in both Denmark and the Netherlands (Benedictus et al., 2000; Nielsen et al., 2007), though the demonstrable achievement would require a more precise definition (Sergeant et al., 2009). The specific goals of a programme often relate to subsequent design of control activities. In Australia, where protecting low risk areas was a priority, animal movement legislation and herd accreditation systems were developed faster than risk classifications to aid control in endemic areas (Citer and Kennedy, 2009). In contrast, when providing tools for control was the priority in Denmark, an accreditation system was only introduced after 5 years (Krogh et al., 2012).

Counteracting a decline in participation is one of the most significant challenges in the USA, the Netherlands (IPP) and Australia, with uncertainty among producers of the cost to benefit ratio of participation being commonly reported as the primary cause. In the USA and Australia, administrators reported that they were over-reliant on 'individual business risk' to drive participation (Citer and Kennedy, 2012; Kelton et al., 2012; Roussel, 2012). Economic decision tree analysis for the option of joining a voluntary control programme (Netherlands) found that the preferred option is not to join without a commodity price incentive (Velthuis et al., 2006). However, a milk price differentiation between accredited and non-accredited herds of only €0.005 per litre milk was already sufficient to economically justify participation in the initial assessment of the MQAP (Velthuis et al., 2006).

In response, programmes in several countries have introduced measures to reduce the costs of participation. These include environmental faecal culture for surveillance (Australia, Canada and the USA), reduced testing requirements of low-risk cattle (Denmark), lower test-frequency in test-negative herds than in test-positive herds (IPP and MQAP, The Netherlands) and self-assessment RAs (USA) (van Roermund et al., 2002; Weber et al., 2006; USDA-APHIS-VS, 2010; AHC, 2012; AJDI, 2012). Several programmes have also provided direct government or processor funding to help drive initial participation (USA, Canada, The Netherlands). This can be effective in the short-term but may mask perceived low cost-benefit. In the USA, when direct financial support was subsequently reduced, voluntary participation declined rapidly (Olson, 2010). The MQAP (Netherlands) has been strongly supported by dairy processors where milk from test positive herds with test positive cattle is not collected for human consumption by any major milk processor. This makes the cost-benefit of control (at least by culling test positive cattle) indisputable, and participation is very high accordingly. This approach would need careful implementation in lower prevalence areas where the positive predictive value of indirect testing is reduced, though follow-up direct testing would reduce the risk of false positives substantially. There was no significant benefit from trading cattle from certified low risk herds in the USA or Australia (Citer and Kennedy, 2012; Roussel, 2012) though compulsory risk-based trading recently initiated in some states in Australia may stimulate more supportive market conditions.

Herd classification facilitates regionally coordinated control by allowing risk-based trading and providing recognition of progress at individual farm and regional level. Australia, Denmark, the Netherlands and the UK have each defined a system to classify all herds with regard to level of engagement in control activities or apparent prevalence of infection. The highest risk status is typically reserved for non-tested herds in endemic areas. Most scoring systems use test-prevalence as a baseline for classification despite the uncertainty of test results and the costs of regular repeat testing. More recently, additional information including time of participation and recent bio-exclusion and bio-containment practices (assessed by RA tools) have been incorporated into scoring systems in Denmark, Australia and the UK. In Denmark, herds cannot achieve the lowest risk scores if they introduce (purchase) stock (Krogh et al., 2012). In Australia, the risk score for individual bovine animals in dairy herds can be improved by implementing preventative calf rearing practices (Citer and Kennedy, 2009). An engagement programme in the UK uses a combination of test prevalence and results from combined bio-exclusion/bio-containment RA to generate a final herd risk rating (Orpin et al., 2012). Where there are large differences in prevalence of infection between different geographical locations or production systems, these can also be included (as is done in Australia where large areas are very low risk and the beef industry is infected at a lower prevalence than the dairy industry). In Denmark, Bayesian modelling (with information from repeat testing and herd age profile) is used to increase the confidence in low risk classifications (Krogh et al., 2012). In all of these systems, herds that do not participate are given the highest risk rating.

Bio-exclusion control measures focus on introduction of stock in all programmes reviewed, being discouraged (but not forbidden) in all cases. Imposition of official trade restrictions on infected herds was not found to be helpful in endemically infected areas in Australia as it increased the economic and social impact of being classified as infected. Trade restrictions are now being actively removed from the Australian programme and replaced by transparent risk-based trading supported by an appropriate herd classification system. A similar system is being developed in Denmark, and is effective in the Netherlands due to the 97% of herds participating in the IPP or MQAP. In the UK, the USA (levels 1–3 only) and the Netherlands (MQAP only), cattle can be introduced from herds of a higher risk status without loss of the purchasing herd's classification if post-movement testing is carried out (CHeCS, 2012). This is permitted to make participation in low-risk classification less inconvenient for producers but increases the risk of introducing infection (Roussel, 2012). In contrast, in Denmark no stock introduction is allowed in the lowest risk categories, and risk associated with the introduced cattle is solely dependent on the risk rating of the herd of origin.

Recommended bio-containment activities are also similar across all control programmes. These focus on calf rearing practices to minimise risk and rate of spread to young cattle (Groenendaal et al., 2003; Ridge et al., 2010; Nielsen and Toft, 2011; CHeCS, 2012; Kelton et al., 2012) and identification and preferential culling of high risk cattle. The latter can significantly increase the costs associated with disease control without significantly reducing spread if implemented without effective calf protection practices (Godden et al., 2012; Kelton et al., 2012).

There are differences in the requirement to have a written RA produced by a trained consultant (mandatory in some Canadian provinces, optional in other countries reviewed). The advantages are improved producer education and the opportunity to tailor control measures to individual producers, though costs associated with training and paying consultants are challenging. Plans to introduce 'self-assessment' tools are being made in the USA to reduce these costs.

The promotion of regular herd testing to facilitate control also varies across the programmes reviewed (mandatory in the Netherlands and strongly promoted in Australia, Denmark, and some programmes in the UK). The advantages are improved identification of high risk cattle for preferential culling or individual management (particularly around calving). In addition, the regular test facilitates herd classification and may help maintain a focus on implementing preventative management measures for producers. The major disadvantage is the cost and subsequent threat to sustained participation. In the USA, state programmes deliberately promote the implementation of control measures before starting any regular herd testing (USDA-APHIS-VS, 2010).

5. Conclusion

We have reviewed the BJD control activities across 6 countries on 3 continents to facilitate comparison of international practices. The data presented has been extensively reviewed by experts from the respective countries to ensure accuracy, despite a lack of existing peer reviewed original source material. The review highlights several differences in control activity design and goals, herd classification methods, recommended control measures and responses to shared challenges. The data presented here and in the supplementary material available online will be of interest to organisations that are involved in developing new or existing regionally coordinated BJD control activities.

Conflict of interest

No authors had any conflict of interest in the preparation of this document.

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Appendix A. Supplementary data

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