Review

Lessons learned during the successful eradication of bovine tuberculosis from Australia

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There are very few international examples of the successful eradication of bovine tuberculosis (TB, caused by infection with Mycobacterium bovis) from a national cattle population. This paper presents a brief overview of the successful TB eradication programme in Australia from 1970, with primary emphasis on lessons of international relevance that were learned from the Australian experience. The national brucellosis and tuberculosis eradication campaign ran for 27 years from 1970 to 1997 and has been followed by ongoing abattoir surveillance. Rapid progress towards eradication was made in southern Australia, but proved much more challenging in extensive pastoral areas of northern Australia. Declaration of TB freedom was made on December 31, 1997. A range of factors were critical to this success, including a compelling rationale for eradication, an agreed final outcome, industry commitment and financial support, a business model for programme planning, implementation and review, consistent and transparent technical standards underpinned by a strict regulatory regime and applied research, the critical role of abattoir surveillance, effective elimination of residual infection and objective measures of programme progress. Although direct translation of some of these experiences may not be possible, many of the lessons learned from the Australian experience may be relevant to other countries.
in infected herds, and during trace-forward and trace-back activities associated with the detection of a TB case (Radunz 2006).

Abattoir surveillance played a central role throughout BTEC, and subsequently, in 1992, its role was further enhanced with the introduction of the National Granuloma Submission Program (NGSP) (Fig 1). This was an abattoir-based TB surveillance programme to maximise the number of granulomas submitted from cattle, buffalo, camels and deer detected during postmortem inspection, for laboratory analysis to preclude the possibility of TB. Throughout this programme, submissions were actively encouraged, as was feedback to inspectors and producers. From 2001, the programme shifted from bulk submission of granulomas (through the NGSP, which ran during 1992 to 2000) to targeting of higher-risk (older) animals and abattoir submission targets (one granuloma for every 1000 cattle slaughtered with two or more permanent teeth) (National Granuloma Submission Program 2 (NGSP2), which ran during 2001 to 2004) (Fig 1). During NGSP, 27,998 granulomas were examined from 82.4 million cattle (including calves) slaughtered (submission rate of one granuloma per 2942 cattle slaughtered). In the Northern Territory, Queensland, South Australia and Western Australia during NGSP2, 16,132 granulomas were examined from 18.9 million eligible cattle slaughtered (those with two or more permanent teeth) (submission rate of one granuloma per 864 eligible cattle slaughtered) (Animal Health Australia 2005).

Rapid progress towards TB eradication was made in farming areas in southern parts of Australia, in large part because of progress already made in the dairy industry before the start of BTEC (Smith 1959). The last confirmed primary cases of TB in bovids were detected in Tasmania in 1975, in Victoria in 1991, in New South Wales in 1995, and in South Australia in 1996. Secondary cases, following movement of animals from states or territories where infection had not yet been cleared, were subsequently detected in Victoria in 1996 (in imported buffalo from the Northern Territory) and in New South Wales in 2001 (on properties where cattle had moved following complete dispersal of a Queensland property, see Appendix C (adapted from More and Roe 2002) (available online as Supplementary Data). Before BTEC, cattle control systems varied greatly across the extensive pastoral areas of northern Australia. On some stations, the management of cattle was limited to irregular harvesting from what were essentially feral cattle populations (Lehane 1996). Within-herd TB prevalence in the pastoral areas was often very low (less than 0.1 per cent). On some stations, however, within-herd prevalence was considerably higher, as a result of epidemiological circumstances that facilitated within-herd transmission, such as flooding or congregation at artificial watering points during the dry season.

In the northern pastoral areas, substantial modifications were needed to classical approaches to TB eradication. Improved property infrastructure, including internal fences and yards, was essential. Further, improved herd management was critical to achieve TB eradication. On many infected pastoral properties, a two-herd system was...
introduced, based on weaker and age segregation, in association with partial destocking or accelerated turnover of high-risk cattle, generally the older breeder herd. To illustrate, in totally feral herds, initial efforts focused on the construction of some paddocks, followed by the mustering of stock from unfenced areas, the removal (to slaughter) of older cattle, the test and retention of younger, test-negative animals, the progressive establishment of a tested herd contained behind fences, and the depopulation of stock from unfenced areas.

Destocking (partial depopulation) of high-risk (older age) groups from paddocked areas and the removal of all cattle and buffalo from areas where a clean muster was not possible (ie, bush areas) was used extensively in northern Australia. This was initially undertaken using commercial mustering, by helicopter and on horseback (Fig 3), generally over a few years to optimise commercial use of the animals and provided that there was no detriment to an Approved Property Programme (APP), see below, on the property or to neighbouring properties. Then, helicopter shooting was conducted over an extended period, until it was no longer cost-beneficial to continue aerial operations. However, it became clear that in many areas a different strategy was needed, as many of the residual animals adopted a nocturnal grazing habit, staying under the cover of vegetation during daylight hours to evade the helicopters. From 1989, and depending on animal density and the nature of terrain and vegetation, radio-tracking was used to locate residual animals. The so-called ‘Judas’ cow technique (using a cow to lead others to a specific destination) was conducted over a period, until it was no longer cost-beneficial to continue aerial operations.

A number of risk-based strategies were used through BTEC and associated programmes, exceeding those required under the OIE Animal Health Code.

First, risk was assessed at the level of the group (or herd or area) rather than at the level of the individual. This approach was taken cognisant of the epidemiology of infection (including the potential for latent or residual infection) and the imperfect sensitivity and specificity of available diagnostic tests.

Second, a dynamic system of risk-based herd and area classification was used throughout the programme (Table 1). The pathway for herd classification is presented in Fig 6. Infected (IN) herds took a minimum of 14 months and eight years to attain confirmed free (CF) 1 and CF3 status, respectively. Extended testing intervals were used throughout the pathway (a minimum of six months each from restricted [RD] to provisionally clear [PC] and from PC to CF1, 12 months from CF1 to CF2 [Fig 6]), to maximise test sensitivity by...
avoiding periods of desensitisation and allowing disease progression, if present. Area classification was based on both the apparent disease prevalence across the whole cattle population, and the proportion of herds in particular status classifications (Cousins and others 1998) (Table 1). The criteria of less than 5 per cent IN herds was used as part of the Provisionally Free area classification to account for the small number of large herds in pastoral areas. In the Northern Territory, for example, up to 50,000 cattle were managed on each of 350 properties over 1.2 million km². Herd and area classification contributed substantially to both national and local TB management. These terms also became meaningful both for producers and programme managers, and were a powerful method to transparently measure progress (Cousins and others 1998). Fig 7 illustrates the change in TB area classification over time during BTEC.

Third, restrictions on the movement of cattle between herds and between areas was determined on the basis of herd and area risk, to limit the potential for spread of infection to lower-risk herds and areas (Table 2, 3). There were marketing benefits for an owner achieving eradication on their property. During the early stages of BTEC, there were also low risk options such as ‘all in, all out’ bullock depots and approved feedlots to enable a cooperating owner to minimise the negative cash flow impacts of an APP. Towards the latter stages of the eradication programme, there were severe restrictions on the movement of cattle from IN, RD and PC herds in Provisionally Free, Impending Free and Free Areas, and from CF1 herds in Provisionally Free Areas (Table 2, 3).

Fourth, a broad range of strategies were used to effectively manage residual TB risk, including:

• a focus on infection risk in the group (or herd or area) rather than the individual;
• a risk-based approach to herd and area classification (Table 1, Fig 6) and to movement restrictions (Table 2, 3), management of infected herds to minimise the population of cattle with TB exposure; and
• a progressive tightening of controls as the programme progressed.

Nonetheless, an ongoing risk of residual infection was assumed until all cattle exposed to an infected animal had been slaughtered. Consequently during the first Tuberculosis Freedom Assurance Programme (TFAP, see below) (Box 1), the risk was managed by early turn off to slaughter to minimise the risk of recrudescence.

<table>
<thead>
<tr>
<th>Area classification</th>
<th>How classified</th>
</tr>
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<tbody>
<tr>
<td>Residual</td>
<td>An area not included in any of the classifications below (only applicable early in the campaign)</td>
</tr>
<tr>
<td>Control</td>
<td>Quarantine of IN herds</td>
</tr>
<tr>
<td>Eradication</td>
<td>As for Control, plus active disease control</td>
</tr>
<tr>
<td>Provisionally Free</td>
<td>As for Eradication, plus apparent disease prevalence less than 0.1 per cent</td>
</tr>
<tr>
<td>Impending Free (from 1986)</td>
<td>Previously a Provisionally Free area</td>
</tr>
<tr>
<td>Free</td>
<td>Impending Free for at least five years</td>
</tr>
</tbody>
</table>

C1 Confirmed free 1, IN Infected, PC Provisionally clear, RD Restricted

FIG 6: The pathway for change in herd classification, based on McGuin (1986) and the final (1995) version of the standard definitions and rules (Box 1). This figure represents the status pathway used during BTEC and should not be strictly interpreted as a hierarchy of risk. For example, depending on herd history, MN status was generally (but not always) considered to represent a lower TB risk than CF.
Financial support measures within BTEC evolved over time. Reactor compensation was available from the start of the campaign. Compensation for destocking (paddock checks, age destocking, bush destocking) became available from the early 1980s with additional assistance from 1984. The latter included a subsidy to hold cattle for the TB test (in yards/holding paddocks), a restocking freight rebate, low interest loans for infrastructure necessary for eradication, and an interest subsidy. From 2000, a freight subsidy was provided for three years to assist in the slaughter of cattle exposed to TB-infected animals younger than the normal slaughter age despite the completion of the required eradication testing (Radunz 2006). Producers also had access to professional support for farm-based economic decision-making.

In northern Australia, the last confirmed primary cases of TB in cattle were detected in Western Australia in 1998, in the Northern Territory in 1999, and in Queensland in 2000 (Fig 8) (Radunz 2006). The last known cases of TB in Australia were detected in 2002: two primary cases in adjacent buffalo herds in the Northern Territory (Radunz 2006, Table 5) and a secondary case in a cattle herd in Queensland (More and Roe 2002, Animal Health Australia 2006). Further details about the latter case is presented in Appendix D (adapted from More and Roe 2002) (available online as Supplementary Data). The whole of Australia was declared Impending Free in 1992 and Free on December 31, 1997. From 2011, infection with *M. bovis* was classified as an exotic disease of cattle.

**Programmes subsequent to BTEC**

Recognising that isolated cases of TB might still occur after freedom from disease was declared, the first TFAP commenced in 1998 and ran through until 2002. This was followed by TFAP2 (which ran from 2003 to 2006). These programmes provided a mechanism to effectively manage the few new cases that arose after 1997 (Anon 2001). The Australian Bovine Tuberculosis Surveillance Project (ABT BSP) was conducted during 2007 to 2010, once TFAP2 had concluded, providing a nationally integrated approach to surveillance for bovine TB (Anon 2014). During TFAP and TFAP2, particular emphasis was placed on the monitoring of all herds known to have been infected since 1988, to ensure that all cattle known to have been exposed to TB infection were sent to slaughter. This was based on the assumption that the maximum productive age of cows in northern areas was about 10 years. In these herds, annual reviews were also conducted and financial assistance was available.

**TB as an exotic disease**

From the start of 2011, bovine TB was included in Australia's Emergency Animal Disease Response Agreement (EADRA), providing the mechanism for government and industry cost-sharing in the event of discovery of what is now considered an exotic disease. It is currently classified as a Category 4 disease (private benefits considered greater than public benefits: 20 per cent government, 80 per cent industry funding in the event of an emergency response) (Table 4). A manual is now available describing the proposed Australian response to a TB incident (Animal Health Australia 2009).

**Subsequent impact on animal health in Australia**

Experiences from the TB eradication program have had a substantial and enduring impact on animal health and welfare in Australia. BTEC was a major driver of development in the northern cattle industry, as discussed later. Further, major developments in Australia’s animal health systems were built on the approaches and partnerships that developed under BTEC. The model of the industry and government partnerships developed during BTEC fostered the establishment of Animal Health Australia (AHA), a not-for-profit company established in 1996 by the Commonwealth, state and territory governments and major national livestock industry organisations. Key outputs included the EADRA and the development and coordination of the delivery of national animal health programmes (Animal Health Australia 2015). The work of this company is guided by government animal health policy, developed in consultation with industry. Further, the Federal and State governments retain legislative authority for animal disease control (Black 2012). Key activities of AHA include the development of strategic and long-term plans for animal health services, and the management of national animal health programmes (Neumann 2002, Animal Health Australia 2014a). Service delivery under these programmes is generally performed by other organisations, particularly federal and state governments.
These were achieved through improved husbandry (for example, two substantial improvements to cattle productivity in northern Australia. To the industry as a whole, and to individual producers, as a result of achieved if TB had not been recognised as an industry problem. Therefore, there was a compelling rationale (47 per cent of total beef and veal exports in 1959 to 1960 were destined the critical role of the US export market for Australian cattle producers trade, initially to the USA, would be threatened as a consequence both of TB infection in the national herd and progress being made towards TB eradication in importing countries. This was a pressing issue, noting the critical role of the US export market for Australian cattle producers (47 per cent of total beef and veal exports in 1959 to 1960 were destined for the USA, increasing to 71.6 per cent in 1969 to 1970 [Australian Bureau of Statistics 2007]). Therefore, there was a compelling rationale for national TB eradication. Further, throughout the campaign, farm-based trading restrictions were closely linked with infection risk, providing substantial advantages to individual producers to progress towards freedom. It is unlikely that TB eradication would have been achieved if TB had not been recognised as an industry problem. There was an additional, but unintended, benefit from BTEC, both to the industry as a whole, and to individual producers, as a result of substantial improvements to cattle productivity in northern Australia. These were achieved through improved husbandry (for example, two annual musters rather than one, controlled mating, removal of feral bulls, enforced weaning, mineral supplementation) and cattel controls through improved fencing. Reproductive rates improved and mortality decreased, allowing heifer selection and the slaughter of culled cows for beef. To illustrate, similar output from the Australian beef cattle population was achieved in the early 1990s with around 24 million cattle as in 1974 to 1975 with 32 million cattle (Lehane 1996). Other aspects of cattle production in northern Australia also fundamentally changed, primarily as a result of BTEC, including cattle movements and marketing patterns, and the genetics of animals in the northern cattle industry.

A clear, agreed outcome Throughout BTEC, there was a clear, agreed final outcome, namely the eradication of M bovis from the Australian cattle and buffalo population. Among both government and industry, there was a shared purpose to a common goal. The criteria for area freedom as used by Australia, is outlined in Table 1. This outcome is in compliance with, but more stringent than, the International Animal Health Code of the OIE, which requires that 99.8 per cent of herds and 99.9 per cent of cattle are free of bovine TB. In comparison, under EU legislation officially TB free (OTF) status is achieved for a region when 99.9 per cent of herds are free of TB each year for six consecutive years (Anon 1964). None of these standards exclude the possibility that TB may still exist in the cattle population, hence the OIE requirement for continuing abattoir surveillance and effective trace back (Tolson and others 2001).

Industry commitment and support Genuine industry commitment Several authors have highlighted the critical role played by industry in BTEC’s success. Indeed, Lehane (1996) says of the key industry organisations that ‘their initiative in gaining a strong voice for industry in the campaign’s management, and their advocacy of various assistance measures for producers, helped ensure a successful outcome’. Further, McCormick (2001) suggested that ‘TFAP enjoyed industry “ownership” and involvement at all levels of management’. These statements reflect a strong and constructive relationship between government and industry, noting that TB eradication was largely administered by state governments under state legislation, but working under nationally agreed guidelines. However, this was not always the case, with industry playing a relatively minor role in decision-making during the initial stages of the programme. This changed fundamentally in 1984, coinciding with rising industry opposition to the use of mass destocking to tackle TB (and brucellosis) in difficult northern areas. Following federal intervention at that time, industry subsequently played a central role in BTEC decision-making, on the national BTEC committee, on state and regional advisory committees, and on teams tasked to review approved property programmes (Lehane 1996, Radunz 2006). In addition, industry champions, working closely – in a paid role – with both government and industry during BTEC and associated programmes, and the lessons learned, has played a key role in the establishment and ongoing operation of animal health programmes in Australia, including AHA.

Key lessons learned The following provides an outline of some of the key lessons learned during BTEC and accompanying programmes. Some have been raised previously (Lehane 1996, Cousins and others 1996, Radunz 2006).

A compelling rationale, both nationally and for individual farmers In Australia, the cattle industry is highly export-oriented. Throughout the 1960s and beyond, there were very real concerns that international trade, initially to the USA, would be threatened as a consequence both of TB infection in the national herd and progress being made towards TB eradication in importing countries. This was a pressing issue, noting the critical role of the US export market for Australian cattle producers (47 per cent of total beef and veal exports in 1959 to 1960 were destined for the USA, increasing to 71.6 per cent in 1969 to 1970 [Australian Bureau of Statistics 2007]). Therefore, there was a compelling rationale for national TB eradication. Further, throughout the campaign, farm-based trading restrictions were closely linked with infection risk, providing substantial advantages to individual producers to progress towards freedom. It is unlikely that TB eradication would have been achieved if TB had not been recognised as an industry problem. There was an additional, but unintended, benefit from BTEC, both to the industry as a whole, and to individual producers, as a result of substantial improvements to cattle productivity in northern Australia. These were achieved through improved husbandry (for example, two annual musters rather than one, controlled mating, removal of feral

### Table 2: Restrictions imposed on the movement of cattle into Impending Free Areas, from Free or Impending Free Areas and from Provisionally Free Areas, by herd status of the exporting herd

<table>
<thead>
<tr>
<th>Movement from</th>
<th>Provisionally Free Areas</th>
<th>Free or Impending Free areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU, IN, RD, PC</td>
<td>SU, IN, RD, PC</td>
<td>SU, IN, RD, PC</td>
</tr>
<tr>
<td>CF1</td>
<td>CF1</td>
<td>CF1</td>
</tr>
<tr>
<td>CF2, CF3, TN, MN</td>
<td>CF2, CF3, TN, MN</td>
<td>CF2, CF3, TN, MN</td>
</tr>
</tbody>
</table>

These are as outlined in the final (1995) version of the standard definitions and rules. Definitions for area classification and herd status are presented in Table 1 and Fig 6, respectively. CF1 Confirmed free 1, CF2 Confirmed free 2, CF3 Confirmed free 3, CVO Chief Veterinary Officer, IN Infected, MN Monitored negative, PC Provisionally clear, RD Restricted, SU Suspect, TN Tested negative.

### Table 3: Restrictions imposed on the movement of cattle within and into a Provisionally Free Area, by herd status of the exporting herd

<table>
<thead>
<tr>
<th>Movement from</th>
<th>Movement into Provisionally Free Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU, IN, RD, PC, CF1</td>
<td>SU, IN, RD, PC, CF1</td>
</tr>
<tr>
<td>CF2, CF3, TN, MN</td>
<td>CF2, CF3, TN, MN</td>
</tr>
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</table>

These are as outlined in the final (1995) version of the standard definitions and rules. Definitions for area classification and herd status are presented in Table 1 and Fig 6, respectively.

CF1 Confirmed free 1, CF2 Confirmed free 2, CF3 Confirmed free 3, IN Infected, MN Monitored negative, PC Provisionally clear, RD Restricted, SU Suspect, TN Tested negative.

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Cost-sharing by government and industry

From a very early stage, industry was a major financial contributor to BTEC (Radunz 2006). Industry funding commenced with the introduction of levies in 1973 on cattle slaughtering and, shortly after, on live exports (Cousins and others 1996). The levy varied over time, to a high of AU$4 in 1982. This was replaced by a transaction levy in 1991, covering live sales as well as sales for slaughter (Lehane 1996). Cost-sharing evolved during BTEC, and it was not until February 1988 that it was formally agreed that industry would cover 50 per cent of the programme costs, with the states paying 20 per cent and the Commonwealth 30 per cent. These costs covered operations, compensation and additional assistance measures. The five years between 1982 and 1992 (when national Impending Freedom was achieved) were perhaps the most critical during BTEC as there was considerable urgency from industry to successfully finalise the eradication effort (Lehane 1996).

Throughout BTEC, all producers paid the above-mentioned levies, in recognition of the industry-wide benefit that would accrue once TB eradication was achieved. Therefore, southern producers were key contributors to eradication efforts in northern Australia, where eradication proved more difficult and costly. To illustrate, an estimated 20 per cent of overall BTEC costs were incurred in the Northern Territory, where approximately 5 per cent of the national cattle population were found.

The programme was supported by legislation, including Stock Diseases Acts in the states and territories, and the National Cattle Disease Eradication Trust Account Act, thereby ensuring that all producers took part in the campaign and shared in the costs (Anon 1982). Under Commonwealth legislation, industry levy monies were held in this trust account for the specific purpose of meeting costs incurred by government ‘for the purpose of the eradication of any disease of cattle that is endemic in Australia’ (Anon 1991). All sectors of the Australian cattle industry, including all producers, had a substantial stake in programme success.

Building on the BTEC experience, cost-sharing is now the norm in national animal health programmes in Australia, with a beneficiary pays approach being used as the basis for cost-sharing between government and industry. To illustrate, a sliding scale is used to calculate cost-sharing as part of EADRA (Table 4) (Animal Health Australia 2001).

A business model for programme planning, implementation and review

Detailed forward planning became a key feature of BTEC and associated programmes, including the development of multi-annual strategic plans and annual operational plans underpinned by legal agreements between the Australian government, state or territory governments and relevant industry organisations. These plans included long-term goals, interim targets, likely activities and associated budgets. This process proved critical in engaging both government and industry, and allowing ongoing critical review of progress. Sequential strategic plans and budgets, with mid-term reviews, were agreed over multi-annual periods: during 1975 to 1984 with a stated outcome of national Provisional Freedom, 1984 to 1992 to national Impending Freedom, and 1992 to 1997 to national Free Area status, respectively (Lehane 1996).

These experiences have contributed substantially to current approaches in Australia, where national animal health programmes are now developed and managed using agreed business processes. For example, Australia’s EADRA is a legally binding, contractual arrangement that brings together government (the Commonwealth, the states and territories) and livestock industry groups to collectively and significantly increase Australia’s capacity to both prepare for and respond to emergency animal disease (EAD) incursions (Animal Health Australia 2014b). EADRA forms just one part of AHA’s strategic plan for 2010 to 2015 (outlining the organisation’s mission, values and strategic priorities) (Animal Health Australia 2010), with defined three-year rolling business plans (incorporating objectives and scope, management plan, activities, stakeholder communications, financial management, strategy, evaluation, business rules) (Animal Health Australia 2014c). A range of other resources has been developed relevant to EAD preparedness including management manuals, disease strategies and operational manuals (Animal Health Australia 2001, 2015). These are also underpinned by three-year rolling business plans.

Consistent and transparent technical standards, underpinned by a strict regulatory regime, as well as applied research

Throughout BTEC (1975, 1979, 1982, 1984, 1986, 1995) and TFAP (1996), standard definitions and rules (SDRs) were developed, providing the minimum national standards agreed by all states and territories for the conduct of the campaign (Lehane 1996) (Box 1). First published in 1975, the SDRs were subject to regular technical review. These documents focused on definitions (such as herd classification and pathways), rules (including movement between areas), animal identification, breakdowns, monitoring and imports. Standard laboratory procedures were also defined from 1975.

The national programme was underpinned by an active research programme, which was funded by both government (Commonwealth, states and territories) and the cattle industry. Two key research strands were pursued, including an improved understanding of TB epidemiology and diagnostics. The role of feral pigs in TB epidemiology was of particular concern (Corner and others 1981, McInerney and others 1998). DNA typing and development of the interferon-gamma assay (Cousins and others 1998) emerged as the primary surveillance method for the interferon-gamma assay (Cousins and others 1998). DNA typing and the interferon-gamma assay did not become available until the latter stages of the programme, and had little impact on the final outcome.

Critical role of abattoir surveillance

Abattoir surveillance rapidly emerged as the primary surveillance method for the...
detection of infection in herds not previously known to be infected, with abattoir surveillance being the primary method for the detection of new TB case herds from 1975. A number of strategies were used to maximise the sensitivity of abattoir surveillance, which were later formalised within the NGSP. These included efforts to raise awareness, encouraging submissions from, and providing feedback to, meat inspectors, and the use of risk-based sampling (during NGSP2) and submission targets. Detailed information about these submissions is published annually (for example, Animal Health Australia 2014b). The cattle-tracing system was critical to the success of the overall eradication programme. Introduced during the early 1970s, it enabled tracing to the property of origin. This system was based on property identification, allocation of a unique PIC and the mandatory application of tail or ear tags bearing the PIC for most cattle movements, particularly to saleyards and abattoirs (Animal Health Australia 2013).

### Effective elimination of residual infection

The number of confirmed primary cases of TB during the final stages of eradication in Australia is presented in Table 5. Case studies of primary and secondary cases from Queensland during 1998 to 2002 are presented in Appendices A to D (adapted from More and Roe 2002) (available online as Supplementary Data). Appendix B was typical of most TB cases detected during the latter parts of the programme throughout northern Australia, where infected animals were most commonly associated with previous infection in the same herd. In these herds, generally only a very small number of infected animals (usually older cows) were detected, with no evidence in approximately 80 per cent of cases of further within-herd transmission. Nonetheless, animals potentially exposed to these TB cases were identified for early removal to slaughter. Appendices A, C and D were not typical, highlighting spread to other farms. Collectively, these case studies illustrate some of the challenges faced during the management of infected (sub)groups, in particular the potential for residually infected cattle.

With industry support, programme managers imposed relatively draconian measures, when needed, to minimise infection risk from known infected herds. A large number of methodological risk-based approaches were used, as outlined previously, underpinned by innovative thinking, meticulous (and at times, ruthless) application and ongoing critical review. Throughout southern Australia, robust movement controls, animal traceability and abattoir surveillance were in place from the early years of BTEC. Further, there was industry support, from the early years of the programme, for whole-herd slaughter in herds where TB clearance proved particularly difficult. In northern Australia, additional methods were introduced for extensive pastoral areas, including the use of helicopter mustering, paddock checks (also using helicopters), complet- ing of bush destocking using destruction from helicopters (and at times, ‘Judas’ cows), herd segregation and accelerated culling of high-risk groups (Lehane 1996).

### Table 5: Confirmed primary cases of bovine TB during the final stages of tuberculosis eradication in Australia (Radunz 2006)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Victoria</th>
<th>New South Wales</th>
<th>South Australia</th>
<th>Western Australia</th>
<th>Queensland</th>
<th>Northern Territory</th>
<th>Tasmania</th>
<th>Victoria</th>
<th>New South Wales</th>
<th>South Australia</th>
<th>Western Australia</th>
<th>Queensland</th>
<th>Northern Territory</th>
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### Box 1: Resources developed in Australia during the national Brucellosis and Tuberculosis Eradication Campaign (BTEC) and subsequent programmes

#### Standard definitions and rules

**Brucellosis and tuberculosis eradication campaign**
- 1975, Australian Bureau of Animal Health, Canberra
- 1986, Volume one. Department of Primary Industry, Bureau of Rural Science, Canberra
- 1987, Volume two. Department of Primary Industry, Bureau of Rural Science, Canberra
- 1995, Department of Primary Industries and Energy, Canberra

**Tuberculosis Freedom Assurance Programme**

#### Brucellosis and Tuberculosis Eradication Campaign, progress reports
- Number 1, Australian Bureau of Animal Health, 1976
- Number 2, Australian Bureau of Animal Health, 1977
- Number 3, Australian Bureau of Animal Health, 1979
- Number 4, Australian Bureau of Animal Health, 1979
- Number 5, Australian Bureau of Animal Health, 1980
- Number 6, 1979-80, Australian Bureau of Animal Health, Canberra, 1982
- Number 9, 1982-83, Bureau of Rural Science, Department of Primary Industry
- Number 10, 1983-84, Bureau of Rural Science, Department of Primary Industry
- Number 11, 1984-85, Bureau of Rural Science, Department of Primary Industry
- Number 12, 1985-86, Bureau of Rural Science, Department of Primary Industry
- Number 13, for the period 1986-87-1993/94, Department of Primary Industries and Energy, 1995
- Number 14, for the period 1994/95, Department of Primary Industries and Energy, 1996
- Number 15, for the period 1995/96, Department of Primary Industries and Energy, 1997
- Number 16, for the period 1996/97, Department of Primary Industries and Energy, 1998
- Summary report 1993-97, Department of Primary Industries and Energy, 1998
Objective and readily understood measures of programme progress

Measures of programme progress were both objective and readily understood. Many of these measures were based on herd and area classification, providing clear evidence of progress towards eradication, both nationally (Fig 7) and locally. Defined areas were progressively cleared of TB, to focus available resources and provide confidence among other producers about the progress that could be achieved. Milestones were used extensively, such as declaration of national Impending Freedom (on December 31, 1992). Changes in herd and area classifications were slightly impacted on individual producers.

The Australian National Disease Information System (ANADIS) computer program was installed in 1976 to 1977 primarily in support of brucellosis eradication (Lehane 1976). However, it also played a valuable role in the tracking of herds and animals for TB eradication. It was later replaced by systems developed within individual states. From the start of 1993, immediately after Australia had declared Impending Freedom, a TB case herd register was developed, with information on all incidents and including confirmed primary cases, suspect primary cases (not confirmed by laboratory testing) and secondary cases (further infection arising from animal movement from known infected herds) (Animal Health Australia 2007).

Conclusions

There are few international examples of the successful eradication of TB from national cattle populations. Australia achieved freedom following a 27-year campaign, followed by ongoing abattoir surveillance. Unique challenges were faced in Australia, noting that about half of the national cattle herd is housed in an extensive pastoral management system. Direct translation of some of these experiences to other countries may not be possible. Nonetheless, there are many lessons to be learned from the Australian experience that may be relevant to other countries. It is important that these lessons are not forgotten.

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References


NEWTON, L. G. (1992) Contagous bovine pleuropneumonia in Australia: some historic highlights from entry to eradication. Australian Veterinary Journal 69, 808-817


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