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Bovine tuberculosis eradication in Ireland

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In Ireland, the bovine tuberculosis (BTB) eradication programme commenced in 1950 and became compulsory throughout Ireland by 1962. The initial driving forces for the programme were production losses in cattle, human health problems and a desire to trade in live bovine animals, primarily store cattle, to the UK. While the operation of the programme has ensured that production losses in cattle and human health concerns are no longer active issues, the programme remains necessary to ensure that trading possibilities, which expanded post-1965, may be taken advantage of by fulfilling the European trading conditions for live animals. Despite strict adherence to testing and control measures, exceeding those of countries that had eradicated BTB, the Irish eradication programme has considerably reduced rather than eradicated BTB. Unlike those countries which have succeeded in eradicating BTB, Ireland has a wildlife species, the badger (*Meles meles*), in which BTB is endemic and shares the same environment as bovine animals. Considerable research effort has been devoted to determining the contribution of wildlife to the BTB problem and in trying to develop a viable long-term solution to the wildlife issue. When the tools are finally developed to control the disease in wild animals, Ireland should at last achieve the target of final eradication it set itself in 1950.

Introduction

Some 15 years after the commencement of the bovine tuberculosis eradication programme in Ireland an account of the success of the programme was written (Watchorn, 1965). Now, 40 years after the country was declared TB attested, it is appropriate to look again at progress towards the eradication of BTB in Ireland.

Progress towards eradication

A number of factors led to the commencement of an eradication programme for BTB in Ireland. These included losses due to overt disease in cattle, human health problems caused by *Mycobacterium bovis* and trading requirements. The programme commenced in 1950, initially on a pilot basis, to assess levels of infection and methodologies. A voluntary eradication programme was introduced, on a phased basis, in September 1954. The BTB programme became compulsory, starting on an area basis, in 1957. The compulsory programme had been extended throughout the whole country by 1962 and, in October 1965, on the basis of the observed trend (**Figure 1**) the Government of the day optimistically declared the country attested i.e., virtually free of tuberculosis (Watchorn, 1965).

The BTB scheme had commenced in Britain in 1935. Consequently, research and experience in the conduct of the tuberculin test in Great Britain was an important contributor to the Irish eradication

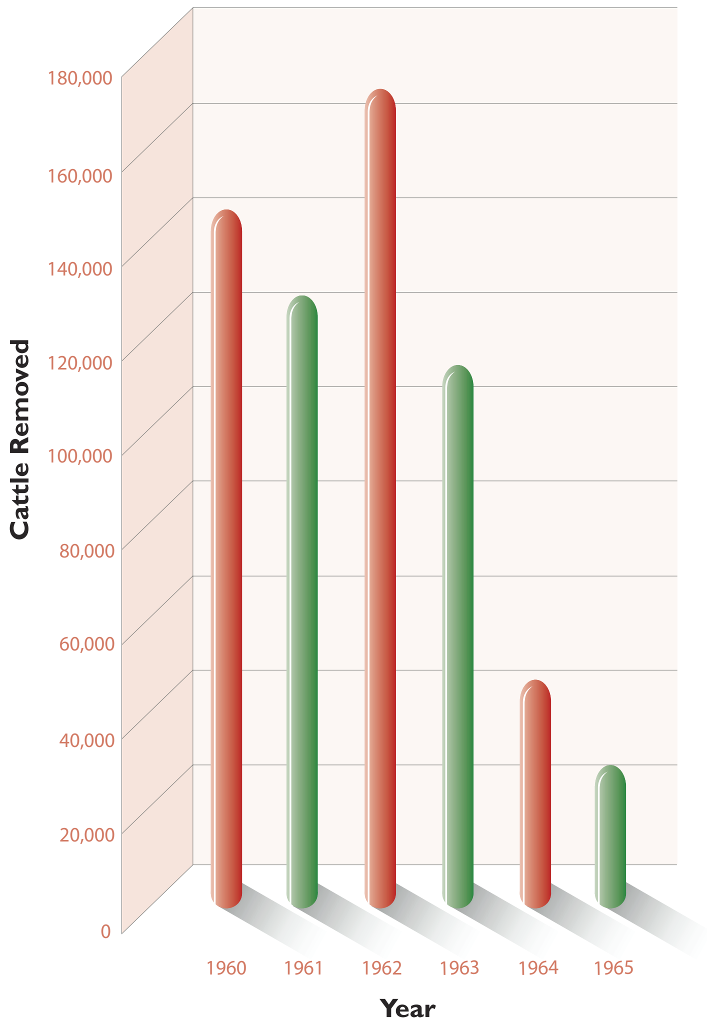

Figure 1: Number of cattle removed as reactor to the tuberculin test, 1960 to 1965.

Glossary:

Tuberculin purified protein derivative

Tuberculin PPD (bovine or avian) is a preparation obtained from the heat-treated products of growth and lysis of *Mycobacterium bovis* or *Mycobacterium avium* (as appropriate) capable of revealing a delayed hypersensitivity in an animal sensitised to microorganisms of the same species.

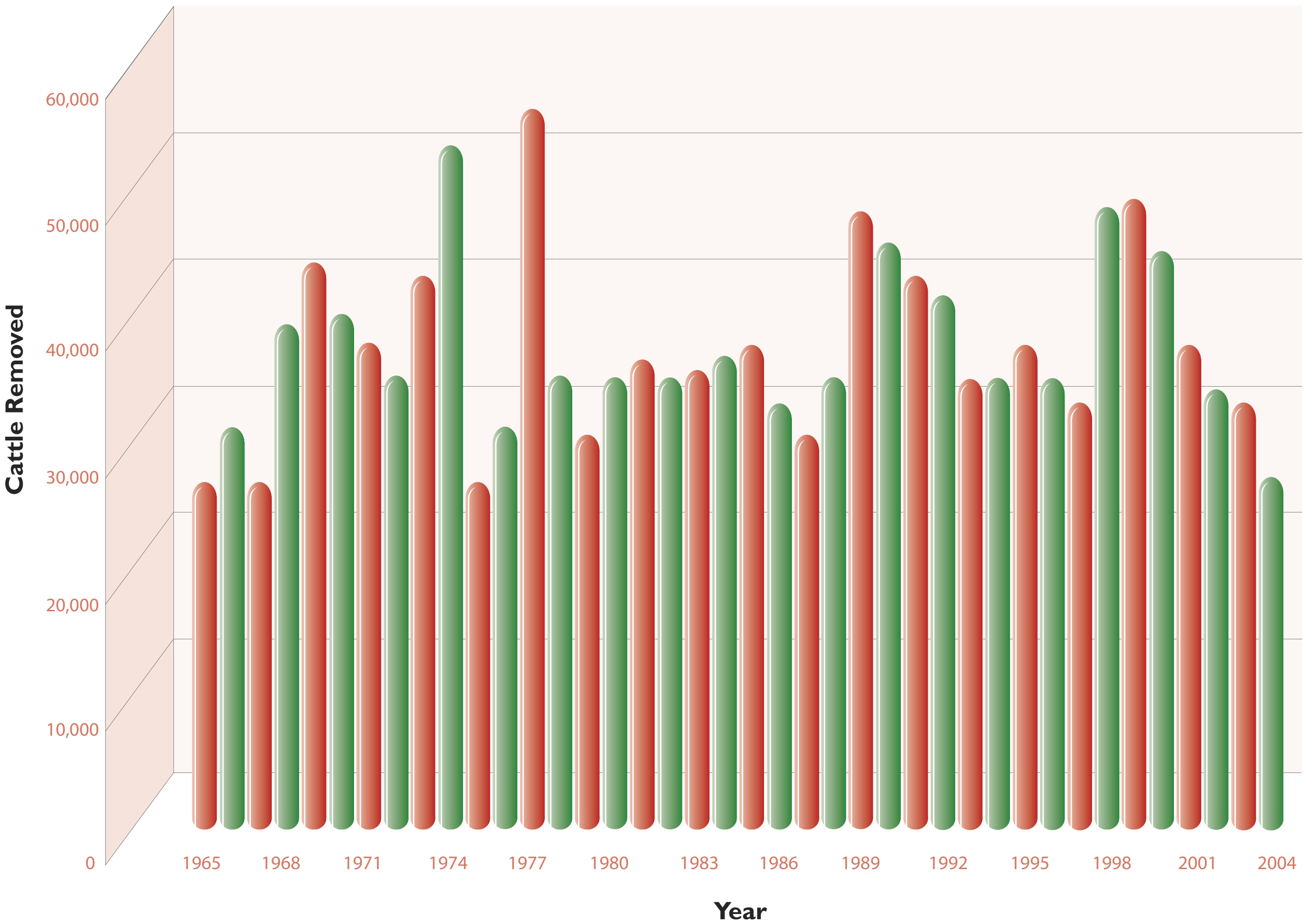

Figure 2: Number of cattle removed as reactor to the tuberculin test, 1965 to 2004.

programme (Ritchie, 1942; Ministry of Agriculture and Fisheries, 1942 a,b). Furthermore, the British requirement for attested store cattle from Ireland was another very significant driver in the Irish programme (Watchorn, 1965).

In 1964, Directive 64/432/EEC, the 'trading' directive, had been adopted by the then European Economic Community. All countries wishing to trade in live bovine animals with member states of the Community would have to conform to this directive. By 1965 there were no herds of unknown disease status in Ireland and on at least one occasion during the 11 years to 1965, all Irish herds had either individually achieved Officially Tuberculosis Free (OTF) status or been designated infected in accordance with this directive. This fulfilled the primary conditions to allow Ireland to take advantage of possible trading opportunities opening up within Europe. Furthermore, at this time, the downward trend was expected to continue towards final eradication. Instead, the eradication programme stalled with circa 30,000 animals failing the tuberculin test and being removed annually (**Figure 2**). The veterinary strikes, in 1975/76 and again in early 1985, curtailed the testing programme while they were ongoing, but seemed to have no lasting impact.

The trend in cattle population and disease incidence since 1960 is presented in **Table 1** (TB Testing Programme, Comparative statistics. DAF). As can be seen from the table, considerable progress was made in the early years of the tuberculosis eradication programmes. However, over the more recent years until 2002, it was difficult to breach the 30,000 reactors *per annum* floor. In 1954, when the eradication programme commenced, there were approximately 250,000 herds, with 4.5 million cattle registered in Ireland, with an animal test reactor incidence of 17% (cows 22%, other cattle 8%) (Watchorn, 1965). In 2003, there were 125,000 herds with approximately 7 million cattle and an animal test reactor incidence of 0.4% (DAF statistics). Over the course of the programme to date, in excess of 250 million individual animal tuberculin tests have been conducted on the Irish cattle population.

The national programme

The current programme - 2006

As the basis of the BTB eradication programme, Ireland has:

*A mandatory registration system for herds as the relevant epidemiological entity

*An individual bovine animal unique identification system

*An animal passport or official permit mandatory to accompany each animal on movement

*A computerised movement monitoring system for bovine animals (CMMS)

*An animal health computer system (AHCS)

*A comprehensive programme of disease surveillance including:

TABLE 1: Cattle population and tuberculin testing statistics over four decades (five-yearly from 1960-1985, then yearly from 1988)

Year	Cattle population under test	Number of animal tests	No. of reactors	Animal disease incidence (%)	APT **	RPT ***	Number herd tested	% herds herds	New reactor detected (%)
1960	4,683,700	*	139,881	2.99	-	29.9			
1965	5,359,300	*	23,378	0.44	-	4.4			
1970	5,956,500	*	35,982	0.60	-	6.0			
1975	7,168,100	*	21,339	0.30	-	3.0			
1980	6,908,900	8,878,924	29,827	0.43	3.6	4.3			8,772
1985	6,907,200	11,180,602	32,608	0.47	2.9	4.7			9,768
1988	6,604,100	11,125,500	29,994	0.45	2.7	4.7	176,019	98.4	10,596(6.0)
1989	6,800,100	12,436,982	43,580	0.64	3.5	6.5	172,976	97.9	13,964(8.1)
1990	6,899,929	12,427,144	41,419	0.60	3.3	6.0	172,765	95.6	13,489 (7.8)
1991	6,814,229	8,209,105	36,832	0.54	4.4	5.4	172,272	41.9	9,873 (5.7)
1992	7,084,441	10,887,513	35,997	0.51	3.3	5.2	172,260	93.7	11,196 (6.5)
1993	7,043,913	10,446,265	30,359	0.43	2.9	4.3	168,591	94.9	10,162 (6.0)
1994	7,137,696	10,435,076	30,439	0.43	2.9	4.3	159,818	97.1	9,453 (5.9)
1995	7,174,016	10,112,939	33,180	0.46	3.3	4.6	154,401	88.7	9,518 (6.2)
1996	7,412,933	10,073,859	30,400	0.41	3.0	4.1	149,128	98.2	8,867 (5.9)
1997	7,725,634	9,910,074	28,647	0.37	2.9	3.7	145,209	98.1	8,139 (5.6)
1998	7,946,989	10,677,291	44,498	0.56	4.2	5.6	142,302	97.8	10,055 (7.1)
1999	7,569,735	10,749,580	44,903	0.59	4.2	5.9	138,263	97.9	10,660 (7.7)
2000	7,032,407	10,304,162	39,847	0.57	3.9	5.7	133,542	98	10,785 (8.2)
2001	7,097,430	9,402,196	33,702	0.48	3.5	4.8	130,525	95.1	9,195 (7.4)
2002	7,025,096	9,400,065	28,930	0.41	3.1	4.1	127,711	97.2	8,338 (6.7)
2003	6,936,820	9,168,722	27,978	0.40	3.1	4.0	125,517	97.2	7,669 (6.3)
2004	6,992,264	8,825,720	22,967	0.33	2.6	3.3	124,414	96.7	6,882 (5.7)

Accurate figures for the total number of animal tests performed per year on the total cattle population were not available until 1978.

** *The APT is used as a measure of the incidence of disease compared to the level of testing being carried out. The APT figures represent the number of reactor animals disclosed per 1,000 tests.*

*** *The RPT is used as a measure of the incidence of disease compared to the total population of animals. The RPT figures represent the number of reactor animals disclosed per 1,000 animals.*

-Farm-based testing: routine use of the single intradermal cervical comparative tuberculin test (SICCT), a mandatory once annual test of all herds, additional testing of herds contiguous to or otherwise epidemiologically linked to infected herds, a check-test of herds in 'at-risk' areas, a herd test six months following restoration of status;

-Veterinary inspection of all bovine carcasses presented for human consumption.

*Disease controls including:

-prompt removal of reactor animals;

-more severe interpretation of farm-based tests following establishment of infection;

-epidemiological investigation following confirmation of infection and spread;

-tuberculin test at approximately 60-day intervals until two clear tests are achieved in succession;

-hygienic controls on infected holdings and of vehicles;

-trace of TB infected or potentially infected animals back from, and forward to, other herds where appropriate;

-use of the interferon-γ assay, the ELISA and the anamnestic ELISA test in problem herds as an adjunct to the tuberculin test;

-depopulation of infected herds where the level or duration of infection indicates that this is necessary to clear the herd and/or protect the neighbourhood.

*Compensation i.e., market value for each animal removed, but with a maximum allowable valuation.

*Quality control, including:

-use of tuberculin PPDs of standardised matched potency;

-tuberculin testing conducted by specifically authorised veterinary surgeons;

-annual monitor on equipment, test performance and results for each testing veterinary surgeon;

-only animals tested within the previous 12 months permitted into slaughter plants.

Programme changes

The eradication programme as it currently exists has evolved over the years and while the basic principles laid down in the 'trading' directive (as amended) continue to be met, the programme has been enhanced by other measures in an effort to achieve eradication. Various other controls such as extended status withdrawal for infected herds have been introduced and later abandoned as not providing any significant benefit towards achieving BTB eradication. Up until 1996, a pre-movement test requirement had been a feature of the Irish eradication programme. This requirement was then abandoned as not being cost efficient and not contributing significantly to the programme, with only 0.8% to 6.9% of breakdowns being attributed to purchased animals (O'Keeffe and Driscoll, 1996). There was also little evidence for onward transmission of infection in the herd to which the animal moved (Flanagan *et al.*, 1998). Accordingly, since 1996, animals may move for up to 12 months from the date of their last tuberculin test. Breakdown severity, during a bovine tuberculosis episode, is a predictor for future herd breakdown (Olea-Popelka *et al.,* 2004). Because of this, high-risk herds with a history of bovine tuberculosis are tested more frequently and thus the window of opportunity for movement from such herds is, in fact, less than 12 months. In 2005, the Centre for Veterinary Epidemiology and Risk Analysis (CVERA) specifically undertook an analysis to determine whether there is a subset of animals, and/or a subset of herds, where a pre-movement test could have a demonstrable cost-benefit for TB eradication. No such cost-benefit was discernable for any group of animals or herds under present circumstances.

Leslie *et al.* (1975) highlighted that bovine tuberculin PPD had both sensitivity and specificity advantages over human PPD and thus, in 1978, the tuberculin PPD used in the programme was changed from human to bovine. Bovine tuberculin PPD of two differing strengths was used in routine monitor testing (single strength) and in infected herds (double strength) (O'Reilly, 1983) until April 1991, when a decision was taken to use one strength tuberculin. In 1994, an Irish reference preparation for bovine tuberculin PPD was calibrated against the International Standard, of which only limited stock remains (O'Reilly and Haagsma, 1997). Since that time, Ireland has used a standardised bovine tuberculin and avian tuberculin (at or about 30,000 IU/ml PPD and 25,000 IU/ml PPD, respectively) supplied under contract by ID-Lelystad. The single intradermal comparative cervical tuberculin test (SICCT) is the most specific of the tuberculin tests available and the greater the strength (tuberculoprotein concentration) of bovine tuberculin relative to the avian tuberculin the less the specificity and the greater the sensitivity of the SICCT, and *vice versa* (O'Reilly, 1993). Thus, to ensure optimum specificity and uniform performance, potency of both tuberculins is matched within 500 IU and the bovine PPD is never less potent than the matched avian. Additionally, periodic validation of tuberculin potency in naturally infected tuberculous cattle is conducted using the Irish reference preparation (Haagsma and Eger, 1989).

Programme support

The establishment of the Eradication of Animal Disease Board

Over the years, the BTB eradication programme has been subject to many reviews by many persons and organisations, in an attempt to develop strategies that would achieve final eradication (O'Connor, 1986, 1989; Sheehy and Christiansen, 1991; Downey, 1991, 1992a,b; More, 2005). Professor Bob O'Connor of the Irish Economic and Social Research Institute conducted a major BTB review in 1986. He consulted widely and listed all the issues that the then current wisdom perceived as reasons for the stalled programme (O'Connor, 1986). In April 1988, in response to his recommendations, the Irish Government established a new initiative, ERAD, the Eradication of Animal Disease Board, as a specialised agency to implement a vigorous four-year eradication programme. ERAD was an executive agency of the Department of Agriculture and Food with a board representative of the various interests, including farmers and veterinarians, involved in TB eradication. A strategic multi-annual plan was developed, a budget provided and an ambitious target set to reduce the reactor numbers by 50%. As well as screening testing, there was a considerable strategic component. This involved additional, special check-testing of black spot areas, known high-risk herds, herds that were linked epidemiologically to infected herds and contiguous herds. Herds were categorised according to disease incidence, with a specific strategy applied to each category. However, as can be seen from **Figure 2**, the reactor numbers stubbornly remained at around the 30,000/annum level, despite an increased reactor identification and extraction rate throughout the four years of the programme. During this phase, and indeed to date, the eradication programme comprised all the usual elements that had worked in countries that had succeeded in eradicating the disease. The eradication programme has, furthermore, ensured compliance with the terms of Directive 64/432/EEC (as amended) ensuring that Ireland met with trading conditions for bovine animals within Europe.

Supporting research

During the last 15 to 20 years, in association with field-based and laboratory-based operations, there has been an extensive programme of research (much of it epidemiological) to address gaps in knowledge of disease epidemiology, to objectively evaluate alternative strategy options and to critically assess the implementation of disease control strategies. The Veterinary Epidemiology and Tuberculosis Investigation Unit, now The Centre for Veterinary Epidemiology and Risk Analysis (CVERA), was established in 1989, at the Faculty of Veterinary Medicine, University College Dublin. At establishment, the purpose of the unit was to investigate the factors that militate against the eradication of tuberculosis in cattle at national or regional levels, and to identify means of improving the rate of eradication. Although the role of CVERA has now broadened considerably, it continues to manage and analyse retrospective and concurrent data relating to the occurrence of tuberculosis in cattle. In addition to data analysis, CVERA undertakes projects to answer specific questions and assess epidemiological elements, various components of infection and the role of wildlife (Costello *et al.*, 1999, and in press). An extensive research programme has also been undertaken looking at the elements of BTB diagnosis (tuberculin skin test, interferon-γ assay, ELISA, anamnestic ELISA etc.) and developments therein (Monaghan, *et al.*, 1994, 1997; Collins, 1995; Costello *et al.*, 1997a, b; Gormley *et al.,* 2004). In addition, the role of environmental mycobacteria has been investigated (Cooney *et al.*, 1997). DAF routinely conducts potency assays of tuberculin in naturally infected cattle (Haagsma and Eger, 1989). The effect of a recent tuberculin test (Doherty *et al.*, 1995) and the nature of the response to the tuberculin test (Basset *et al.*, 2002) have been elucidated and strain typing of *M. bovis* has been undertaken (Costello *et al.*, 1999 and in press). These research outputs have contributed to the development and ongoing assessment of national animal health policy.

Research findings

Knowledge about disease epidemiology (including disease causation and, if infectious, the transmission and maintenance of infection) is central to the development of disease control strategies (Thrusfield, 1995). In 1974, the first infected badger (*M. meles*) was detected in Ireland (Noonan *et al.*, 1975) and by the mid-1980s infected badgers

TABLE 2: The outcome of the East Offaly Study over the years of the project 1988-1995 in terms of cattle removed as tuberculin test reactors in the removal and control areas (per cent change from 1988 figure)

	Removal		Control	
Year	No. of reactors	APT	No. of reactors	APT
1988	326	3.9	910	3.4
1989	362	3.5	982	3.3
1990	299	2.9	904	3.2
1991	194	2.7	979	4.5
1992	89	1.4	594	2.5
1993	54	0.8	404	1.9
1994	54	0.8	443	2.1
1995	30 (-91%)	0.5 (-88%)	430 (-53%)	2.1 (-38%)

had been found throughout the whole country. Over the subsequent 30 years, evidence has been building of the potential role of wildlife in bovine tuberculosis (O'Boyle, 1998, 1999, 2001; O'Boyle *et al.*, 2003). The same strain types of *M. bovis* are detected in both badgers and cattle (Grange *et al.*, 1990). In a review of the Irish TB Eradication programme, commissioned by the ERAD Board in 1990, Morris and Pfeiffer (unpublished) said that infection in the badger is the underlying driving factor causing special difficulties, that this has been present for at least 30 years, and that a strategy was required to develop a solution for this wildlife constraint. DAF commissioned a number of research projects to accurately estimate the contribution of the tuberculous badger population. First of these was the East Offaly study, which removed badgers from a central area and used an area around this as a control, with a buffer zone between the two. The central area was kept as clear of badgers as was possible, given that there were minimal barriers preventing badger immigration from the surrounding area. The results showed a reduction in the number of cattle being removed as reactor over the study period. This reduction was 40% greater in the project area compared with the control area (**Table 2**). The number of reactor animals per 1,000 animal tests (APT) had also significantly reduced and this decrease was 50% greater in the project area (Dolan *et al.*, 1995). This work has been replicated, with greater scientific rigour, in four additional areas in Ireland and the findings of the East Offaly study have been validated in that there was a significant difference between the removal and reference areas in each county (Griffin *et al.*, 2005).

One of the recognised criteria for the eradication of a pathogen is that there is a single host species with no external reservoir species. However, at present, the wild life reservoir is the major impediment to the eradication of tuberculosis in cattle in New Zealand, southwest Britain, and Ireland. To ignore this impediment would be tantamount to dismissing one of the basic tenets of eradication. Ireland has commenced a project to develop a vaccination strategy for badgers, in an attempt to overcome this obstacle to eradication (Gormley and Collins, 2000). The initial phases of vaccine development have included the evaluation of the immune response of *M. bovis* BCG injected subcutaneously in badgers, the comparison of response in vaccinates and non-vaccinates, the measurement and comparison of the immune responses of vaccinated badgers against a panel of known T-cell antigens, the assessment of the heterogeneity of immune responses among individual badgers to vaccination (Southey *et al.*, 2001) and the development of an infection model in the badger. Initial challenge trials currently underway have shown promise and a field trial is due to commence in 2006. There is optimism that this research will bear fruit over the next five to eight years.

Conclusion

Ireland continues to comply with, and go beyond, the requirements of EU Directive 64/432/EEC (as amended), thereby ensuring that Irish farmers meet the conditions required to trade within Europe and further afield. The consistent application of the programme ensures that BTB is no longer the scourge it was when it caused economic losses because of overt disease in cattle. Bovine tuberculosis is no longer a significantly important disease in humans. As a result of the lower incidence of the disease in cattle, and also because of pasteurisation of milk and other veterinary and public health controls which ensure minimal opportunities of exposure, BTB is not currently considered a significant public health threat (FSAI, 2002, 2003, 2004). Eradication of BTB is the ultimate objective of the national programme. Realistically, however, this can only be achieved by simultaneously tackling the disease in all the maintenance hosts in which the disease is endemic and which share the same environment as cattle. Ireland is not alone in experiencing problems with the occurrence of BTB in wildlife species and the spill-over from those species into cattle, as was evidenced at the Fourth International Conference on *M. bovis*, held in Dublin during 2005 (More *et al.*, in press). Scientists, and those who manage the occurrence and control of bovine tuberculosis in wild and domestic species, are sharing knowledge and co-operating in developing methodologies to achieve this objective. When the tools are finally developed to control the disease in wild animals, Ireland should at last achieve the target it set itself in 1950.

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