Institution: Imperial College London

Unit of Assessment: 02 Public Health, Health Services and Primary Care

Title of case study: TB in Cattle and Badgers: Improving Control of a Multi-species Disease

1. Summary of the impact (indicative maximum 100 words)

The bovine tuberculosis (TB) research programme led by Professor Donnelly at Imperial College has been informing policymakers for over a decade. Professor Donnelly played a leading role in the design, oversight, analysis and interpretation of the £50 million Randomised Badger Culling Trial (RBCT, 1998-2006), overseeing a bovine-TB research team at Imperial since 2001. The RBCT compared two candidate culling policies (large-scale culling repeated annually and one-off small-scale culls near farms affected by bovine TB) with areas in which no badger culling took place. Informed by RBCT results (in which widespread culling decreased cattle incidence inside the culling area but increased it on neighbouring farms), the Secretary of State Hilary Benn ruled out badger culling as a control measure in July 2008. However, the coalition government took a different view and in December 2011 announced that farmers could apply for licences to undertake farmer-led (and farmer-funded) badger culling to control TB in cattle. Several of the government's licensing requirements for badger culls in England were based on many of the team's results. In contrast, having proposed in 2010 a large government-led cull, the Welsh government chose in March 2012 to vaccinate, rather than cull, badgers informed by the same set of results.

2. Underpinning research (indicative maximum 500 words)

Key Imperial College London researcher:
Professor Christl Donnelly, Professor of Statistical Epidemiology (2000-present)

Professor Donnelly played a leading role in the design, oversight, analysis and interpretation of the Department for Environment, Food and Rural Affairs (Defra)-funded Randomised Badger Culling Trial (RBCT, 1998-2006) as deputy chair of the Independent Scientific Group on Cattle TB (ISG). She joined Imperial College in October 2000 and between 2001 and 2007 she led a team of (two to four) government-grant-funded research associates undertaking RBCT-related research within the Department of Infectious Disease Epidemiology at Imperial.

The RBCT was very large in scope involving 30 areas of England each of 100sq-km. Each area was randomised to one of three study arms: no culling; small-scale reactive culling undertaken in response to confirmed infection found in a cattle herd within the area; and large-scale, annually repeated, proactive culling which was carried out across the entire 100sq-km area. Badger culls were undertaken within the trial between 1998 and 2005.

The reactive culling strategy was suspended in 2003 when Professor Donnelly and colleagues found it to be associated with increased TB incidence in cattle herds (1). Proactive culling continued until 2005 and in 2006 Professor Donnelly and colleagues found that proactive culling was associated with significantly decreased TB incidence in cattle herds within proactively culled trial areas, but significantly increased TB incidence among cattle herds up to 2km outside proactively culled trial areas (2, 6).

There were several other strands of complementary research being undertaken as part of the bovine TB research programme, published in peer-reviewed scientific journals but also summarised in the Final Report of the ISG to Ministers (5). Of particular note was the baitmarking study in which the ranging behaviour of badgers was compared in the three different types of areas (no culling; reactive culling and proactive culling). Badger densities were, as expected, highest in the unculled areas and lowest in the proactive culled areas. Furthermore, badgers in culled areas (reactive and proactive) and crucially up to 2km outside proactively culled areas were found to range significantly more widely than badgers in undisturbed unculled areas (3). Thus, it was hypothesized that this social "perturbation" to badger populations was responsible for the

increased transmission risks to cattle within reactively culled areas and up to 2km outside proactively culled areas.

Badgers culled in follow-up proactive culls (i.e. those after the initial proactive cull) were found to be significantly more likely to be infected with Mycobacterium bovis, the aetiological agent of bovine TB (4). This is consistent with the social perturbation caused by recent culling increasing the risk of badger-to-badger transmission, as well as the risk of badger-to-cattle transmission.

Professor Donnelly's current TB research (with two post-doctoral researchers) focuses on modelling and cost-effectiveness analysis of cattle vaccination in the presence of transmission risks from both badgers and bought-in cattle. She met with Defra officials in March 2013 to discuss how the results of current work could inform the government's planned field trial of a Bacillus Calmette-Guérin (BCG) cattle vaccine.

3. References to the research (indicative maximum of six references)

(1) Donnelly, C.A., Woodroffe, R., Cox, D.R., Bourne, J., Gettinby, G., Le Fevre, A.M., McInerney, J.P., & Morrison, W.I. (2003). Impact of localized badger culling on tuberculosis incidence in British cattle. *Nature,* 426, 834-837. DOI. Times cited: 136 (as at 30th October 2013 on ISI Web of Science). Journal Impact Factor: 38.59

(2) Donnelly, C.A., Woodroffe, R., Cox, D.R., Bourne, F.J., Cheeseman, C.L., Clifton-Hadley, R.S., Gao, Wei, Gettinby, G., Gilks, P., Jenkins, H., Johnston, W.T., Le Fevre, A.M., McInerney, J.P. & Morrison, W.I. (2006). Positive and negative effects of widespread badger culling on tuberculosis in cattle. *Nature*, 439, 843-846. DOI. Times cited: 132 (as at 30th October 2013 on ISI Web of Science). Journal Impact Factor: 38.59

(3)Woodroffe, R., Donnelly, C.A., Cox, D.R., Bourne, F.J., Cheeseman, C.L., Delahay, R.J., Gettinby, G., McInerney, J.P., & Morrison, W.I. (2006). Effects of culling on badger *Meles meles* spatial organization: implications for the control of bovine tuberculosis. *Journal of Applied Ecology* 43, 1-10. DOI. Times cited: 62 (as at 30th October 2013 on ISI Web of Science). Journal Impact Factor: 4.74

(4) Woodroffe, R., Donnelly, C.A., Jenkins, H.E., Johnston, W.T., Cox, D.R., Bourne, F.J., Cheeseman, C.L., Delahay, R.J., Clifton-Hadley, R.S., Gettinby, G., Gilks, P., Hewinson, R.G., McInerney, J.P., & Morrison, W.I. (2006). Culling and cattle controls influence tuberculosis risk for badgers. *Proceedings of the National Academy of Sciences* 103, 14713-14717. DOI. Times cited: 56 (as at 30th October 2013 on ISI Web of Science). Journal Impact Factor: 9.6

(5) Bourne, J., Donnelly, C., Cox, D., Gettinby, G., McInerney, J., Morrison, I., & Woodroffe, R. (2007). Bovine TB: the Scientific Evidence. A Science Base for a Sustainable Policy to Control TB in Cattle. *Final Report of the Independent Scientific Group on Cattle TB* presented to the Secretary of State for Environment, Food and Rural Affairs the Rt Hon David Miliband MP. 287pp. http://webarchive.nationalarchives.gov.uk/20081107201922/http://defra.gov.uk/animalh/tb/isg/pdf/final_report.pdf

(6) Jenkins, H.E., Woodroffe, R., & Donnelly, C.A. (2010). The Duration of the Effects of Repeated Widespread Badger Culling on Cattle Tuberculosis Following the Cessation of Culling. *PLoS ONE* 5(2): e9090. DOI. Times cited: 25 (as at 30th October 2013 on ISI Web of Science). Journal Impact Factor: 3.73

Key funding:

- The Randomised Badger Culling Trial (RBCT) was funded by and implemented directly by Defra and Defra staff, under advice from the Independent Scientific Group on Cattle TB (of which Christl Donnelly was Deputy Chair).

"The RBCT represents nearly 10 years of work (1998-2007) and nearly £50 million of taxpayer investment." according to Defra's Annex B for their Consultation Document on Badger Culling http://webarchive.nationalarchives.gov.uk/20120616115816/http:/archive.defra.gov.uk/corporate/consult/tb-control-measures/100915-tb-control-measures-annexb.pdf

- Ministry of Agriculture, Fisheries and Food (2002-2004; £140,549), Principal Investigator (PI)

C. Donnelly, Bovine TB in Cattle and Badgers.
- Veterinary Laboratories Agency ((2002-2004; £124,957), PI C. Donnelly, Analysis of data derived from Randomised Culling Trial
- Defra (2004-2007; £880,315), PI C. Donnelly, Analysis of data derived from Randomised Badger Culling Trial.
- Defra (2009-2011; £379,625), PI C. Donnelly, Further analyses of spatial and temporal trends in the cattle data associated with the Randomised Badger Culling Trial
- Defra (2011-2014; £481,855), PI C. Donnelly, Transmission modelling and cost-effectiveness analysis of cattle vaccination at a herd level

4. Details of the impact (indicative maximum 750 words)

Impacts include: health and welfare; society; public policy and services; environment; production
Main beneficiaries include: UK and Welsh Assembly Governments, Defra, cattle industry

Bovine TB in cattle remains a high priority for the Defra and one of the key challenges facing cattle farmers, particularly in the west and south west of England and in Wales. Although the Krebs Committee (of which Professor Donnelly was a member) identified in 1997 “compelling” evidence that badgers were involved in transmitting infection to cattle, it was the Randomised Badger Culling Trial (RBCT, 1998-2006) which demonstrated conclusively that badger transmission contributed significantly to the incidence of bovine TB in cattle and that badger culling could significantly decrease that incidence. Badger culling is a politically sensitive issue, and the results of this trial have been critically examined by various stakeholders. They have undoubtedly stimulated public debate [1] and have informed Government policy.

In light of the trial results, Defra had considered Government-led (and Government-funded) culling but their impact assessment showed that the costs were “too high to justify the benefits achieved in the RBCT” (para 3.26 [2]). Instead the Government proposed that farmers apply for licences to undertake farmer-led badger culling to control TB in cattle. The Government [3, 4, 5] used scientific evidence published by Professor Donnelly and colleagues as the basis for several of their proposed criteria for culling licenses, including:
- that the culling areas were large (at least 150sq-km, based on extrapolation of RBCT results);
- that there is land access for culling for >70% of the area (as in the RBCT);
- that culling in a licensed area would be carried out annually for at least 4 years (as undertaken in the RBCT proactive areas).

The Government stated that “the RBCT provides the best scientific evidence available from which to predict the effects of a future culling policy” [5; see page 1].

The research impacted upon the Welsh government, who similarly proposed to undertake badger culling in a large area, again based on the RBCT finding that the overall benefits were increased as the culling area increased in absolute size (“based on previous experience and studies of badger culling strategies, including the latest published results of the Randomised Badger Culling Trial (RBCT), reducing the reservoir of infection in this way is expected to reduce the number of confirmed cattle herd breakdowns in the area. There is evidence from the RBCT that 40-50% of confirmed herd breakdowns in high incidence areas can be attributed to a local badger source. Although the RBCT differs considerably from the approach we are proposing for the Intensive Action Area, the analysis of its results suggests that a sustained reduction in confirmed herd breakdowns within the area following culling can be achieved.”) [6; see page 5].

Furthermore, the Welsh government proposal followed the RBCT protocol of culling using cage-trapping and shooting and used RBCT results to predict the expected minimum impact:
“The data from the RBCT shows that there was a benefit in the cull area but there was a short term increase in bovine TB in cattle in the surrounding area. Accounting for this, at the end of a cull and post cull period of 10 years, we expect to have reduced bovine TB by approximately 22%, overall preventing an estimated 83 confirmed herd breakdowns that would otherwise have occurred in the absence of culling badgers in the area.” [6; see page 5]

On 20 March 2012 the Welsh Government [7] announced it would launch a badger vaccination project, rather than a badger culling programme, as part of its work to eradicate cattle TB from Wales. This decision was based on the judgement that the effects of culling, informed by RBCT results, would be not sufficient "to eliminate or substantially reduce the incidence of bovine TB in cattle" [7].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[1] Examples of public debate:
- http://www.teambadger.org.uk/rbct_sm.html - Archived on 1st November 2013
- http://www.nfuonline.com/tackling-tb-document--august-2013/ - Archived on 1st November 2013
- http://www.theguardian.com/environment/2012/sep/18/badger-cull-shot-in-the-dark - Archived on 1st November 2013
- http://www.shropshirewildlifetrust.org.uk/Badgers%20and%20bovine%20TB/Bovine%20tb%20and%20badger%20culling – Archived on 1st November 2013

[2] Defra. The Government's policy on Bovine TB and badger control in England. December 2011. (archived 01/11/2013)

[3] Defra. Bovine Tuberculosis: The Government's approach to tackling the disease and consultation on a badger control policy. September 2010. 54pp
http://webarchive.nationalarchives.gov.uk/20120616115816/http://archive.defra.gov.uk/corporate/consult/tb-control-measures/100915-tb-control-measures-condoc.pdf (archived on 01/11/2013)
Also of particular interest is Annex B "Scientific Evidence on Culling"
http://webarchive.nationalarchives.gov.uk/20120616115816/http:/archive.defra.gov.uk/corporate/consult/tb-control-measures/100915-tb-control-measures-annexb.pdf (archived on 01/11/2013)

[4] Bovine TB and Badgers - Commons Library Standard Notes. This information is provided to Members of Parliament in support of their parliamentary duties.
Badgers and Bovine TB: Background. Standard Note SN/SC/3751 Last updated: 15 February 2011 Author: Dr Elena Ares http://www.parliament.uk/briefing-papers/SN03751 (archived on 01/11/2013)
Badger Culling. Standard Note SNSC-5873 Last updated: 16 February 2012 Author: Dr Elena Ares http://www.parliament.uk/briefing-papers/SN05873 (archived on 01/11/2013)

[5] Defra. Bovine TB - Key conclusions from the meeting of scientific experts, held at Defra on 4th April 2011. From a meeting between Bob Watson (Chief Scientific Adviser, Defra), Nigel Gibbens (Chief Veterinary Officer, Defra), Professor Lord John Krebs, Professor Lord Robert May, Prof Christl Donnelly and 6 other scientists.
http://archive.defra.gov.uk/foodfarm/farmanimal/diseases/atoz/tb/documents/bovinetb-scientificexperts-110404.pdf (archived on 01/11/2013)

[6] Welsh Assembly Government. Consultation Document. Bovine TB Eradication Programme: Consultation on Badger Control in the Intensive Action Area**.** 20 September 2010. 14pp.
http://wales.gov.uk/docs/drah/consultation/100921badgercontroliaaen.pdf (archived on 01/11/2013)

[7] Welsh Assembly Government. Environment Minister announces programme of badger vaccination. 20 March 2012. Archived on 01/11/2013.