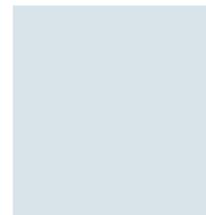
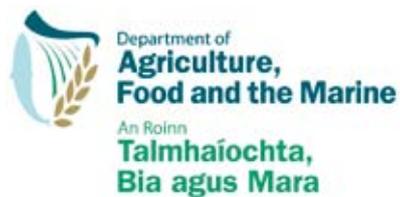
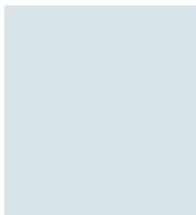
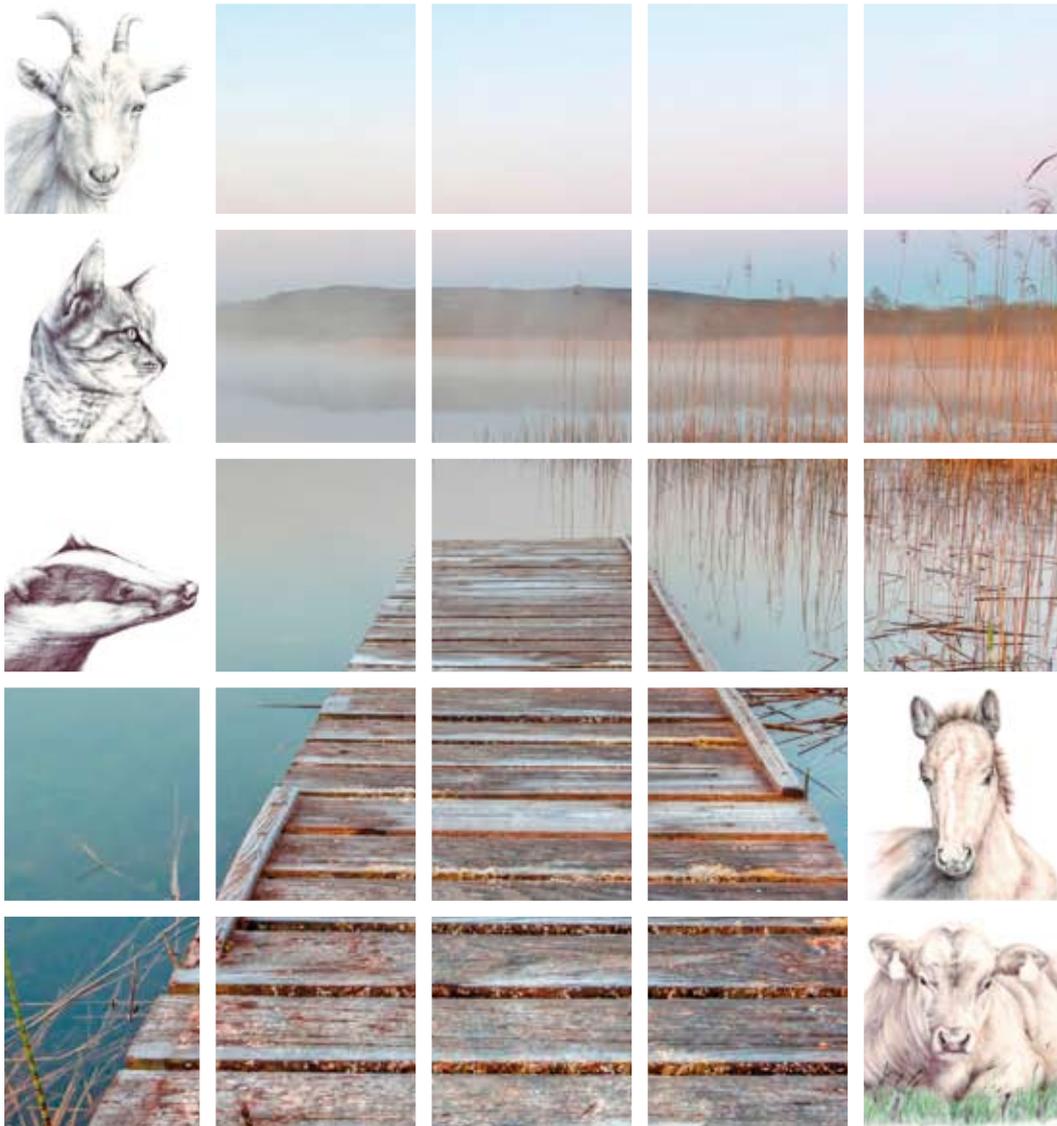


# The Centre for Veterinary Epidemiology and Risk Analysis

## The TB Diagnostics and Immunology Research Centre

### The Badger Vaccine Project

*Biennial Report, 2012-13*



**The Centre for Veterinary Epidemiology and Risk Analysis**  
**The TB Diagnostics and Immunology Research Centre**  
**The Badger Vaccine Project**

## **Biennial Report, 2012-13**

*S.J. More and D.M. Collins (editors)*

*H.K. More (illustrations)*

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## Preface

The Department of Agriculture, Food and the Marine (DAFM) provides ongoing financial support to three research units within the UCD School of Veterinary Medicine at University College Dublin:

- The UCD Centre for Veterinary Epidemiology and Risk Analysis (UCD CVERA);
- The TB Diagnostics and Immunology Research Centre; and
- The Badger Vaccine Project.

These units each work to support DAFM policy, inspectorate and laboratory staff in the area of animal health. The TB Diagnostics and Immunology Research Centre and the Badger Vaccine Project focus on bovine tuberculosis research. UCD CVERA is a national resource centre, providing policy advice and conducting epidemiological research on a wide range of animal health issues. In addition, UCD CVERA provides general support to government, industry and the veterinary profession (pre- and post-graduation).

This report documents work conducted by, or in association with, these three UCD-based research units during 2012 and 2013.

Simon J. More  
Eamonn Gormley  
Leigh Corner

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## Acknowledgements

### *The Centre for Veterinary Epidemiology and Risk Analysis*

UCD CVERA works closely with colleagues from a wide range of organisations, both in Ireland and internationally, and their input is gratefully acknowledged.

Staff from each of the following organisations were co-authors, with UCD CVERA staff, of international peer-reviewed scientific papers published during 2012-13:

#### **University College Dublin**

- UCD School of Mathematical Sciences
- UCD School of Public Health, Physiotherapy and Population Science
- UCD School of Veterinary Medicine

#### **Rest of the Republic of Ireland**

- Animal Health Ireland
- Cork County Council
- DAFM State Veterinary Service
- DAFM Veterinary Laboratory Service
- Irish Cattle Breeding Federation
- MSD Animal Health
- Private consultants
- Trinity College Dublin
- Teagasc
- UCC School of Biological, Earth and Environmental Sciences
- Waterford County Council

#### **United Kingdom**

- Animal Health and Veterinary Laboratories Agency, Weybridge, England
- Broadview Ecological Consultants, Gloucestershire, England
- Centre for Evidence-based Veterinary Medicine, School of Veterinary Medicine and Science, The University of Nottingham, Nottingham, England
- Department of Agriculture and Rural Development, Belfast, Northern Ireland
- Office of the Chief Veterinary Officer, Welsh Government, Cardiff, Wales
- Queens University Belfast, Belfast, Northern Ireland
- Royal Veterinary College (RVC), London, England
- School of Veterinary Medicine, University of Glasgow, Glasgow, Scotland
- Scottish Agricultural College, Edinburgh, Scotland
- The Roslin Institute, Edinburgh, Scotland
- Veterinary and Science Team, Scottish Government, Edinburgh, Scotland
- Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast, Northern Ireland

## Rest of the world

- Animal, Plant and Fisheries Quarantine and Inspection Agency, Anyang, Korea
- ANSES, Laboratoire de Sophia-Antipolis, Unité pathologie des ruminants, Sophia-Antipolis, France
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- Department of Population Medicine, University of Guelph, Ontario, Canada
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- European Food Safety Authority (EFSA), Parma, Italy
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- Laboratory of Biodiversity and Evolutionary Genomics, University of Leuven, Leuven, Belgium
- SAFOSO, Safe Food Solutions Inc., Bern, Switzerland
- University of California, Davis, California, USA
- University of Colorado, Colorado, USA
- University of Pretoria, Onderstepoort, South Africa
- Wageningen University, Wageningen, The Netherlands

## *The TB Diagnostics and Immunology Research Centre*

Staff from the Centre acknowledge the help and support of District Veterinary Office (DVO) staff in providing samples for the IFN- $\gamma$  test.

## *The Badger Vaccine Project*

Staff working on the Badger Vaccine Project acknowledge the contribution and support of Kevin Kenny, and colleagues at the mycobacteriology laboratory (DAFM Veterinary Laboratory Service, Backweston, Celbridge, Co. Kildare, Ireland), and Paddy Sleeman of University College Cork for fieldcraft. Mark Chambers, Sandrine Lesellier, and staff at the Animal Health Veterinary Laboratories Agency (AHVLA, Weybridge, England) are also thanked for developing and carrying out many of the immunoassays used in the badger vaccine studies, and for contributing technical expertise and advice for the research programme.

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## Personnel

### *The UCD Centre for Veterinary Epidemiology and Risk Analysis*

#### **Board of management**

##### *UCD CVERA Director*

- Simon J. More (UCD)

##### *School, College and University representatives*

- University Vice-President for Research
- Principal, UCD College of Agriculture, Food Science and Veterinary Medicine
- Head, UCD School of Veterinary Medicine
- Michael Doherty, UCD School of Veterinary Medicine

##### *From the Department of Agriculture, Food and the Marine*

- Martin Blake
- Margaret Good
- John Griffin
- Richard Healy
- Dónal Sammin
- Michael Sheridan

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##### **Full-time**

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 Tracy A. Clegg (UCD)  
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 Tara Fitzsimons  
 Kevina McGill

### *The Badger Vaccine Project*

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 Leigh Corner  
 Anthony Duignan (DAFM)  
 Deirdre Ní Bhuachalla  
 Marian Teeling

## Overview

### *The Centre for Veterinary Epidemiology and Risk Analysis*

The UCD Centre for Veterinary Epidemiology and Risk Analysis (UCD CVERA) is the national resource centre for veterinary epidemiology in Ireland, located within the UCD School of Veterinary Medicine at University College Dublin. The Centre was initially established as the Tuberculosis Investigation Unit, but in recent years has broadened its remit to cover a wide range of international, national and local animal health matters, including:

- Epidemiological support for the control and eradication of regulatory animal diseases, which includes national programmes for bovine tuberculosis, bovine brucellosis and bovine spongiform encephalopathy;
- Work in support of Animal Health Ireland ([www.animalhealthireland.ie](http://www.animalhealthireland.ie)), which is providing a proactive, coordinated and industry-led approach in Ireland to non-regulatory animal health concerns (such as mastitis, bovine viral diarrhoea and Johne's disease); and
- Epidemiological support for a broad range of other animal health and welfare issues relating to emergency animal disease preparedness and response (for example, avian influenza, bluetongue and equine infectious anaemia), on-farm investigations, welfare of farmed livestock and horses, health of companion animals and farmed fish, and international collaboration.

UCD CVERA staff work closely with national policy-makers, both in government and industry. Staff also contribute to training in veterinary medicine, both to undergraduates and postgraduate. A broad range of expertise is represented within the Centre, including database development and management, geographic information systems, statistics, veterinary medicine and epidemiology. The Centre is staffed by employees of University College Dublin and of the Department of Agriculture, Food and the Marine (DAFM).

### *The Badger Vaccine Project*

The badger vaccine project is a programme of research with the objective to develop a vaccine to control tuberculosis in badgers and to break the link of infection to cattle. In studies with captive badgers, we have demonstrated that vaccination of badgers with BCG by a number of routes, including oral delivery, generates high levels of protective immunity against challenge with *M. bovis*. We are continuing to carry out studies with captive population of badgers to refine the vaccine and address issues relating to the eventual licensing of the vaccine as a veterinary medicine. In our most recent captive badger study, the preliminary analysis of data indicates that lower doses of oral BCG vaccine ( $10^5$  colony forming units) are just as effective at protecting badgers against experimental challenge, compared with the standard dose ( $10^7$  colony forming units). This may have important implications for cost of manufacture of an oral vaccine. The vaccine field trial, which commenced in 2009 to test the efficacy of the oral BCG vaccine in free-living badgers over a wide geographic area in Co. Kilkenny, is nearing completion. The vaccination phase of the field trial finished in 2012, and 273 badgers have since been removed from the site for detailed post-mortem analysis. The analysis of the data has commenced and it is hoped to present preliminary results early in 2014.

## *TB Diagnostics and Immunology Research Centre*

The gamma-interferon (IFN- $\gamma$ ) assay is used as a tool by ERAD to assist in the eradication of bovine tuberculosis from the national cattle herd. All of the testing is carried out in the laboratory based at UCD. In the period 2012-2013, approx. 27,000 blood samples were submitted to the laboratory for testing. The samples originated mainly from:

- bovine reactor re-test herds, where the test was used to diagnose infected animals that were missed by the SICTT (false negatives). Approximately 30% of all samples submitted were positive to IFN- $\gamma$ ,
- SICTT reactor animals where the IFN- $\gamma$  test was used to confirm the exposure status of SICTT positive animals. The correlation between positive SICTT result and positive IFN- $\gamma$  results exceeds 80%, consistent with figures published elsewhere. This reactor testing was conducted as part of the ERAD Quality Assurance programme (lead by Anthony Duignan).

The laboratory continues to conduct research with a view to improving the performance of the assay under Irish conditions. Recent studies have investigated the risk factors associated with disclosure of false positive reactors using the IFN- $\gamma$  assay, in TB free or low prevalence herds. In these herds, a simple univariate model revealed that the region of herd origin, the time of year when the testing was carried out, and the age of the animal were all significant risk factors. In the multivariate models, only animal age and region of herd origin were found to be significant risk factors. A high proportion of herds with multiple IFN- $\gamma$  false positive animals were located in one county, with evidence of within-herd clustering, suggesting a localised source of non-specific sensitization. Knowledge of the underlying factors influencing the IFN- $\gamma$  test specificity could be used to optimize the test performance in different disease level scenarios in order to reduce the disclosure rate of false positive reactors. The laboratory is also involved in studies to use the IFN- $\gamma$  assay to help understand factors contributing to the potency of tuberculin.

## Further information

In this report, projects are either:

- Complete, which includes those projects where relevant peer-reviewed papers, or equivalent, have been published in 2012/13, or
- Current, which includes the balance of active projects covering the spectrum from an advanced research concept through to final write-up or manuscripts in press.

Manuscript preparation is conducted in accordance with Uniform Requirements for Manuscripts Submitted to Biomedical Journals of the International Committee of Medical Journal Editors (previously the Vancouver Group). For further information, see [www.icmje.org](http://www.icmje.org). Guidelines for the transparent reporting of specific study types (for example, the CONSORT statement for transparent reporting of trials, [www.consort-statement.org](http://www.consort-statement.org)) are followed.

An up-to-date list of all peer-review papers produced by, or in association with, the UCD Centre for Veterinary Epidemiology and Risk Analysis, the TB Diagnostics and Immunology Research Centre and the Badger Vaccine Project is available at [www.ucd.ie/cvera](http://www.ucd.ie/cvera).

## Professor John Daniel Collins

*MVB MVM MS (Calif.) PhD MRCVS*



*John D. Collins* Photograph by A. Kelly (UCD)

Professor John Daniel Collins passed away on the 25th of April 2012. Dan, born in Waterford in 1938, made immense contributions to a wide range of veterinary, public health and food safety issues in Ireland, Europe and around the World. He was Professor Emeritus of Farm Animal Clinical Studies at University College Dublin (UCD), the first Director of the Tuberculosis Investigation Unit (now the UCD Centre for Veterinary Epidemiology and Risk Analysis), the longest serving Board member of the Food Safety Authority of Ireland (FSAI), a past President of the Society for Veterinary Epidemiology and Preventive Medicine, and a former Chair of the Scientific Panel on Biological Hazards at the European Food Safety Authority (EFSA).

He entered University College Dublin in 1956 and graduated with a Bachelor of Veterinary Medicine (MVB) in 1961. In 1960, he was the recipient of the Mettam Memorial Medal and the Kehoe Memorial Medal of the Irish Veterinary Medical Association. Dan was awarded a Masters of Veterinary Medicine by the National University of Ireland in 1966 with a thesis on “Aspects of salmonella infection in animals with particular reference to latent infection in Irish livestock”, and a Masters of Science in Comparative Pathology (MS) by the University of California, Davis in 1968 with a thesis titled “An investigation of the in-vitro bactericidal activity of bovine sera”. In 1979, Dan was awarded a PhD by the National University of Ireland for “A study of the haemolytic anaemias of cattle with particular reference to the anaemias of lead intoxication and *Eperythrozoon wenyonii* infection”. In 1996, Dan was awarded the Distinguished Service Medal by the Irish Veterinary Association.

Dan held various lecturing and chair positions (assistant lecturer/lecturer/statutory lecturer) in the UCD Faculty of Veterinary Medicine from 1961 until he became the Associate Professor of Preventive Veterinary Medicine in 1978. He became Professor of Farm Animal Clinical Studies in 1998 and Professor Emeritus of Farm Animal Clinical Studies in 2003.

Dan’s research career is extensive. His first peer reviewed paper titled “Tuberculosis in the dog as a zoonosis” was published in the Irish Veterinary Journal in 1965. The paper described a clinical case of tuberculosis in a domestic terrier and confirmed that the disease in the dog was caused by a human strain of *Mycobacterium tuberculosis*. Throughout his

career, Dan authored and co-authored on a wide range of public and animal health issues including bovine tuberculosis, TSEs, antibiotic usage and resistance, and food safety and contamination. Dan co-wrote and contributed to a number of books particularly relating to food hygiene. He also contributed to a number of institutional and governmental official reports, both nationally and internationally.

Dan's contribution to the understanding of bovine tuberculosis in Ireland was invaluable. He understood that eradication of the infection in cattle could not be achieved without addressing the infection in wildlife. As part of a study tour in 1989, Dan and colleagues from UCD and the Department of Agriculture, Food and the Marine developed long standing collaborative relationships with research institutions in Australia, New Zealand and North America. These collaborations continue to this day. He co-organised and hosted the first International Conference on *Mycobacterium bovis* in UCD in 1991. Dan made key contributions to a number of reports upon which the Irish TB vaccine development programme is based.

On a professional level, Dan was proudest of his contribution to the area of food safety. His family were involved in the meat trade in Waterford and so, he understood the importance of food quality, hygiene and safety. After retiring from UCD in 2004, Dan continued his work with the FSAI and EFSA right up until his death. He was especially proud of the work done by the EFSA Panel on Biological Hazards (BIOHAZ) of which he was Chair from 2003-2011.

Away from work, Dan's main passions were rugby, cowboy movies, politics and his beloved Waterford. Despite living in Leinster for over 50 years, Dan was a Munster man through and through. He was immensely proud of the Munster rugby team in both times of glory and defeat. Unlike most of Munster, he wasn't present when Munster beat the All Blacks in Thomond Park in 1978!! He was however present when Munster claimed their first Celtic League title against Neath in 2003 and their two European titles in 2006 and 2008. He was as happy to watch a match between two local amateur teams as he was to watch an international match. Dan grew up watching cowboy movies. If ever there was a western movie on the TV, he would always have to stop and watch it, especially if it featured John Wayne. At every opportunity, Dan would happily reminisce about his youth in Waterford and particularly his summers spent at Tramore beach.

Dan is survived by his loving wife Phil, sons John, David, Kevin, Daniel, brother Eddie, sister-in-law Lelia, uncle Andy and eight grandchildren.

Suaimhneas síoraí duit (eternal rest to you).

**Daniel M. Collins**

*For more information:*

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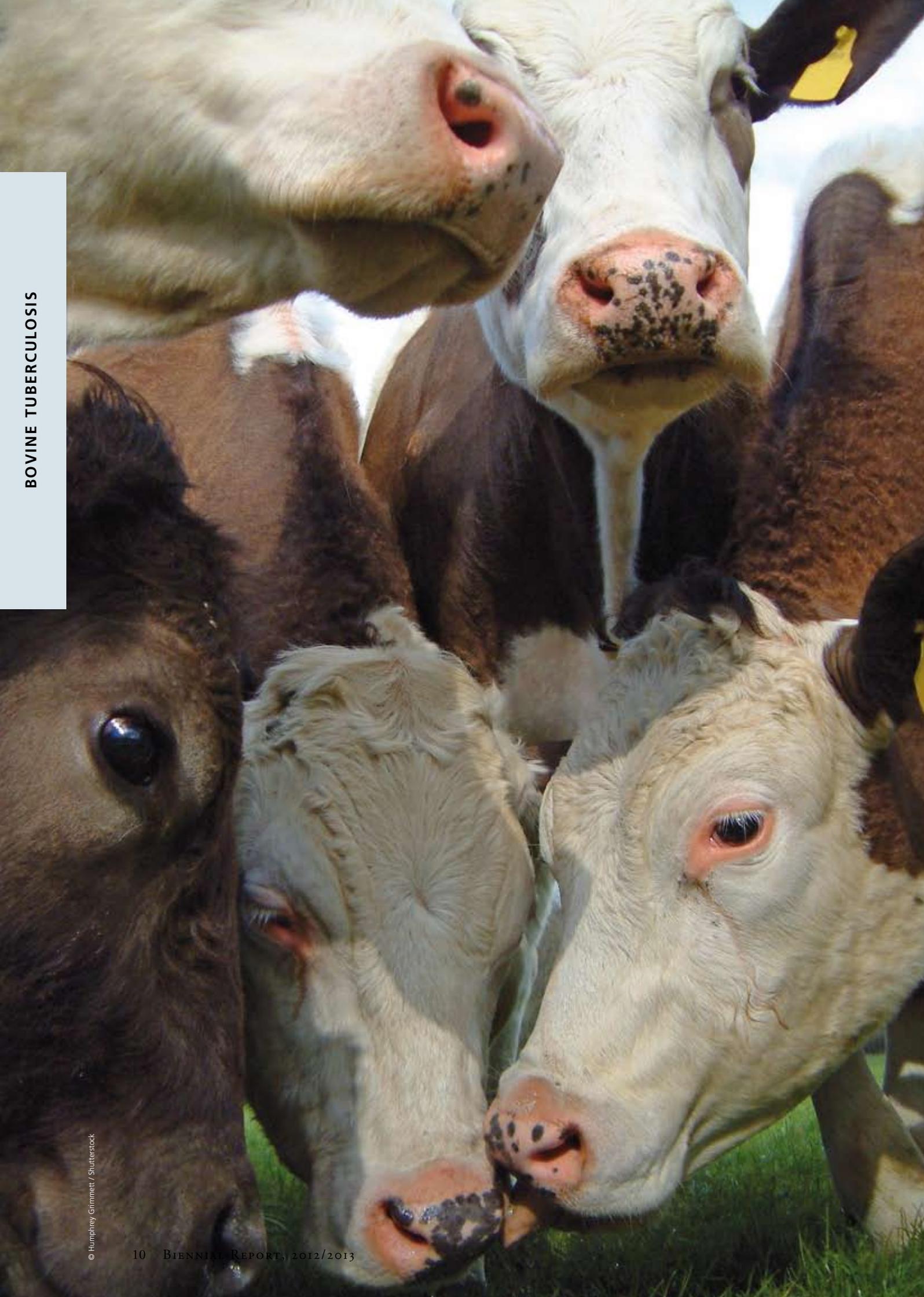
Irish Farmers Journal, 2012. Obituary – Professor Dan Collins, Emeritus Professor of Farm Animal Clinical Studies.

*Irish Farmers Journal*, 09/06/2012, page 21.

The Irish Times, 2012. Obituaries - Dan Collins, lecturer who championed food safety.

*The Irish Times*, 05/05/2012, page 14.

BOVINE TUBERCULOSIS





## Bovine tuberculosis

### ***Tuberculosis in cattle***

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## Improving surveillance

### Field-based surveillance

#### Primary isolation of *Mycobacterium bovis* from bovine tissues: conditions for maximising the number of positive cultures

Corner, L.A.L.<sup>1</sup>, Gormley, E.<sup>1</sup>, Pfeiffer, D.U.<sup>2</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> Royal Veterinary College, Hertfordshire, England

#### Veterinary Microbiology 156, 162-171 (2012)

In studies of *Mycobacterium bovis* infection in animals a definitive diagnosis requires the isolation of the organism. However, the optimum conditions for the primary isolation of *M. bovis* have not been determined. The aim of this study was to determine for primary isolation of *M. bovis*, (a) the incubation time required to achieve maximum sensitivity (i.e., the number of positive samples identified), (b) the effect of decontaminants on bacterial growth rates, and (c) the influence of media and the number of slopes of media on the number of positive samples detected. Two agar-based media, modified Middlebrook 7H11 (7H11) and tuberculosis blood agar (B83), and an egg-based medium, Stonebrink's (SB) were compared. Three decontaminants, 2% (w/v) sodium hydroxide (NaOH), 0.75% (w/v) and 0.075% (w/v) cetylpyridinium chloride (CPC, also called hexadecylpyridinium chloride, HPC) and 0.5% (w/v) benzalkonium chloride (BC) were evaluated against treatment with sterile distilled water. The inoculated media slopes were incubated for up to 15 weeks. Colonies first appeared after 2 weeks on all media types and 75% of positive slopes were identified by 8 weeks. An incubation time of 15 weeks was required to identify all positive samples. The slowest growth was associated with inocula that contained the fewest viable bacilli. The time to the appearance of colonies was influenced by medium type: the median time to detection of colonies was 28 days on 7H11 and B83, and 36 days on SB. However, SB returned the greatest number of positive samples. Decontamination procedures increased the minimum incubation time required to detect positive cultures, probably due to the toxic effect of the decontaminants. Increasing the number of inoculated slopes resulted in an increased number of positive samples and a decreased time to the detection of colonies. Overall, the detection of *M. bovis* was significantly influenced by the choice of media, the decontaminant and the duration of incubation of cultures.

*Reprinted from Veterinary Microbiology, 156, Corner, L.A.L., Gormley, E., Pfeiffer, D.U., Primary isolation of Mycobacterium bovis from bovine tissues: conditions for maximising the number of positive cultures, 162-171, Copyright 2012, with permission from Elsevier B.V.*

#### Evaluation of the methodological quality of studies of the performance of diagnostic tests for bovine tuberculosis in cattle using QUADAS adapted for veterinary use

Downs, S.H.<sup>1</sup> et al.

<sup>1</sup> Centre for Epidemiology and Risk Analysis, Animal Health and Veterinary Laboratories Agency, Weybridge, Surrey, England

A systematic review was conducted to identify studies that measured the performance of diagnostic tests for bovine tuberculosis (bTB) in cattle. There has been little assessment of the methodological quality of these studies despite the importance of these tests in national surveillance and control schemes. The purpose of this work was to evaluate the methodological quality of studies of the performance of diagnostic tests for bovine tuberculosis in cattle using QUADAS adapted for veterinary use.

## Systematic review to identify primary research estimating the performance of diagnostic tests for bovine tuberculosis in cattle

Downs, S.H.<sup>1</sup> et al.

<sup>1</sup> Centre for Epidemiology and Risk Analysis, Animal Health and Veterinary Laboratories Agency, Weybridge, Surrey, England

The aim of this study was to conduct a systematic review to identify studies that have estimates of the sensitivity and specificity of diagnostic tests for bovine tuberculosis (bTB) in cattle that could be used in a statistical meta-analysis of test performance.

## Identification of risk factors associated with disclosure of false positive bovine tuberculosis reactors using the gamma-interferon (IFN $\gamma$ ) assay

Gormley, E.<sup>1</sup>, Doyle, M.<sup>1</sup>, Duignan, A.<sup>2</sup>, Good, M.<sup>2</sup>, More, S.J.<sup>3,4</sup>, Clegg, T.A.<sup>4</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> DAFM, <sup>3</sup> UCD School of Veterinary Medicine, <sup>4</sup> UCD CVERA

**Veterinary Research 44, 117 (2013)**

The gamma-interferon assay (IFN $\gamma$ ) is often used as an ancillary diagnostic test alongside the tuberculin skin test in order to detect *Mycobacterium bovis* infected cattle. The performance of the IFN $\gamma$  test has been evaluated in many countries worldwide and wider usage as a disease surveillance tool is constrained due to the relatively low and inconsistent specificity at a herd and area level. This results in disclosure of a higher proportion of false positive reactors when compared with the skin test. In this study, we used cohorts of animals from low prevalence tuberculosis herds ( $n = 136$ ) to assess a range of risk factors that might influence the specificity of the test. Univariate and multivariate logistic generalised estimating-equation (GEE) models were used to evaluate potential risk factors associated with a false positive IFN $\gamma$  test result. In these herds, the univariate model revealed that the region of herd origin, the time of year when the testing was carried out, and the age of the animal were all significant risk factors. In the final multivariate models only animal age and region of herd origin were found to be significant risk factors. A high proportion of herds with multiple IFN $\gamma$  false positive animals were located in one county, with evidence of within-herd clustering, suggesting a localised source of non-specific sensitization. Knowledge of the underlying factors influencing the IFN $\gamma$  test specificity could be used to optimize the test performance in different disease level scenarios in order to reduce the disclosure rate of false positive reactors.

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## Results from a meta-analysis of sensitivity and specificity of diagnostic tests for bovine tuberculosis in cattle

Nuñez-García, J.<sup>1</sup> et al.

<sup>1</sup> Centre for Epidemiology and Risk Analysis, Animal Health and Veterinary Laboratories Agency, Weybridge, Surrey, England

A meta-analysis study was conducted using data extracted during a systematic review of available scientific literature that reported the sensitivity (Se) and/or specificity (Sp) of diagnostic tests for bovine tuberculosis (bTB) in cattle.

## Specificity of the tuberculin test in cattle herds adjacent to peat-land areas in Co. Tipperary

White, P.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

In Ireland, where peat-lands occur on the margins of grassland, there is some concern that cattle may become sensitized to environmental mycobacteria, and result in false positive reaction to the tuberculin skin test, or a so called non-specific reactor (NSI). This is evidenced by the finding of low lesion rates in reactors from certain areas. To date, little work has been done to assess this issue of test specificity. This study describes the relationship between visible lesion rates at slaughterhouse among standard reactor animals and likelihood of exposure to environmental mycobacteria at pasture adjacent to peat land, within Co. Tipperary, over the period 2007-2009. The aim of this study is to model the likelihood of detecting a post mortem lesion at slaughter in standard reactors derived from herds grazing within 500m of peat land (exposed) compared to herds grazed more than 2km away from peat-land (unexposed).



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## Factory surveillance

### Relative effectiveness of Irish factories in the surveillance of slaughtered cattle for visible lesions of tuberculosis, 2005-2007

Olea-Popelka, F.J.<sup>1</sup>, Freeman, Z.<sup>1</sup>, White, P.<sup>2,3</sup>, Costello, E.<sup>4</sup>, O'Keeffe, J.<sup>2,3</sup>, Frankena, K.<sup>5</sup>, Martin, S.W.<sup>6</sup>, More, S.J.<sup>2,7</sup>

<sup>1</sup> Colorado State University, Colorado, USA, <sup>2</sup> UCD CVERA, <sup>3</sup> DAFM, <sup>4</sup> DAFM Veterinary Laboratory Services, <sup>5</sup> Quantitative Veterinary Epidemiology, Wageningen University, Wageningen, The Netherlands, <sup>6</sup> Department of Population Medicine, University of Guelph, Ontario, Canada, <sup>7</sup> UCD School of Veterinary Medicine

#### Irish Veterinary Journal 65, 2 (2012)

In Ireland, every animal is examined at slaughter for its fitness for human consumption. The aim of this study was to determine the relative effectiveness of factories in submitting and subsequently in having suspect lesions confirmed as bovine tuberculosis (TB) lesions during the years 2005-2007. This work provides an update from previously published data for years 2003-2004. During 2005-2007 data were available on 4,401,813 cattle from attested herds (*i.e.* herds classified free of bovine TB), from which data for potential confounding factors were available for 3,344,057 slaughtered animals at one of the 37 export-licensed factories. From these animals, 8,178 suspect lesions were submitted for laboratory confirmation. Lesions from 5,456 (66.7%) animals tested as positive, and 269 (3.2%) were inconclusive for bovine TB. Logistic regression was used to determine adjusted submission and confirmation risks for each factory while controlling for confounding factors. Factory rankings based on adjusted and crude risks were similar. The average crude submission risk for all the factories was 25 lesions per 10,000 animals slaughtered, ranging from 0 to 52. The crude confirmation risk varied between 30.3% and 91.3%. Substantial variation in the effectiveness of lesion submission and subsequent confirmation as bovine TB was found among the 37 factories. Compared to previous years (2003-2004), there was an increased bovine TB lesion submission and confirmation risk. Continued monitoring of the effectiveness of slaughter surveillance in Ireland is recommended; emphasis should be placed on efforts to improve bovine TB surveillance in factories with lower rankings.

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## Improving management of high risk herds

### *Introduced infection*

#### The impact of animal introductions during herd restrictions on future herd-level bovine tuberculosis risk

Clegg, T.A.<sup>1</sup>, Blake, M.<sup>2</sup>, Healy, R.<sup>2</sup>, Good, M.<sup>2</sup>, Higgins, I.M.<sup>1</sup>, More, S.J.<sup>1,3</sup>

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM, <sup>3</sup> UCD School of Veterinary Medicine

#### **Preventive Veterinary Medicine 109, 246-257 (2013)**

In Ireland new cases of bovine tuberculosis (bTB) are detected using both field (with the single intradermal comparative tuberculin test (SICTT)) and abattoir surveillance. Once a new case has been detected, herd restrictions, including restrictions on animal movements into and out of the herd, are implemented until the herd has passed two consecutive clear tests. While a herd is restricted, there may be several reasons why it may be desirable to introduce new stock, such as enabling routine management practices to continue 'as near to normal'. In Ireland, introduction of animals during a bTB episode is permitted under specific conditions, with permission from the local veterinary office. The objectives of this study were (1) to provide an overview of movement events associated with each bTB episode, (2) to determine whether introduction of animals during a bTB episode is associated with increased future bTB risk and (3) to identify the practices relating to the introduction of animals that are the most risky. All herds that were not restricted at the start of 2006, but experienced a bTB episode during 2006 with 2 or more SICTT standard reactors (the eligible bTB episode) were included in the study. We calculated the number of extended eligible bTB episodes and subsequent bTB episodes that could be directly attributed to introduced animals. The main outcome of interest was the time from de-restriction of the eligible bTB episode to the start of a subsequent bTB episode or the date of the last test prior to the end of the study (31 December 2010). Cox proportional-hazard models were developed, each using a different introduction variable: introduced animals during an episode (yes/no), introduced animals prior to the first retest/first clear test, time from start of episode until first animals introduced and number of animals introduced during the episode. Only a small proportion of subsequent bTB episodes (1.8%) or extended eligible bTB episodes (2.7%) could be directly attributed to introduced animals. The results highlight an increased risk of a subsequent bTB episode among only a subset of herds that introduced animals during the eligible bTB episode. Specifically, herds that introduced animals early during the eligible bTB episode were at significantly greater future bTB risk than herds where animals were only introduced later. To illustrate, herds that introduced animals after the first retest did not have a significantly different risk compared to herds that did not introduce animals at all. In contrast, herds that did introduce animals prior to the first retest had 1.5 times higher risk of a subsequent bTB episode. Future practices concerning the introduction of animals during an episode now need to be reviewed.

*Reprinted from Preventive Veterinary Medicine, 109, Clegg, T.A., Blake, M., Healy, R., Good, M., Higgins, I.M., More, S.J., The impact of animal introductions during herd restrictions on future herd-level bovine tuberculosis risk, 246-257, Copyright 2013, with permission from Elsevier B.V.*

## Local TB persistence

### Risk of bovine tuberculosis for cattle sold out from herds during 2005 in Ireland

Berrian, A.M.<sup>1</sup>, O’Keeffe, J.<sup>2,3</sup>, White, P.W.<sup>2,3</sup>, Norris, J.<sup>4</sup>, Litt, J.<sup>4</sup>, More, S.J.<sup>2,5</sup>, Olea-Popelka, F.J.<sup>1</sup>

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#### Veterinary Record 170, 620 (2012)

A retrospective cohort study was conducted to determine the risk of bovine tuberculosis (TB) among animals sold out from herds that were free to trade animals during the year 2005 according to their bovine TB testing history during the year 2005. The present study sample comprised of 338,960 animals, of which 124,360 animals were sold out from herds that were restricted from trading at some stage during 2005 (bovine TB ‘exposed’) and 214,600 animals that were sold from herds which did not have their trading status withdrawn in 2005 (bovine TB ‘non-exposed’). The overall risk of a diagnosis of bovine TB during the two-year period after the animals were sold out was 0.69 per cent. The odds of bovine TB were 1.91 higher for animals sold out from bovine TB ‘exposed’ herds compared with animals sold out from bovine TB ‘non-exposed’ herds (OR 95 per cent CI: 1.76 to 2.07, P < 0.0001). Ten per cent of animals identified during field surveillance with bovine TB did so less than two months after being sold out in 2005, and similarly, 10 per cent of the animals classified as bovine TB positive by finding a bovine TB lesion at slaughter did so within 25 days (or less) of being sold out in 2005.

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### A retrospective cohort study of the risk of TB among suckler calves whose dam tested positive to the single intradermal comparative tuberculin test (SICTT)

Bourke, M.<sup>1</sup> et al.

<sup>1</sup> DAFM

The very close relationship of a suckling dam with her offspring and their contact via the suckling process and grooming raises the question of whether or not an infected dam could possibly transmit tuberculosis to her offspring via either the oral or respiratory route. The aim of this study is to assess the hypothesis that calves whose dams failed the Single Intradermal Comparative Tuberculin Test (SICTT) will have an increased risk of failing the test in the future compared to those whose dams were negative to the SICTT.

### Risk of bTB associated with animals moving out of derestricted herds

Doornbosch, M.<sup>1</sup> et al.

<sup>1</sup> Wageningen University, Wageningen, The Netherlands

This study seeks to answer the following question - for herds that were recently derestricted, what is the animal-level risk of bovine tuberculosis (bTB) for animals sold to other herds compared to those remaining within the herds?

## The temporal and spatial patterns of bovine tuberculosis in County Kilkenny cattle herds, 1998 to 2008

Fennelly, N.<sup>1</sup> et al.

<sup>1</sup> DAFM

The use of epidemiological methods is an intrinsic component of disease management and control. The objective of this study is to examine Bovine Tuberculosis (bTB) in County Kilkenny cattle herds from 1998 to 2008 inclusive and use the information to enhance the understanding of the epidemiology of the disease in the county. The study will examine the long term changes that have occurred over the decade (secular trends), and will investigate cyclical disease patterns and seasonal disease patterns. Spatial disease patterns may be visualised and analysed by using cartographic (mapping) or geographic information systems (GIS) methods.

### Comparison of bovine tuberculosis recurrence in Irish herds between 1998 and 2008

Gallagher, M.J.<sup>1</sup>, Higgins, I.M.<sup>1</sup>, Clegg, T.A.<sup>1</sup>, Williams, D.H.<sup>2</sup>, More, S.J.<sup>1,3</sup>

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Mathematical Sciences, <sup>3</sup> UCD School of Veterinary Medicine

#### Preventive Veterinary Medicine 111, 237-244 (2013)

During the last several decades in Ireland, there has been substantial scientific progress in our understanding and related policy changes in the bovine tuberculosis (bTB) eradication programme. A range of performance measurements are routinely available, each highlighting a steadily improving situation in Ireland. However, recent research has highlighted an on-going problem of residual infection, contributing to recurrent breakdowns. In light of this general improvement, but also cognisant of residual infection, a critical evaluation of changes in effectiveness of managing recurrence is particularly valuable. Therefore, the objective of the study was to compare the herd-level risk of recurrence of bTB in Ireland between 1998 and 2008. A retrospective cohort study was carried out, using a Cox proportional-hazards model, to compare the risk of restriction recurrence in herds derestricted during 1998 and 2008. These herds were observed for up to 3 years from the end of the 'index restriction'. At the univariable level, 46.4% and 34.8% of study herds derestricted in 1998 and 2008, respectively, had a subsequent breakdown during the study period ( $\chi^2 = 70.6$ ,  $P < 0.001$ ). In the multivariable analysis, there has been a significant reduction in bTB recurrence in Ireland, with 2008-derestricted herds being 0.74 times (95% confidence interval: 0.68–0.81) as likely to be restricted during the subsequent study period compared with 1998-derestricted herds. In the final Cox model, the rate of a future breakdown increased with increasing herd size, increasing number of standard reactors in the index restriction, increasing percentage of newly restricted herds within the District Electoral Division (DED) and if the herd had a previous bTB episode in the previous 5 years. The risk varied across herd type. The results from the current study provide further reassurance of an improved national situation, both in terms of limiting the establishment of new infection (bTB incidence) and in effectively clearing infection once detected (recurrence following derestriction). Recurrence of bTB requires effective implementation of multiple control strategies, focusing on identifying and removing residually infected cattle, and limiting environmental sources of infection, which in Ireland primarily relates to badgers.

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## An association between rainfall and bovine TB in Wicklow, Ireland

Jin, R.<sup>1</sup>, Good, M.<sup>2</sup>, More, S.J.<sup>3,4</sup>, Sweeney, C.<sup>1</sup>, McGrath, G.<sup>4</sup>, Kelly, G.E.<sup>1</sup>

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### Veterinary Record 173, 452 (2013)

There has been limited work evaluating the influence of weather variables on herd bovine tuberculosis (bTB) occurrence. In this study, we conducted a preliminary evaluation of the influence of weather variables on bTB incidence in cattle herds together with well-established risk factors from 2005 to 2009 in the area of west county Wicklow in the east of Ireland. Data were obtained on herd- and animal-level bTB testing history, land usage and weather, and analysis was conducted, with herd bTB occurrence as the outcome, using a logistic linear mixed model with random herd effect. Herd bTB occurrence was positively associated with log (herd size), herd bTB history during the past three years, annual total rainfall and presence/absence of commonage. The association between annual total rainfall and herd bTB occurrence may be linked with cattle housing (and the potential for increased cattle-to-cattle transmission with close contact in shared airspace) or to changes in bTB susceptibility in both cattle and badgers.

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## The importance of 'neighbourhood' in the persistence of bovine tuberculosis in Irish cattle herds

White, P.W.<sup>1,2</sup>, Martin, S.W.<sup>3</sup>, de Jong, M.C.M.<sup>4</sup>, O'Keeffe, J.<sup>1,2</sup>, More, S.J.<sup>2,5</sup>, Frankena, K.<sup>4</sup>

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### Preventive Veterinary Medicine 110, 346-355 (2013)

Local persistence of infection is a key feature of bovine tuberculosis (bTB) among cattle herds in the Republic of Ireland. The aim of this study was to determine the relative importance of 'neighbourhood', specifically farm-to-farm spread and spread from wildlife, in the persistence of bTB by investigating herds having a bTB episode in 2006. A case-control study was conducted on the association between the occurrence of a bTB episode in 2006 and the occurrence of bTB in previous years among neighbouring herd(s) within 1 km, while controlling for each herd's bTB history and other risk factors. Neighbouring herds were grouped into three zones, based on distance, and bTB incidence measures summarised within each zone and by calendar year (2001–2005). The incidence of bTB was associated with an increased animal incidence in two subsets of neighbouring herds: (i) herds directly contiguous during the previous 2 years (attributable fraction = 0.20), and (ii) herds at a distance of >25 m in the previous year (attributable fraction = 0.19). Other predictors of bTB in a herd in 2006 included the occurrence of a bTB episode within that herd in any of the previous 5 years, herd size, and the number of animals purchased at age greater than 12 months. An infected wildlife source best explains the existence of a "neighbouring herd risk" for bTB at distances greater than 25 m. Further studies will be necessary to determine to what extent neighbouring herd risk within 25 m may be confounded by the same wildlife (badger) source.

*Reprinted from Preventive Veterinary Medicine, 110, White, P.W., Martin, S.W., de Jong, M.C.M., O'Keeffe, J., More, S.J., Frankena, K., The importance of 'neighbourhood' in the persistence of bovine tuberculosis in Irish cattle herds, 346-355, Copyright 2013, with permission from Elsevier B.V.*

## Estimation of the between-herd reproduction ratio for contiguous spread of bovine tuberculosis

White, P.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Bovine tuberculosis (bTB) is a recurring disease burden for the Irish cattle sector, with between 20,000-30,000 reactors being removed annually under the national herd testing program. While GIS techniques have demonstrated that clustering of bTB exists in cattle herds on a wider spatial scale, relatively little work has been published on the risk of bTB transmission among herds within 25m (i.e. directly contiguous) of one other. Neighbouring herds within 25m of a herd experiencing a new bTB episode (index herd) may come into contact with bTB infected cattle and could become infected with bTB as a result. Alternatively, both index and neighbouring herds could be exposed to a common infected wildlife source. The pattern of contiguous spread among herds within areas of differing badger density may provide some useful insights into the nature bTB clustering. The study population will consist of herds within Removal (lower badger density) and Reference (higher badger density) areas of the Four Area Project, comprising parts of Cork, Donegal, Kilkenny and Monaghan. By use of herd testing data for the period of proactive badger removal, between August 1997 and September 2002, we will identify herds experiencing one or more bTB episodes (index herds). Using LPIS data for 2001, we will identify contiguous herds within 25m of an index herd, and assess the previous bTB history of those (contiguous) herds as a potential source of bTB exposure for the index herd. Using this information we will develop a mathematical model to calculate the between-herd reproduction ratio ( $R_0$ ) for a bTB episode among neighbouring herds at 25m. The key factor of interest as a determinant of  $R_0$  will be treatment area (removal or reference).

### *Predictive models*

## Stochastic herd-level modelling of freedom from bTB infection for testing strategies applied in differing risk scenarios in Great Britain

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<sup>1</sup> Centre for Epidemiology and Risk Analysis, Animal Health and Veterinary Laboratories Agency, Weybridge, Surrey, England

The performance of surveillance system components (including diagnostic tests and slaughterhouse inspection), which make up a bovine tuberculosis (bTB) surveillance system were evaluated using a stochastic model. This first calculates the probability that a herd, with specific characteristics and bTB surveillance history, is free from infection. The sensitivity of further surveillance required to meet a 'target' probability of freedom from infection is then calculated and subsequent decisions on the selection of components, which offer adequate sensitivity, can be based on specificity (expected number of false positives), time to achieve freedom, and therefore cost. The model required several inputs including evidence from previous herd surveillance, the prior probability that the herd was infected (estimated using local prevalence of bTB), the distributions of animal-level sensitivity and specificity of diagnostic tests (derived from a meta-analysis of diagnostic test performance) and the risk of introduction of infection into the herd (derived from the observed incidence of bTB in GB risk scenarios). Where the probability of introduction of infection was high, it was difficult to achieve and maintain a high target probability of herd freedom from infection even with the most sensitive of components. Conversely, where introduction of infection was low, components with low sensitivity may still provide adequate probability of freedom from TB.

## Supporting studies

### Genetics, milk production

#### Bovine tuberculosis and udder health in Irish dairy herds

Boland, F.<sup>1</sup>, Kelly, G.E.<sup>1</sup>, Good, M.<sup>2</sup>, More, S.J.<sup>3,4</sup>

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**The Veterinary Journal 192, 71-74 (2012)**

The association between bovine tuberculosis (TB) infection status based on results from the single intradermal comparative tuberculin test (SICTT) and milk production has been described in dairy cows in TB-infected herds in Ireland. The biological basis was uncertain, but could be related to increased TB susceptibility among lower producing dairy cows. In this study, the relationship between somatic cell count (as an objective measure of udder health) and SICTT reactivity (as a proxy for TB infection status) was investigated. Somatic cell counts of TB infected cows, both during and prior to the lactation of diagnosis of TB infection, were examined and compared to non-infected cows. All Irish dairy herds restricted from trading between June 2004 and May 2005 as a result of two or more TB reactors (test positive) to the SICTT were considered for study. Data were collected on 4340 cows from 419 herds. Previous lactation data for the cows were taken into consideration and all lactations on a cow were analysed together with the years of lactations. There was an inherent hierarchical structure in the data, with lactations nested within cows and cows within herds and so a linear mixed model with two random effects was used to describe the data. Milk production (305-day milk yield) was also included in the model as a fixed effect. The results of the study showed that for all lactations and years under investigation, somatic cell counts for SICTT reactor cows when compared to the non-reactor cows were not significantly different. In this study population, TB infection status was not associated with udder health.

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## A genome wide association scan of bovine tuberculosis susceptibility in Holstein-Friesian dairy cattle

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**PLoS One 7, e30545 (2012)**

Bovine tuberculosis is a significant veterinary and financial problem in many parts of the world. Although many factors influence infection and progression of the disease, there is a host genetic component and dissection of this may enlighten on the wider biology of host response to tuberculosis. However, a binary phenotype of presence/absence of infection presents a noisy signal for genome wide association study. We calculated a composite phenotype of genetic merit for TB susceptibility based on disease incidence in daughters of elite sires used for artificial insemination in the Irish dairy herd. This robust measure was compared with 44,426 SNP genotypes in the most informative 307 subjects in a genome wide association analysis. Three SNPs in a 65 kb genomic region on BTA 22 were associated (*i.e.*  $p < 10^{-5}$ , peaking at position 59588069,  $p = 4.02 \times 10^{-6}$ ) with tuberculosis susceptibility. A genomic region on BTA 22 was suggestively associated with tuberculosis susceptibility; it contains the taurine transporter gene SLC6A6, or TauT, which is known to function in the immune system but has not previously been investigated for its role in tuberculosis infection.

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## Global gene expression and systems biology analysis of bovine monocyte-derived macrophages in response to *in vitro* challenge with *Mycobacterium bovis*

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**PLoS One 7, e32034 (2012)**

*Mycobacterium bovis*, the causative agent of bovine tuberculosis, is a major cause of mortality in global cattle populations. Macrophages are among the first cell types to encounter *M. bovis* following exposure and the response elicited by these cells is pivotal in determining the outcome of infection. Here, a functional genomics approach was undertaken to investigate global gene expression profiles in bovine monocyte-derived macrophages (MDM) purified from seven age-matched non-related females, in response to *in vitro* challenge with *M. bovis* (multiplicity of infection 2:1). Total cellular RNA was extracted from non-challenged control and *M. bovis*-challenged MDM for all animals at intervals of 2 hours, 6 hours and 24 hours post-challenge and prepared for global gene expression analysis using the Affymetrix® GeneChip® Bovine Genome Array. Comparison of *M. bovis*-challenged MDM gene expression profiles with those from the non-challenged MDM controls at each time point identified 3,064 differentially expressed genes 2 hours post-challenge, with 4,451 and 5,267 differentially expressed genes detected at the 6 hour and 24 hour time points, respectively (adjusted *P*-value threshold  $\leq 0.05$ ). Notably, the number of downregulated genes exceeded the number of upregulated genes in the *M. bovis*-challenged MDM across all time points; however, the fold-change in expression for the upregulated genes was markedly higher than that for the downregulated genes. Systems analysis revealed enrichment for genes involved in: (1) the inflammatory response; (2) cell signalling pathways, including Toll-like receptors and intracellular pathogen recognition receptors; and (3) apoptosis. The increased number of downregulated genes is consistent with previous

studies showing that *M. bovis* infection is associated with the repression of host gene expression. The results also support roles for MyD88-independent signalling and intracellular PRRs in mediating the host response to *M. bovis*.

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## Whole-transcriptome, high-throughput RNA sequence analysis of the bovine macrophage response to *Mycobacterium bovis* infection *in vitro*

Nalpas, N.C.<sup>1</sup>, Park, S.D.<sup>1</sup>, Magee, D.A.<sup>1</sup>, Taraktoglou, M.<sup>1</sup>, Browne, J.A.<sup>1</sup>, Conlon, K.M.<sup>2</sup>, Rue-Albrecht, K.<sup>1</sup>, Killick, K.E.<sup>1</sup>, Hokamp, K.<sup>3</sup>, Lohan, A.J.<sup>4</sup>, Loftus, B.J.<sup>4</sup>, Gormley, E.<sup>2</sup>, Gordon, S.V.<sup>2,4</sup>, MacHugh, D.E.<sup>1,4</sup>

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### BMC Genomics 14, 230 (2013)

*Mycobacterium bovis*, the causative agent of bovine tuberculosis, is an intracellular pathogen that can persist inside host macrophages during infection via a diverse range of mechanisms that subvert the host immune response. In the current study, we have analysed and compared the transcriptomes of *M. bovis*-infected monocyte-derived macrophages (MDM) purified from six Holstein-Friesian females with the transcriptomes of non-infected control MDM from the same animals over a 24 h period using strand-specific RNA sequencing (RNA-seq). In addition, we compare gene expression profiles generated using RNA-seq with those previously generated by us using the high-density Affymetrix® GeneChip® Bovine Genome Array platform from the same MDM-extracted RNA. A mean of 7.2 million reads from each MDM sample mapped uniquely and unambiguously to single *Bos taurus* reference genome locations. Analysis of these mapped reads showed 2,584 genes (1,392 upregulated; 1,192 downregulated) and 757 putative natural antisense transcripts (558 upregulated; 119 downregulated) that were differentially expressed based on sense and antisense strand data, respectively (adjusted *P*-value  $\leq 0.05$ ). Of the differentially expressed genes, 694 were common to both the sense and antisense data sets, with the direction of expression (i.e. up- or downregulation) positively correlated for 693 genes and negatively correlated for the remaining gene. Gene ontology analysis of the differentially expressed genes revealed an enrichment of immune, apoptotic and cell signalling genes. Notably, the number of differentially expressed genes identified from RNA-seq sense strand analysis was greater than the number of differentially expressed genes detected from microarray analysis (2,584 genes versus 2,015 genes). Furthermore, our data reveal a greater dynamic range in the detection and quantification of gene transcripts for RNA-seq compared to microarray technology. This study highlights the value of RNA-seq in identifying novel immunomodulatory mechanisms that underlie host-mycobacterial pathogen interactions during infection, including possible complex post-transcriptional regulation of host gene expression involving antisense RNA.

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## *Mycobacterium bovis*: A model pathogen at the interface of livestock, wildlife and humans

Palmer, M.V.<sup>1</sup>, Thacker, T.C.<sup>1</sup>, Waters, W.R.<sup>1</sup>, Gortázar, C.<sup>2</sup>, Corner, L.A.L.<sup>3</sup>

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### **Veterinary Medicine International 2012, 236205 (2012)**

Complex and dynamic interactions involving domestic animals, wildlife, and humans create environments favorable to the emergence of new diseases, or re-emergence of diseases in new host species. Today, reservoirs of *Mycobacterium bovis*, the causative agent of tuberculosis in animals, and sometimes humans, exist in a range of countries and wild animal populations. Free-ranging populations of white-tailed deer in the US, brushtail possum in New Zealand, badger in the Republic of Ireland and the United Kingdom, and wild boar in Spain exemplify established reservoirs of *M. bovis*. Establishment of these reservoirs is the result of factors such as spillover from livestock, translocation of wildlife, supplemental feeding of wildlife, and wildlife population densities beyond normal habitat carrying capacities. As many countries attempt to eradicate *M. bovis* from livestock, efforts are impeded by spillback from wildlife reservoirs. It will not be possible to eradicate this important zoonosis from livestock unless transmission between wildlife and domestic animals is halted. Such an endeavor will require a collaborative effort between agricultural, wildlife, environmental, and political interests.

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## Variance components for susceptibility to *M. bovis* infection in dairy and beef cattle

Richardson, I.W.<sup>1,2</sup> et al.

<sup>1</sup> Teagasc Moorepark, <sup>2</sup> Trinity College Dublin

Infection of livestock with bovine tuberculosis (bTB) is of major economical concern in many countries; approximately 15,000 to 20,000 cattle are infected *per annum* in Ireland. The objective of this study was to quantify the genetic variation for bTB susceptibility in Irish dairy and beef cattle.

## Impact of delayed processing of bovine peripheral blood on differential gene expression

Sheridan, M.P.<sup>1</sup>, Browne, J.A.<sup>2</sup>, MacHugh, D.E.<sup>2,3</sup>, Costello, E.<sup>4</sup>, Gormley, E.<sup>1</sup>

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### **Veterinary Immunology and Immunopathology 145, 199-205 (2012)**

RT-qPCR can be used to accurately determine expression levels of genes following RNA extraction from tissue samples. If blood is the source of total RNA, it is often desirable to process the samples immediately following collection because delays in processing for RNA extraction may influence mRNA expression estimates obtained from RT-qPCR analyses.

However, this may not be feasible if the site of blood collection is distant from the processing laboratory. In the present study, the effects of delays in the processing of blood samples on mRNA expression data was investigated using a panel of 23 functionally diverse genes from five different gene ontology (GO) categories in peripheral blood sampled from ten age-matched healthy cattle. Venous blood was collected in Tempus™ Blood RNA tubes, which contain reagents that lyse blood cells immediately and stabilise the RNA signature ( $T_0$ ). Blood was also collected in conventional lithium heparin collection tubes, and stored at ambient temperature for  $T_4$ ,  $T_6$  and  $T_8$  h, prior to total RNA extraction. The mRNA expression profiles of these 23 genes were determined by RT-qPCR and compared across the time course. Thirteen genes showed significant up- or down-fold changes in mRNA expression over the 8 h time course. Among the GO categories, genes in the Immune response category showed the most differential expression. These results also demonstrated that the changes in mRNA expression for the *IFNG* gene, which encodes the cytokine IFN- $\gamma$ , did not correspond to IFN- $\gamma$  protein levels estimated using ELISA.

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## Tuberculosis in other farmed livestock

### Application of the Enfer Chemiluminescent Multiplex ELISA System for the detection of *Mycobacterium bovis* infection in goats

Shuralev, E.<sup>1</sup>, Quinn, P.<sup>1</sup>, Doyle, M.<sup>2</sup>, Duignan, A.<sup>3</sup>, Kwok, H.F.<sup>4</sup>, Bezos, J.<sup>5</sup>, Olwill, S.A.<sup>4</sup>, Gormley, E.<sup>2</sup>, Aranaz, A.<sup>5</sup>, Good, M.<sup>3</sup>, Davis, W.C.<sup>6</sup>, Clarke, J.<sup>1</sup>, Whelan, C.<sup>1</sup>

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#### Veterinary Microbiology 154, 292-297 (2012)

A study was conducted to optimise a multiplex serological immunoassay for use in identification of goats infected with *Mycobacterium bovis*. To assess assay specificity, 31 goats with a history of being free from *M. bovis* infection were used. To determine assay sensitivity, 180 Single Intradermal Comparative Tuberculin test (SICTT) positive goats were recruited. Additionally, 286 SICTT negative goats classed as potentially exposed animals present in the same positive herds were also included in the study. The results of the assay demonstrated a specificity of 100%. The multiplex assay detected 57/60 SICTT (95.0%) positive animals in one *M. bovis* infected herd and 120/120 (100%) in a second herd. In a separate experiment, 28 *M. caprae* culture confirmed infected goats from Spain were assayed, of which 24 (85.7%) were found positive in the test. The results show that inclusion of an antibody based assay can improve the ability to identify *M. bovis* and *M. caprae* infected goats. With further development and validation the multiplex assay may prove to be a useful tool for control of *M. bovis* and *M. caprae* infection in goats.

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## Improved understanding of ecology and TB epidemiology

### *Badger ecology*

#### The ecology of the Eurasian badger (*Meles meles*) in Ireland: a review

Byrne, A.<sup>1,2,3</sup>, Sleeman, D.P.<sup>2</sup>, O’Keeffe, J.<sup>3,4</sup>, Davenport, J.<sup>2</sup>

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#### **Biology and Environment: Proceedings of the Royal Irish Academy 112B, 105-132 (2012)**

The badger is an ecologically and economically important species. Detailed knowledge of aspects of the ecology of this animal in Ireland has only emerged through research over recent decades. Here, we review what is known about the species’ Irish populations and compare these findings with populations in Britain and Europe. Like populations elsewhere, setts are preferentially constructed on south or southeast facing sloping ground in well-drained soil types. Unlike in Britain, Irish badger main setts are less complex and most commonly found in hedgerows. Badgers utilise many habitat types, but greater badger densities have been associated with landscapes with high proportions of pasture and broadleaf woodlands. Badgers in Ireland tend to have seasonally varied diets, with less dependence on earthworms than some other populations in northwest Europe. Recent research suggests that females exhibit later onset and timing of reproductive events, smaller litter sizes and lower loss of blastocysts than populations studied in Britain. Adult social groups in Ireland tend to be smaller than in Britain, though significantly larger than social groups from continental Europe. Although progress has been made in estimating the distribution and density of badger populations, national population estimates have varied widely in the Republic of Ireland. Future research should concentrate on filling gaps in our knowledge, including population models and predictive spatial modelling that will contribute to vaccine delivery, management and conservation strategies.

*Reprinted from Biology and Environment: Proceedings of the Royal Irish Academy, 112B, Byrne, A., Sleeman, D.P., O’Keeffe, J., Davenport, J., The ecology of the Eurasian badger (Meles meles) in Ireland: a review, 105-132, Copyright 2012, with permission from the Royal Irish Academy.*

#### Estimating relative abundance using biogeographical modelling: a cross-validation approach using data gathered at different scales and intensities

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Robust estimates of species abundance for population monitoring or risk assessments require planned systematic surveying. At large spatial scales this is often unfeasible, resulting in inadequate (biased) data collection. We used two datasets, collected at different scales and intensities, to cross-validate predictions of badger abundance in the Republic of Ireland (ROI). Distribution modelling was employed using 7,724 badger main-setts (burrows) locations across the ROI at a 1ha scale. The survey of badgers (an important wildlife host for bovine tuberculosis, bTB) was directed towards areas with cattle bTB-breakdowns, thus there was a potential sampling bias within the dataset. Two strategies were employed to manage sampling bias: one allowing all of ROI to be sampled and one geographically constraining the pseudo-absences to potential survey areas only. Models predictive performance (discrimination and calibration) was assessed using internal (splitting the national-scale dataset) and external validation on independent datasets, the latter included 278 main setts from a local-scale unbiased intensive survey (755km<sup>2</sup>). The relationship between probability-classes and known-abundance was used to predict social-group densities at the national level. The distribution and abundance predictions from these models will be compared with other recent

independent estimations of the badger population, and will be extremely valuable for epidemiological (risk mapping) and conservation planning (assessing the impact of wildlife management).

## Factors affecting badger movement lengths and propensity

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Understanding badger movements is essential when modelling dispersal and disease (*Mycobacterium bovis*, bovine tuberculosis) spread across populations. Whether badger movement is related to density in either the movement 'source' or density at the 'sink' is also important. A fundamental question, with implications for disease management, is whether badgers move from higher density areas into lower density areas or vice-versa? A mark-release-recapture (MRR) study was undertaken in an extensive large-scale study area of 755km<sup>2</sup> in Kilkenny, Ireland. Other research describes the dispersal kernel for this population, but here we will use random-effects modelling to investigate badger movements in relation to sex, time between captures, age and weight. We will also investigate whether movements are related to local badger density using metrics of social group size. Two movement measures will be investigated: displacement length (distance between recaptures) and movement score (the propensity to make movements between putative territories). The findings from this study will uncover whether there are density-dependent mechanisms influencing badger movement patterns. The results will also have important implications for future badger management and disease intervention strategies.

## Long-term large scale ecological study of European badgers

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Badger culling has been implemented in Ireland as a means to reduce intra- and interspecific transmission of *Mycobacterium bovis* (the causative agent of bovine tuberculosis (bTB)) amongst badgers and cattle. These activities have reduced badger abundance significantly in many areas of the Republic of Ireland, especially in areas with chronic cattle disease problems and where large-scale experimental trials have taken place. Badger vaccination is a possible alternative means of controlling disease within badger populations without removal and is currently being implemented within a large study area (ca. 200km<sup>2</sup>) of Co. Cork. The study aims to answer key questions, which are currently poorly understood in Ireland, pertaining to badger ecology using the study population within this area. The study will be novel for Ireland, as it represents the first long-term study of badger population dynamics undertaken. Key parameters will be estimated including: population size, population growth rates, social structure and movement connectivity across the population. The study represents a unique opportunity to record how badger populations respond to reduced anthropogenic induced mortality at an unprecedented spatial scale, and to document the recovery of the population over time. The project aims to become an important study site for disease ecology as: i. the spatial scale is very large, ii. the study population will be rebounding from anthropogenic depression, but maybe likely exposed to removals perturbing the population iii. the estimated population density (<1km<sup>2</sup>) is representative of badger populations across the species range iv. the large effort and multiple measures that are planned (mark-recapture, genetics, camera trapping, setts surveys etc.) to build up a comprehensive picture of the population.

## The ecology of badgers in Ireland: density, movement and survival within six large-scale vaccine trial areas

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Knowledge of the ecology of badgers is essential for the planning and interpretation of disease management, and is critical in evaluating the success or otherwise of such interventions. Six large-scale (mean extent: 400km<sup>2</sup> each; within 6 designated counties Longford, Monaghan, Cork, Galway, Tipperary, and Waterford) field projects are planned to assess the viability of transferring from a predominantly cull orientated to a vaccine orientated wildlife disease management strategy. Mark-recapture data will be generated during these field projects, which will allow for the estimation of badger densities, coarse movement metrics and potentially survivorship. The relationship between capture-effort estimates of badger numbers and mark-recapture estimates will be investigated. If capture-effort estimates are reliable, estimates of badger numbers within culled areas will also be performed and compared with vaccine areas. These analyses will form part of the fundamental baseline knowledge required to understand whether vaccination is a viable option for the control of *Mycobacterium bovis* in European badger populations within Ireland.

## Trophic enrichment factors for blood serum in the European badger (*Meles meles*)

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**PLoS ONE 7, e53071 (2012)**

Ecologists undertaking stable isotopic analyses of animal diets require trophic enrichment factors (TEFs) for the specific animal tissues that they are studying. Such basic data are available for a small number of species, so values from trophically or phylogenetically similar species are often substituted for missing values. By feeding a controlled diet to captive European badgers (*Meles meles*) we determined TEFs for carbon and nitrogen in blood serum. TEFs for nitrogen and carbon in blood serum were  $+3.0 \pm 0.4\%$  and  $+0.4 \pm 0.1\%$  respectively. The TEFs for serum in badgers are notably different from those published for the red fox (*Vulpes vulpes*). There is currently no data for TEFs in the serum of other mustelid species. Our data show that species sharing similar niches (red fox) do not provide adequate proxy values for TEFs of badgers. Our findings emphasise the importance of having species-specific data when undertaking trophic studies using stable isotope analysis.

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## What proportion of badgers (*Meles meles*) are killed on roads in rural areas in the Republic of Ireland?

Sleeman, D.P.<sup>1</sup>, Collins, D.M.<sup>2</sup>, Davenport, J.<sup>1</sup>

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### Mammal Notes Note 6, 1-4 (2012)

Road casualties are often believed to be a significant cause of mortality for badgers. This study examines badger road casualties in relation to a number of previously investigated populations in rural areas in the Republic of Ireland. This study found that rates of badger mortality due to collisions with road vehicles in rural Ireland are low by comparison with those reported for populations in other parts of Europe.

*Adapted from Mammal Notes, Sleeman, D.P., Collins, D.M., Davenport, J., Note 6, 1-4, Copyright 2012, The Mammal Society.*

## Where and when Badger (*Meles meles*) road casualties occurred in Four Area Study

Sleeman, D.P.<sup>1</sup> et al.

<sup>1</sup> UCC School of Biological, Earth and Environmental Sciences

This project will look at the locations and seasons associated with road casualty badgers found in the Irish Four Area Project (FAP) over a five year period.

## TB epidemiology

### Mycobacterial infections in multiple species: implications for diagnosis and control

Corner, L.A.L.<sup>1</sup>, Gormley, E.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine

### The Veterinary Journal 191, 141-142 (2012)

This paper discusses the significance of the ever-increasing numbers of different pathogenic mycobacterial species affecting both domestic and wild animals. Through advances in diagnostics and increased epidemiological investigations, it should be possible to define the reservoir status of each animal host and to establish the significance in terms of infection risk.

*Adapted from The Veterinary Journal, 191, Corner, L.A.L., Gormley, E., Mycobacterial infections in multiple species: implications for diagnosis and control, 141-142, Copyright 2012, with permission from Elsevier Ltd.*

## The distribution of *Mycobacterium bovis* infection in naturally infected badgers

Corner, L.A.L.<sup>1</sup>, O'Meara, D.<sup>2</sup>, Costello, E.<sup>2</sup>, Lesellier, S.<sup>3</sup>, Gormley, E.<sup>1</sup>

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**The Veterinary Journal 194, 166-172 (2012)**

Populations of Eurasian badgers (*Meles meles*) with tuberculosis (*Mycobacterium bovis* infection) are a significant reservoir of infection for cattle in Ireland and the United Kingdom. In this study the distribution of infection, histological lesions and gross lesions was determined in a sample of 132 culled badgers from naturally-infected wild populations. Badgers were culled when an epidemiological investigation following a tuberculosis breakdown in a cattle herd implicated badgers as the probable source of infection. The definition of tuberculosis infection was based on the isolation of *M. bovis* from tissues or clinical samples. An accurate diagnosis of infection was achieved by culturing a wide range of lymph nodes (LN) and organ tissues (mean 32.1) and clinical samples (faeces and urine) from each badger. Infection was detected in 57/132 badgers (43.2%). Histological lesions consistent with tuberculosis were seen in 39/57 (68.4%) culture-positive and 7/75 (9.3%) culture-negative animals. Gross lesions were seen in only 30/57 (52.6%) infected badgers, leaving a high proportion (47.4%) of infected animals with latent infection (no grossly visible lesions). The most frequently infected tissues were the lungs and axillary LN, followed by the deep cervical LN, parotid LN and tracheobronchial LN. The data support the hypotheses that in badgers there are only two significant routes of infection, namely, the lower respiratory tract and bite wounds, and that badgers are very susceptible to infection but resistant to the development and progression of the disease. At all levels of disease severity, infection was found in widely dispersed anatomical locations suggesting that there is early dissemination of infection in the period preceding the development of active immunity.

*Reprinted from The Veterinary Journal, 194, Corner, L.A.L., O'Meara, D., Costello, E., Lesellier, S., Gormley, E., The distribution of Mycobacterium bovis infection in naturally infected badgers, 166-172, Copyright 2012, with permission from Elsevier Ltd.*

## DNA typing of *Mycobacterium bovis* isolates from badgers (*Meles meles*) culled from areas in Ireland with different levels of tuberculosis prevalence

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**Veterinary Medicine International 2012, 742478 (2012)**

Badgers (*Meles meles*) have been implicated in the transmission of *Mycobacterium bovis* infection to cattle in Ireland and UK. Recent studies in Ireland have shown that although the disease is endemic in badgers, the prevalence of disease is not uniform throughout the country and can vary among subpopulations. The extent to which the prevalence levels in badgers impact on the prevalence in cattle is not known. Previously, DNA fingerprinting has shown that *M. bovis* strain types are shared between badgers and cattle, and that there are a large number of strain types circulating in the two species. In this study we have carried out spoligotyping and variable number tandem repeat (VNTR) analysis of *M. bovis* isolates from two groups of badgers, representing a wide geographic area, with different tuberculosis prevalence levels. The results of the typing show that there is no geographic clustering of strain types associated with prevalence. However, two VNTR profiles were identified that appear to be associated with high- and low-prevalence *M. bovis* infection levels, respectively. In addition, spoligotyping and VNTR analysis has provided evidence, for the first time, of multiple infections of individual badgers with different *M. bovis* strains.

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## Infection control strategies

### Badger removal

#### Factors affecting European badger (*Meles meles*) capture numbers in one county in Ireland

Byrne, A.W.<sup>1,2,3</sup>, O'Keeffe, J.<sup>3,4</sup>, Sleeman, D.P.<sup>2</sup>, Davenport, J.<sup>2</sup>, Martin, S.W.<sup>5</sup>

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#### Preventive Veterinary Medicine 109, 128-135 (2013)

Understanding factors affecting the number of badgers captured at and around badger setts (burrows) is of considerable applied importance. These factors could be used to estimate probable badger densities for bovine tuberculosis (bTB) control and also for monitoring badger populations from a conservation perspective. Furthermore, badger management and vaccination programs would benefit by increasing the probability of efficiently capturing the target badger populations. Within this context, it was investigated whether badger capture numbers can be estimated from field signs and previous capture histories. Badger capture records (initial and repeated capture numbers at a sett) from a large-scale removal program (405 km<sup>2</sup>, 643 setts) were used. Univariable count models indicated that there were a number of significant potential predictors of badger numbers, during initial capture attempts. Using a multivariable zero-inflated Poisson (ZIP) model of initial captures we found that badger capture numbers were significantly affected by sett type, season, year, and the number of sett entrances in active use. Badger capture numbers were also affected by the total previous catch during repeated capture events and by the number of previous capture attempts. There was a significant negative trend in badger captures across events. Measures of the ability of these models to estimate badger captures suggested that the models might be useful in estimating badger numbers across a population; however the confidence intervals associated with these predictions were large.

*Reprinted from Preventive Veterinary Medicine, 109, Byrne, A.W., O'Keeffe, J., Sleeman, D.P., Davenport, J., Martin, S.W., Factors affecting European badger (Meles meles) capture numbers in one county in Ireland, 128-135, Copyright 2013, with permission from Elsevier B.V.*

#### Impact of culling on relative abundance of the European badger (*Meles meles*) in Ireland

Byrne, A.W.<sup>1,2,3</sup>, O'Keeffe, J.<sup>3,4</sup>, Sleeman, D.P.<sup>2</sup>, Davenport, J.<sup>2</sup>, Martin, S.W.<sup>5</sup>

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#### European Journal of Wildlife Research 59, 25-37 (2013)

The European badger (*Meles meles*) has been implicated in the epidemiology of bovine tuberculosis in cattle populations in the Republic of Ireland. Badger populations have been subject to a culling regime in areas with chronic histories of bTB cattle herd breakdowns. Removal data from 2004 to 2010 were used to model the impact of culling on populations in areas under capture. Additionally, changes in field signs of badger activity were used as an index of abundance to support, or otherwise, the outcomes of the removal models. Significant reductions in standardised badger captures over time were found across three large study areas (total area, 1,355 km<sup>2</sup>). Assuming that all inactive setts were vacant, an overall linear trend model suggested that badger captures had decreased by 78% for setts with 6 years of repeated

capturing operations. Given the uncertainty associated with the relationship between sett activity and badger presence, we repeated the linear modelling using two 'what if' scenarios. Assuming that individual badgers were missed on 10% or 20% of occasions at inactive setts, the estimated decline over 6 years is lowered to 71% or 64%, respectively. The decline profile consisted of a steep initial decrease in captures within the first 2 years, followed by a more gradual decrease thereafter. The number of active openings at setts (burrows) declined significantly in all three areas; but the magnitude of this decline varied significantly amongst study areas (41–82%). There was a significant increase in the probability of setts becoming dormant with time. The removal programme was more intense (mean, 0.45 badgers culled km<sup>-2</sup> year<sup>-1</sup>) than previous experimental badger removals in Ireland but some captures may be attributed to immigrant badgers as no attempt was made to limit inward dispersal from areas not under management. Results from this study suggest that significant reductions in badger density occurred in the areas where management had taken place. Since other non-culled badger populations in Northern Ireland and Britain exhibited stable population trends, we attribute the reduction in relative abundance to the culling regime. Further studies of the dynamics of this reduction are required to quantify how it is counteracted by immigration from populations outside of culled areas.

*Reprinted from European Journal of Wildlife Research, 59, Byrne, A.W., O'Keeffe, J., Sleeman, D.P., Davenport, J., Martin, S.W., Impact of culling on relative abundance of the European badger (Meles meles) in Ireland, 25-37, Copyright 2013, with permission from Springer, Part of Springer Science+Business Media.*

## Population estimation and trappability of the European badger (*Meles meles*): implications for tuberculosis management

Byrne, A.W.<sup>1,2,3</sup>, O'Keeffe, J.<sup>3,4</sup>, Green, S.<sup>1</sup>, Sleeman, D.P.<sup>2</sup>, Corner, L.A.L.<sup>5</sup>, Gormley, E.<sup>5</sup>, Murphy, D.<sup>4</sup>, Martin, S.W.<sup>6</sup>, Davenport, J.<sup>2</sup>

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**PLoS One 7, e50807 (2012)**

Estimates of population size and trappability inform vaccine efficacy modelling and are required for adaptive management during prolonged wildlife vaccination campaigns. We present an analysis of mark-recapture data from a badger vaccine (Bacille Calmette–Guérin) study in Ireland. This study is the largest scale (755 km<sup>2</sup>) mark-recapture study ever undertaken with this species. The study area was divided into three approximately equal-sized zones, each with similar survey and capture effort. A mean badger population size of 671 (SD: 76) was estimated using a closed-subpopulation model (CSpM) based on data from capturing sessions of the entire area and was consistent with a separate multiplicative model. Minimum number alive estimates calculated from the same data were on average 49–51% smaller than the CSpM estimates, but these are considered severely negatively biased when trappability is low. Population densities derived from the CSpM estimates were 0.82–1.06 badgers km<sup>-2</sup>, and broadly consistent with previous reports for an adjacent area. Mean trappability was estimated to be 34–35% per session across the population. By the fifth capture session, 79% of the adult badgers caught had been marked previously. Multivariable modelling suggested significant differences in badger trappability depending on zone, season and age-class. There were more putatively trap-wary badgers identified in the population than trap-happy badgers, but wariness was not related to individual's sex, zone or season of capture. Live-trapping efficacy can vary significantly amongst sites, seasons, age, or personality, hence monitoring of trappability is recommended as part of an adaptive management regime during large-scale wildlife vaccination programs to counter biases and to improve efficiencies.

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## Large-scale movement patterns in a bovine TB host: have badger movements been under-estimated?

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Characterising patterns of movement in populations is a major aim in population ecology, and yet doing so at an appropriate spatial-scale remains a major challenge. Estimating movement distances accurately can also be of importance where species that are implicated in the transmission of zoonotic diseases. European badgers (*Meles meles*) are classically viewed as exhibiting limited dispersal, and yet their movements bring them into conflict with farmers due to the potential spread of bovine tuberculosis (TB) in parts of their range. Considerable uncertainty surrounds the movement potential of badgers, and this may be related to the spatial-scale of existing empirical studies. We conducted the largest spatial-scale mark-recapture study on badgers to date (755km<sup>2</sup>) to investigate movement patterns, and undertook a comparative meta-analysis using published data from 15 European populations. The study outcomes will have implications for the design of disease intervention strategies and the understanding of badger movements.

## Monitoring trap-related injury status during large scale wildlife management programs

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Wildlife management programs aimed at reducing and controlling population densities often rely on capturing animals before being dispatched humanely. Standardised protocols are often developed at the beginning of a program, or alternatively, evaluated sporadically/periodically during longer term intervention programs. However, ideally monitoring of injuries should be completed concurrently with the intervention program to allow for adaptive management strategies to be implemented where necessary. We intend to analyse such data (2009-2012) on large-scale monitoring of trap related injuries to badgers that were captured as part of a population management program aimed at controlling tuberculosis spread within cattle populations. Badgers were captured in wire-stopped restraints before being dispatched by rifle. We developed a standardised operating procedure (SOP) to allow for the necropsy of large numbers of badgers (ca. 6000 per annum) by a veterinary pathologist. Injury status was evaluated using a categorical severity scale ranging from 0 (no visible injuries) to 6 (death). We contend that this type of monitoring is essential to wildlife management strategies to maintain the highest possible animal welfare standards.

## Quantifying bias in trappability estimates derived from the Minimum Number Alive population index

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Minimum Number Alive (MNA) is a widely used index of abundance and trappability in mark-recapture programs. MNA is a negatively-biased abundance index, and is sensitive to capture probability and the capture session number. This suggests that MNA-trappability will be positively-biased, and that the extent of the bias will vary with true trappability and trapping regime. Inappropriate use of the index may lead to over optimistic estimates of trappability. In this study, we highlight the dangers of using MNA-trappability by using closed-population stochastic simulation with known population size and trappability. Using severely-biased trappability estimates could have serious consequences for wildlife conservation, management or vaccination studies.

## Spatio-temporal trends in tuberculosis prevalence in the European badger (*Meles meles*) across the Republic of Ireland

Byrne, A.W.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Badgers are a wildlife host of *Mycobacterium bovis*, the causative agent of bovine tuberculosis (bTB), in a number of countries in Western Europe. In Ireland and Britain in particular, infected badgers represent an important contributor to the epidemiology of bTB infection in cattle. Culling of badgers has been used in Ireland as one tool to reduce intra- and interspecific transmission of *M. bovis* across populations of cattle and badgers. These large-scale operations have led to the removal of circa 5,500 badgers per annum at the national scale. These badgers are assessed at post-mortem, and a sample (~30%) of badgers are selected for laboratory culturing of *M. bovis*. The results of these investigations from 2009-2012 will be interrogated to assess trends in bTB apparent prevalence over time and across space. Badger infection (culture) status will be linked to capture locations and individual level badger variables (weight, age, sex, pregnancy status), to investigate associations between these variables and infection status. Badger status will also be modelled against metrics of local badger density (distance to nearest neighbouring sett(s)), local badger infection risk (distance to nearest neighbouring infected sett(s)) and the cattle bTB prevalence at different scales (15m, 250m, 500m, 1km).

### Control strategies for wildlife tuberculosis in Ireland

Gormley, E.<sup>1</sup>, Corner, L.A.L.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine

#### Transboundary and Emerging Diseases 60, S1, 128-135 (2013)

The principal domestic maintenance host for *Mycobacterium bovis* is infected cattle. In countries where comprehensive surveillance schemes have been applied, tuberculosis rarely affects an animal to the extent that it presents with clinical disease. In the latter stages of an eradication campaign, the aim is to maintain the disease-free status of clear herds and eliminate *foci* of infection in herds as well as restricting movement of infected animals from these herds, other than to slaughter. However, the eradication of tuberculosis from cattle herds may be compromised if infected wildlife species, such as Eurasian badgers (*Meles meles*), share the same environment and contribute to transmission of infection. The options for dealing with tuberculosis in the wildlife reservoir hosts are limited to segregation of domestic animals from the wildlife, culling of the wildlife host or vaccination. Options are further limited by conservation and social reasons, particularly where culling is concerned. In Ireland and the UK, vaccination of badgers against *M. bovis*, if successfully employed, could directly facilitate the completion of bovine tuberculosis eradication. Programmes of research into vaccination of badgers are being undertaken in both countries, and there is clear evidence that vaccination induces protection. Vaccine trials in captive badgers have established that the *M. bovis* bacille Calmette-Guérin (BCG) vaccine can induce a protective response that limits the distribution and severity of tuberculosis disease following experimental challenge. In Ireland, a large-scale field trial of oral BCG vaccination is being conducted to measure the protection generated in wild badgers subjected to natural transmission of infection and to estimate vaccine efficacy. The results will provide a framework for the development and implementation of a national strategy to address the disease in badger populations and if successful will remove this major impediment to tuberculosis eradication from cattle.

*Reprinted from Transboundary and Emerging Diseases, 60,S1, Gormley, E., Corner, L.A.L., Control Strategies for Wildlife Tuberculosis in Ireland, 128-135, Copyright 2013, with permission from Blackwell Verlag GmbH.*

## A comparison of the effectiveness of badger removal programs: Wildlife Administration Unit vs. pre-2004 licenced capture

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

In response to severe outbreaks of tuberculosis in cattle, an epidemiological investigation is carried out to establish the source of infection. If badgers are implicated, badger removal is conducted under licence by the Department of Agriculture, Food and the Marine. From the late 1980's until 2004, the badger removal program comprised of the removal of badgers as a single event from setts found within 1 kilometre of the breakdown herd. Since 2004, the method of badger removal changed from this single removal event to a continued removal of badgers from setts (main setts 1.5 kilometres and other setts 2km from the breakdown herd). This study aims to compare the effectiveness of these two badger removal approaches by examining their comparative survival times following the initial badger removals. Severity of future breakdowns could also be used as a measure of determining effectiveness. The study could be expanded to include the effect on neighbouring farms and/or farms up to a defined distance.

## The RBCT: reappraisal of logic

More, S.J.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Veterinary Medicine

The Randomised Badger Culling Trial (RBCT) is a very important scientific study, which now underpins bTB science and policy in England and Wales. Given its central importance, it is crucial that there is ongoing discussion and critique of the RBCT results. In this article, we outline two issues relating to the RBCT results where, as yet, there has been limited discussion.

## Temporal and spatial association between presence of badgers and bovine tuberculosis status of herds within areas of badger removal in Co. Monaghan

White, P.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Under the current medium-term program of badger removal, capture efforts are targetted around herds experiencing more serious bTB episodes. Where epidemiological investigation of a herd implicates badgers and rules out a purchased bovine source (an index herd), a survey of the surrounding area is undertaken, and setts approved for capture under the program (under capture). The dates and locations of all subsequent badger removal are recorded, and from these data the previous presence of badgers at/around a sett may be inferred. The aim is to assess temporal and spatial association between badger presence and herd bTB. A spatial association is made between a herd and a sett if >33% of a herd's land area lies within within a 500m of the sett (a "surrounding herd"). Using Cox survival models, we will assess indices of badger presence, and risk of bTB episode within surrounding herds. We will control for confounders including previous bTB herd history, herd size, index-herd status, enterprise type, and herd location with respect to the former Four Area Project.

## Progress towards a badger vaccine

### Badger tuberculosis vaccine

Gormley, E.<sup>1</sup>, Ní Bhuachalla, D.<sup>1</sup>, Duignan, A.<sup>2</sup>, Corner, L.A.L.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> DAFM

#### *a. Vaccine development (studies with captive badgers)*

The first phase of research into BCG vaccination against tuberculosis in captive badgers, an integrated series of eight experiments and associated studies that commenced in 2001, has been completed. These studies have established as proof of principle that vaccination of badgers with BCG, when delivered by a variety of routes, can protect badgers against tuberculosis. The BCG vaccine has been chosen for use based on its availability, low production cost and much experience of its application in domestic and wild animals, and humans. In our most recent study, we have shown that oral vaccination with low doses of BCG ( $10^5$  colony forming units) is just as effective against challenge with a low dose of *M. bovis*, compared with the standard oral BCG dose ( $10^7$  colony forming units). The data has given us a much better understanding of how the vaccine is likely to perform under natural conditions and will facilitate the development of strategies to deliver the vaccine to badger populations. As part of these studies, and working closely with colleagues at AHVLA (Weybridge UK), we helped develop and assess a range of in vitro diagnostic assays based on the immunological responses of badgers to challenge with *M. bovis*. We are also investigating the interactions of captive badgers with cattle at our experimental facility at DAFM Longtown farm. Tunnels connect the badger pens with cattle sheds and the badgers have free access to the sheds and yard. To date we have video recorded many interactions between the badgers and the cattle. We are continuing to monitor to cattle with the skin test and IFN- $\gamma$  assay to detect evidence of transmission of *M. bovis* from badgers to cattle.

#### *b. The vaccine field trial*

The success of the captive badger studies has paved the way for the testing of oral BCG vaccine in a large-scale field trial. The BCG vaccine field trial has two principal objectives. These are to validate the results of captive badger studies and show that BCG vaccine is protective in naturally exposed wild badgers, and to estimate vaccine efficacy under field conditions. A secondary outcome of the field trial will be to measure the effect of BCG vaccine in badgers with pre-existing *M. bovis* infection. In addition, the field trial will provide a practical basis for understanding the logistics of oral vaccine delivery to wild badger populations.

The trial area of approx. 755 km<sup>2</sup> is divided into three zones (Figure 1) each with a different level of vaccine coverage. Badgers captured in the middle zone are randomly assigned vaccine or placebo on approximately a 50:50 basis, 100% of badgers captured in the north and south will receive either vaccine or placebo. This trial is double blinded to eliminate bias, all staff associated with the trial including field staff and veterinary pathologists are unaware of treatment status of each badger (vaccine or placebo). A capture-tag-release system is in place to identify all badgers included in the trial and treatment type is recorded (Table 1).

A total of seven capture sweeps of the trial area have been completed. The first capture sweep commenced in September 2009 and the final sweep finished in October 2013. During the final sweep, sweep 7 & 7b (September 2012 – October 2013), the trial site was depopulated. A total of 273 badgers (Table 2) were removed and each carcass was examined for gross lesions of tuberculosis by detailed post mortem examination. Each badger was assigned a preliminary gross lesion status based on post mortem findings. Multiple samples were collected aseptically from each badger, and histological examination and mycobacteriology are currently underway. The isolation of *M. bovis* from post mortem or clinical samples (wound exudates or tracheal swabs) will be used for definitive diagnosis of a case of tuberculosis. The preliminary results are expected to be available in early 2014. The results and experience gained from the field trial will provide scientific support and facilitate the development of strategies for introduction of vaccination into the national tuberculosis control and eradication program.

*c. Development of badger immunodiagnostics*

We have continued to develop and assess a range of immunodiagnostic tests that will be required for tuberculosis surveillance in badger populations to monitor the effect of vaccination. This work, carried out in collaboration with AHVLA Weybridge and with the Enfer group, is focused on antibody based diagnostic tests for badgers. We have established that the sensitivity of all the immunodiagnostic assays improves as the disease severity increases and that this is more pronounced with the serological based assays. The serology tests are being applied to the field trial blood samples and will assist in the validation of the tests on naturally infected badgers.

*Table 1. Treatment to date in the three zones of the trial area\**

	1*	2*	Total
<b>Zone A</b>	1	474	<b>475</b>
<b>Zone B</b>	129	134	<b>263</b>
<b>Zone C</b>	435	1	<b>436</b>
<b>Total</b>	<b>565</b>	<b>609</b>	<b>1174**</b>

\* Badgers receive either vaccine or placebo, blind-coded 1 & 2

\*\* Total includes 208 badgers that were revaccinated in sweep 3, 4 and 5

*Table 2. Total number of badgers removed during Sweep 7 and 7b (n = 273)*

	Total
<b>Zone A</b>	118
<b>Zone B</b>	68
<b>Zone C</b>	87
<b>Total</b>	<b>273</b>



*Figure 1 – Outline of vaccine trial area and divisions into three zones*

## Estimating the power of a *Mycobacterium bovis* vaccine trial in Irish badgers

Aznar, I.<sup>1</sup>, More, S.J.<sup>1,2</sup>, Frankena, K.<sup>3</sup>, de Jong, M.C.M.<sup>3</sup>

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Veterinary Medicine, <sup>3</sup> Quantitative Veterinary Epidemiology, Wageningen University, Wageningen, The Netherlands

### Preventive Veterinary Medicine 111, 297-303 (2013)

The aim of this study was to estimate the power, using simulation techniques, of a group randomized vaccine field trial designed to assess the effect of vaccination on *Mycobacterium bovis* transmission in badgers. The effects of sample size (recapture percentage), initial prevalence, sensitivity and specificity of the diagnostic test, transmission rate between unvaccinated badgers, Vaccine Efficacy for Susceptibility (VE<sub>S</sub>) and Vaccine Efficacy for Infectiousness (VE<sub>I</sub>), on study power were determined. Sample size had a small effect on power. Study power increased with increasing transmission rate between non-vaccinated badgers. Changes in VE<sub>S</sub> had a higher impact on power than changes in VE<sub>I</sub>. However, the largest effect on study power was associated with changes in the specificity of the diagnostic test, within the range of input values that were used for all other modelled parameters. Specificity values below 99.4% yielded a study power below 50% even when sensitivity was 100% and, VE<sub>I</sub> and VE<sub>S</sub> were both equal to 80%. The effect of changes in sensitivity on study power was much lower. The results from our study are in line with previous studies, as study power was dependent not only on sample size but on many other variables. In this study, additional variables were studied, i.e. test sensitivity and specificity. In the current vaccine trial, power was highly dependent on the specificity of the diagnostic test. Therefore, it is critical that the diagnostic test used in the badger vaccine trial is optimized to maximize test specificity.

*Reprinted from Preventive Veterinary Medicine, 111, Aznar, I., More, S.J., Frankena, K., de Jong, M.C.M., Estimating the power of a Mycobacterium bovis vaccine trial in Irish badgers, 297-303, Copyright 2013, with permission from Elsevier B.V.*

## Infection dynamics and effective control strategies of tuberculosis in badgers and cattle of Ireland

Aznar, I.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

The main objective of this study is to assess the impact of interventions on bovine tuberculosis (bTB) prevalence in cattle and badgers. A mathematical model of bTB transmission that describes the disease in cattle and badgers in the Republic of Ireland will be developed. The hypothesis is that control, with the ultimate goal of eradication, cannot be achieved until badger-to-cattle transmission is effectively addressed. Data from ongoing field trials (particularly data related to efficacy of the badger vaccine) and data from previous research work will be utilized to inform parameter estimation. Experimental work (the exact nature of which will depend on identified gaps in the knowledge required for parameter estimation) will also be carried out.

## Optimising and evaluating a multiple antigen ELISA for detection of *Mycobacterium bovis* infection in a vaccine field trial

Aznar, I.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

This study sought to optimize a diagnostic test for *M. bovis* infection in live badgers trapped during the badger vaccine trial in Ireland using a multiplex chemiluminiscent assay (Enfer Scientific). A total of 215 blood samples (including 200 blood samples used by Whelan et al., 2009) were tested against a panel of 8 *M. bovis* antigens. The optimization was done while keeping specificity at 99.99% to allow for a reasonable power (60-80%) to be obtained in the vaccine trial. In the study, we also examined the effects of vaccination on test characteristics and reviewed the implications for analysis of the data obtained from the Kilkenny badger vaccine trial.

## BCG vaccination against tuberculosis in European badgers (*Meles meles*): A review

Robinson, P.A.<sup>1</sup>, Corner, L.A.L.<sup>2</sup>, Courcier, E.A.<sup>1</sup>, McNair, J.<sup>3</sup>, Artois, M.<sup>4</sup>, Menzies, F.D.<sup>1</sup>, Abernethy, D.A.<sup>1</sup>

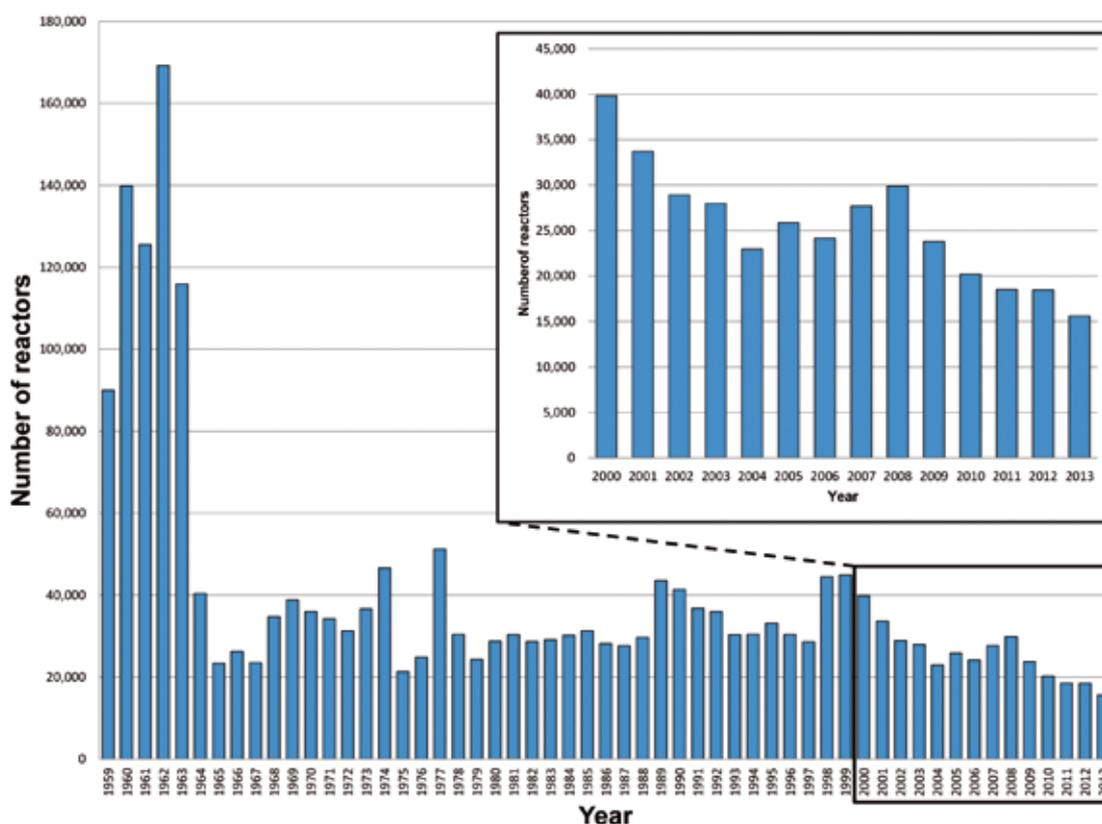
<sup>1</sup> Department of Agriculture and Rural Development, Belfast, Northern Ireland, <sup>2</sup> UCD School of Veterinary Medicine, <sup>3</sup> Agri-Food and Biosciences Institute, Belfast, Northern Ireland, <sup>4</sup> VetAgro Sup, Campus Vétérinaire de Lyon, Marcy, L'Etoile, France

**Comparative Immunology, Microbiology and Infectious Diseases 35, 277-287, (2012)**

Tuberculosis (TB) is a significant animal health problem in many parts of the world, and reservoirs of infection in wild animals complicate disease control efforts in farmed livestock, particularly cattle. Badgers (*Meles meles*) are a significant wildlife reservoir of *Mycobacterium bovis* infection for cattle in the United Kingdom (UK) and Republic of Ireland (ROI). Vaccination of badgers using an *M. bovis* strain bacille Calmette–Guérin (BCG) vaccine could potentially be an option in the national TB eradication strategy. Wildlife vaccination has been used successfully for other diseases in wildlife species, and may have a role to play in reducing *M. bovis* transmission at the wildlife–livestock interface. Research to date has provided evidence that BCG is protective in badgers, and a parenteral badger BCG vaccine has been licensed in the UK. Further research is required to develop effective strategies for vaccine deployment and to determine the effect of badger vaccination on cattle TB incidence.

*Reprinted from Comparative Immunology, Microbiology and Infectious Diseases, 35, Robinson, P.A., Corner, L.A.L., Courcier, E.A., McNair, J., Artois, M., Menzies, F.D., Abernethy, D.A., BCG vaccination against tuberculosis in European badgers (Meles meles): A review, 277-287, Copyright 2012, with permission from Elsevier Ltd.*

## The national programme



The number of TB reactors detected in Ireland each year between 1959 and 2013.

### Bovine tuberculosis trends in the UK and the Republic of Ireland, 1995–2010

Abernethy, D.A.<sup>1</sup>, Upton, P.<sup>2</sup>, Higgins, I.M.<sup>3</sup>, McGrath, G.<sup>3</sup>, Goodchild, A.V.<sup>2</sup>, Rolfe, S.J.<sup>4</sup>, Broughan, J.M.<sup>2</sup>, Downs, S.H.<sup>2</sup>, Clifton-Hadley, R.<sup>2</sup>, Menzies, F.D.<sup>5</sup>, de la Rua-Domenech, R.<sup>6</sup>, Blissitt, M.J.<sup>7</sup>, Duignan, A.<sup>8</sup>, More, S.J.<sup>3,9</sup>

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<sup>4</sup> Office of the Chief Veterinary Officer, Welsh Government, Cardiff, Wales, <sup>5</sup> Department of Agriculture and Rural Development, Belfast, Northern Ireland,

<sup>6</sup> Animal Health and Veterinary Laboratories Agency, London, England, <sup>7</sup> Veterinary and Science Team, Rural and Environmental Directorate, Scottish Government, Edinburgh, Scotland, <sup>8</sup> DAFM, <sup>9</sup> UCD School of Veterinary Medicine

#### Veterinary Record 172, 312 (2013)

Selected demographic features and trends in bovine tuberculosis (BTB) from 1995 to 2010 are described for the countries of the UK and the Republic of Ireland, using standardised definitions and measures. All countries experienced a reduction in the number of cattle and herds and in the proportion of dairy herds, while average herd size increased. In general, the trends indicate a stable situation of very low BTB prevalence in Scotland and, over most of the period, a rising prevalence in England and Wales. The prevalence in the Republic of Ireland declined while Northern Ireland experienced both a rise and fall. Differences in demography, BTB programme structure and test results were noted, particularly between the island of Ireland and Great Britain. Further investigation of these differences may provide valuable insights into risk factors for BTB and optimisation of existing BTB programmes.

*Reproduced from Veterinary Record, Abernethy, D.A., Upton, P., Higgins, I.M., McGrath, G., Goodchild, A.V., Rolfe, S.J., Broughan, J.M., Downs, S.H., Clifton-Hadley, R., Menzies, F.D., de la Rua-Domenech, R., Blissitt, M.J., Duignan, A., More, S.J., 172, 312, Copyright 2013, with permission from BMJ Publishing Group Ltd.*

## Bovine tuberculosis trends in the UK and the Republic of Ireland, 2011-2013

**Abernethy, D.A.<sup>1</sup> et al.**

<sup>1</sup> University of Pretoria, Pretoria, South Africa

A paper was recently published, presenting bovine tuberculosis trends in the UK and the Republic of Ireland during 1995 to 2010. The work provided an opportunity for rigorous assessment of intercountry comparison, using common measures of progress. This work is being extended to include 2011 to 2013, and to consider some aspects of surveillance and control in greater detail.

## A framework to quantify the risk of importing animals infected with bTB into Scotland

**Bessell, P.R.<sup>1</sup> et al.**

<sup>1</sup> The Roslin Institute, Edinburgh, Scotland

A proportion of the bTB cases reported in Scotland, an officially bTB-free region, can be traced back to imports of animals from areas of higher bTB incidence. These areas include the Republic of Ireland, Northern Ireland, Wales and south western areas of England. This study presents a framework to quantify the risk of importing animals infected with bTB from these areas into Scotland.

## A retrospective study to examine temporal trends in bovine tuberculosis over a 20 year period in Ireland

**Gallagher, M.<sup>1</sup> et al.**

<sup>1</sup> UCD CVERA

The objective of the study is to investigate seasonal variation and temporal trends in herd disclosure of bovine tuberculosis in Ireland by test type, controlling for known risk factors. The reference population is all bovine herds subjected to bTB surveillance during the period from 1 January 1993 to 31 December 2012, and the outcome measure is the test-specific monthly bTB herd restriction rate.

## A retrospective qualitative and quantitative study to investigate changing characteristics of bovine tuberculosis episodes over a 20 year period in Ireland

**Gallagher, M.<sup>1</sup> et al.**

<sup>1</sup> UCD CVERA

The objective of the study is to describe bTB episodes over time in terms of severity, duration and recurrence of infection. The reference population is all bovine herds in Ireland subjected to bTB surveillance during the period from 1 January 1993 to 31 December 2012. The outcome measures include the number and percentage of episodes over time, triggered by field and abattoir surveillance, allowing annual comparisons in terms of episode duration, severity and recurrence.

## Visualisation of the reduction in bovine tuberculosis in the Republic of Ireland

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

The current methodologies used to visualise the prevalence of bovine tuberculosis (bTB) in Ireland include thematic mapping (positive animal tests per thousand tests per district electoral division) and density maps (kernel densities of positive animals/population). This project will investigate possible new ways of displaying the changes in bTB prevalence over time to provide a better visualisation of the recent decrease in reactor numbers. A methodology is required that is more sensitive to representing proportionally small changes. The proposed method will involve assigning herd level data to a uniform hexagonal grid. A measure of mean prevalence will be calculated for a defined period of time. Each year will then be displayed as a deviation above or below this mean level thus showing the relative temporal trend in prevalence for each unit through time.

### Singleton area risk: Can areas of temporo-spatial clustering in singleton reactors be defined?

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

There is evidence that non-specific infection or singleton reactors occur as a result of environmental conditions found on farms close to bog, reclaimed wetland and lakes. If this is the case, they should cluster in space and time. We would expect there to be a spatial consistency which should be discernible. The objective of this study is to attempt to identify if this spatial/temporal clustering of singleton reactors exists. If there is a discernible effect, areas of persistent high singleton risk could be defined and assigned back to all herds falling within these areas providing veterinary inspectors with an additional layer of information to aid in deciding how to interpret and manage herds with singleton reactors.

### Evaluation of single reactor bovine tuberculosis breakdowns based on analysis of reactors slaughtered at an Irish export meat plant

Murray, D.<sup>1</sup>, Clegg, T.A.<sup>2</sup>, More, S.J.<sup>2,3</sup>

<sup>1</sup> DAFM, <sup>2</sup> UCD CVERA, <sup>3</sup> UCD School of Veterinary Medicine

#### **Veterinary Record 170, 516 (2012)**

The 'Singleton Protocol' was adopted by the Irish Department of Agriculture, Food and the Marine (DAFM) in 1996 to address the incomplete specificity of the single intra-dermal comparative tuberculin test (SICTT) used in Ireland for the detection of animals infected with bovine tuberculosis (bTB). The protocol allows the early restoration of disease-free status to herds with a single reactor breakdown, where the herd was not confirmed as infected with *Mycobacterium bovis* by epidemiological investigation, by postmortem examination or by further test. The current study examines the ability of the Singleton Protocol to identify false-positive reactors. It investigates the subsequent herd-reactor rate following single reactor removal and analyses the factors leading to a positive postmortem lesion outcome and a positive reactor retest result. Postmortem lesion results were obtained for 371 reactor animals from single reactor breakdowns that were killed at an export meat plant over a 19-month period. Epidemiological and test data for these animals and their herds were obtained from DAFF databases and analysed by univariate and multivariate statistical analysis. Singleton candidates had an 18.7 per cent lower lesion rate than single animal breakdowns not meeting the singleton criteria. No significant

difference was found between Singletons and non-singletons in the subsequent reactor retest results. Skin thickness at the SICTT is the most significant determinant of a positive lesion result. The area bTB history was shown to be a significant variable in producing a positive reactor retest result.

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## The impact of an integrated wildlife and bovine tuberculosis eradication programme in Ireland

Sheridan, M.<sup>1</sup> et al.

<sup>1</sup> DAFM

Significant improvement in bovine tuberculosis (TB) levels has been achieved in Ireland over the past ten years. This is attributed to a coordinated programme of control and eradication in both the cattle herd and also in the wildlife reservoir, the badger. A comprehensive research and development programme underpins the national eradication programme and it is hoped that a new drive towards final eradication will commence in the next few years once the novel badger vaccination strategy has been proved and refined. A detailed review of the national TB eradication programme is presented in this book chapter.



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## Quality control

The relative effectiveness of, and reporting accuracy among, testers during field surveillance for bovine tuberculosis in Ireland

Clegg, T.A.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Testing of bovine tuberculosis using the single intradermal comparative tuberculin test (SICTT), is reliant on the skills and experience of the tester. This study applies mixed logistic regression to assess the relative effectiveness of testers. These methods have been used to assess the efficiency of factory surveillance for bTB, however, to the authors' knowledge, they have not been applied to assess the relative performance of testers before.

### Quality control in the national bovine tuberculosis eradication programme in Ireland

Duignan, A.<sup>1</sup>, Good, M.<sup>1</sup>, More, S.J.<sup>2,3</sup>

<sup>1</sup> DAFM, <sup>2</sup> UCD School of Veterinary Medicine, <sup>3</sup> UCD CVERA

**Revue Scientifique et Technique / Office International des Épizooties  
(OIE Scientific and Technical Review) 31, 845-860 (2012)**

The Irish bovine tuberculosis (BTB) eradication programme operates under national legislation and fulfils the requirements of the European Union Trade Directive 64/432. The programme includes annual single intradermal comparative tuberculin test (SICTT) screening of all herds, prompt removal of test reactors and further consequential retesting of herds. Continuous evaluation of all relevant activities is essential to deliver an effective national programme and to reassure all stakeholders that the highest possible standards are attained. Quality control (QC) is a recognised process in the delivery of quality products or services. This paper presents a review of QC in the BTB eradication programme in Ireland, with particular emphasis on field surveillance and the assessment of private veterinary practitioner performance. A broad range of programme elements subjected to QC are described, including personnel, training, equipment, tuberculins and laboratories.

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## Challenges to quality testing for bovine tuberculosis in Ireland: perspectives from major stakeholders

Meskill, P.<sup>1</sup>, Devitt, C.<sup>2</sup>, More, S.J.<sup>3,4</sup>

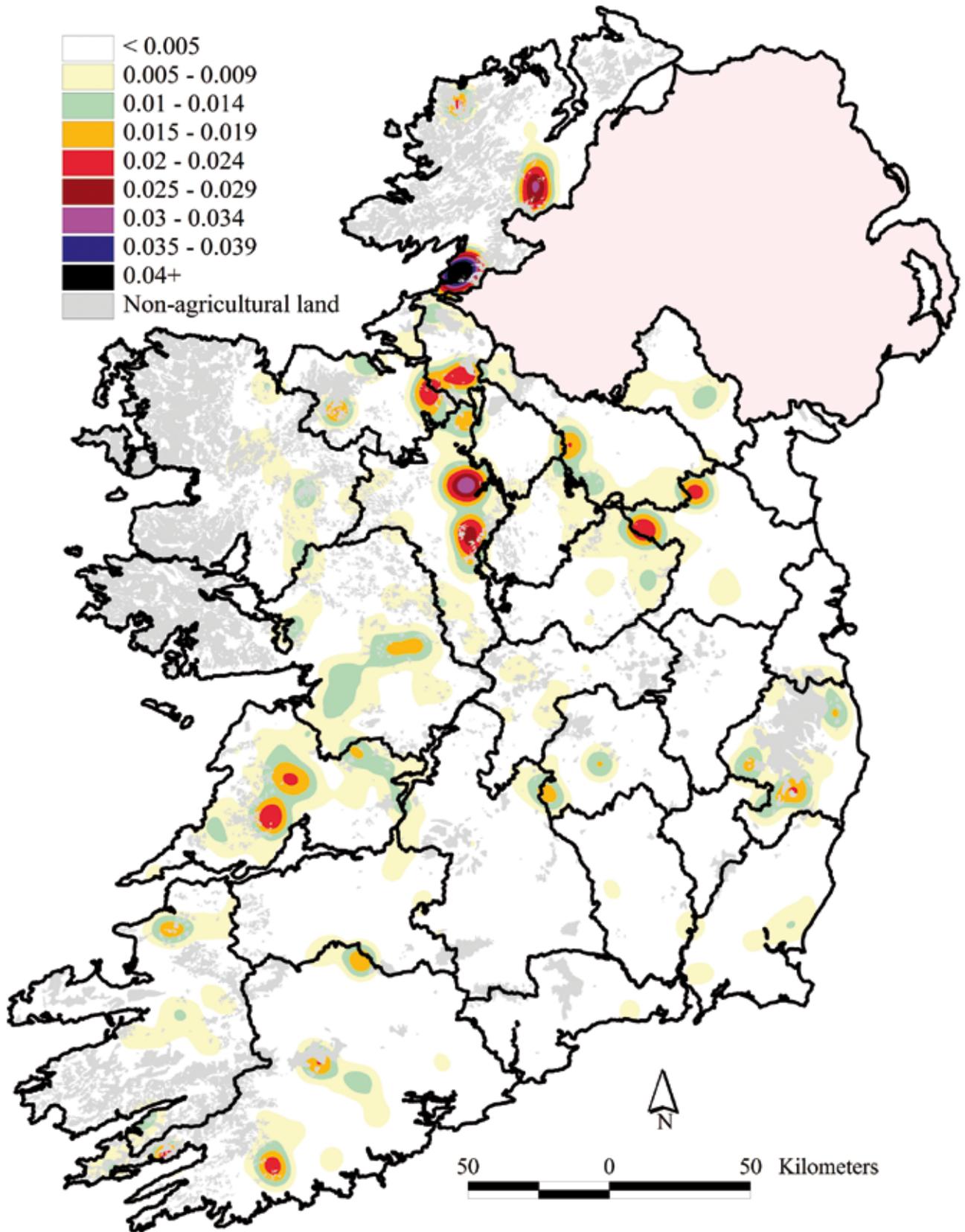
<sup>1</sup> DAFM, <sup>2</sup> Glendalough, Co. Wicklow, <sup>3</sup> UCD CVERA, <sup>4</sup> UCD School of Veterinary Medicine

### **Veterinary Record 173, 94 (2013)**

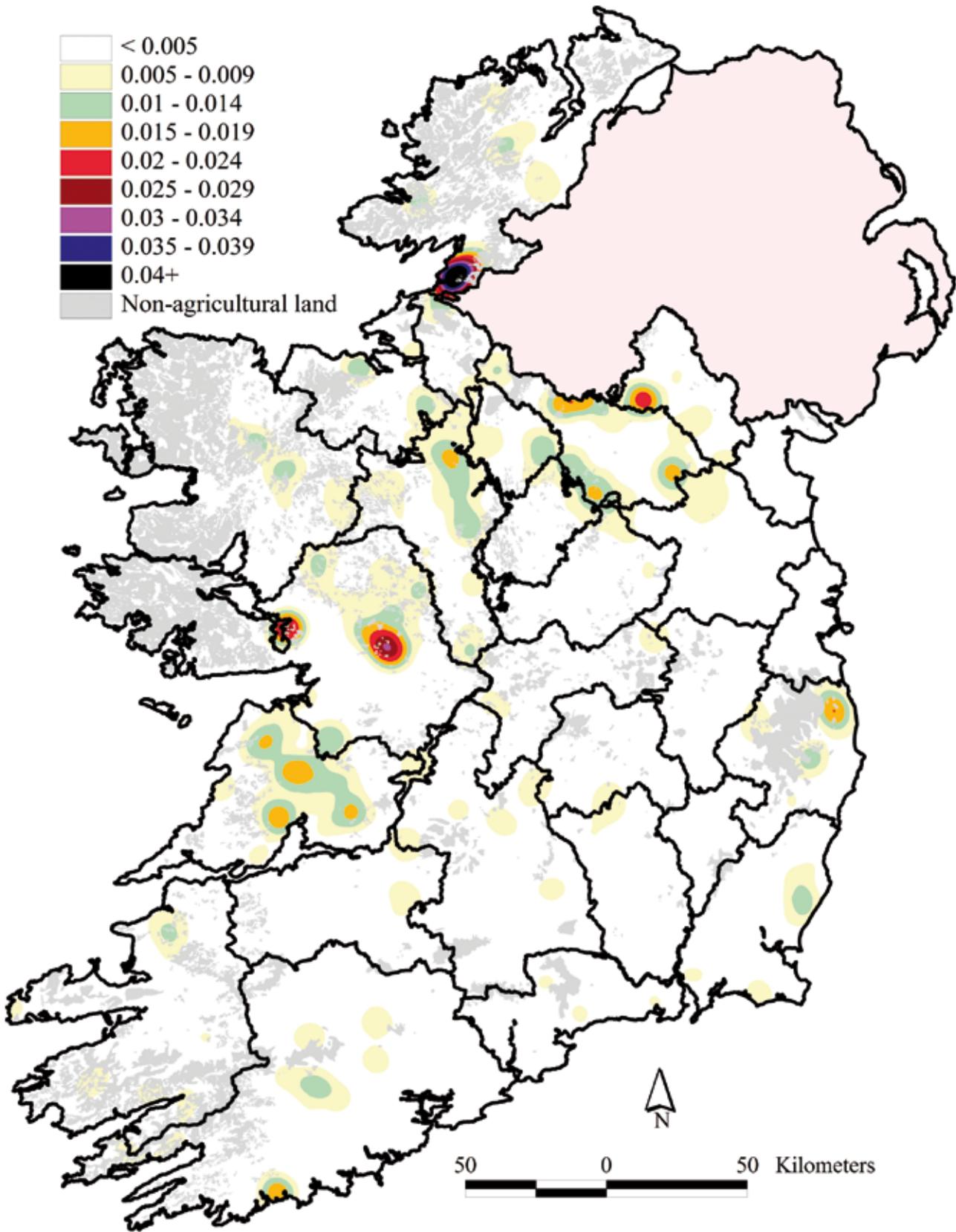
Within the national bovine tuberculosis (bTB) eradication programme in Ireland, concern has been expressed about the quality of testing by veterinarians. However, there is little published evidence supporting this concern, or the challenges that undermine quality testing. Qualitative research methods were used to gather the perspectives of major stakeholders in the bTB eradication (BTE) scheme on the challenges to quality testing for bovine tuberculosis in Ireland. These stakeholders included private veterinarians, government veterinarians, senior managers and herd owners, on the quality of bTB testing and the barriers to improvement. Results are grouped into challenges that exist in the testing environment (i.e. at a farm level), and challenges associated with the skills environment (i.e. professional skills involved with conducting the test). Challenges in the testing environment include inadequate on-farm testing conditions; lack of clarity on responsibility to ensure adequate testing environment; and the influence of the veterinarian-client relationship. Challenges in the skills environment include deficiencies in the development and supervision of testing skills among trainees and newly qualified veterinarians; and deficiencies in testing standards at a practice level. Regular supervision of testing is necessary to ensure standards. The importance of a continued understanding of the disease (and its eradication) supported by a partnership, cooperative approach between all stakeholders, is emphasised.

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## Density of TB incidence

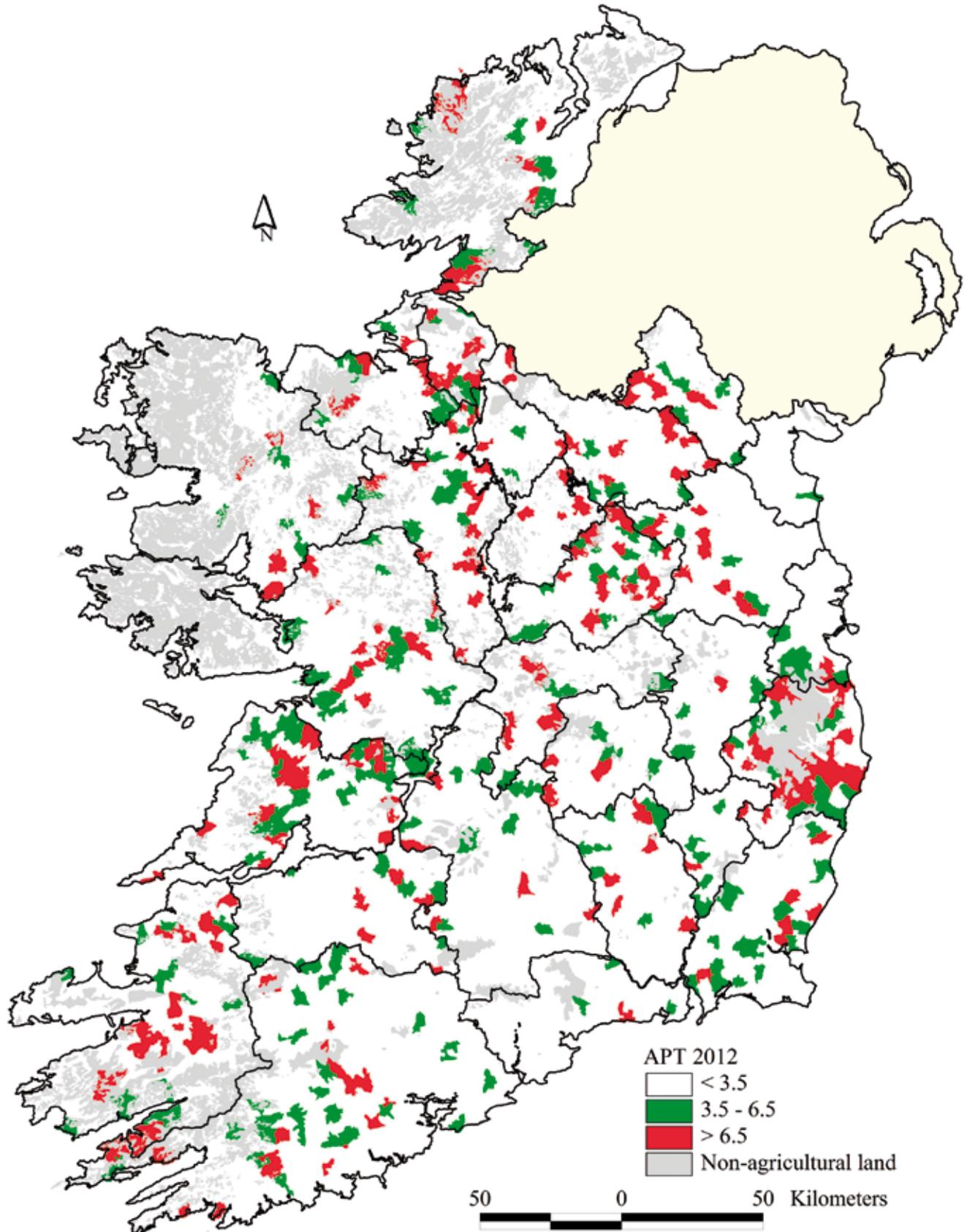


*Density of TB incidence per square km during 2012 (kernel density with search radius at 10km)*

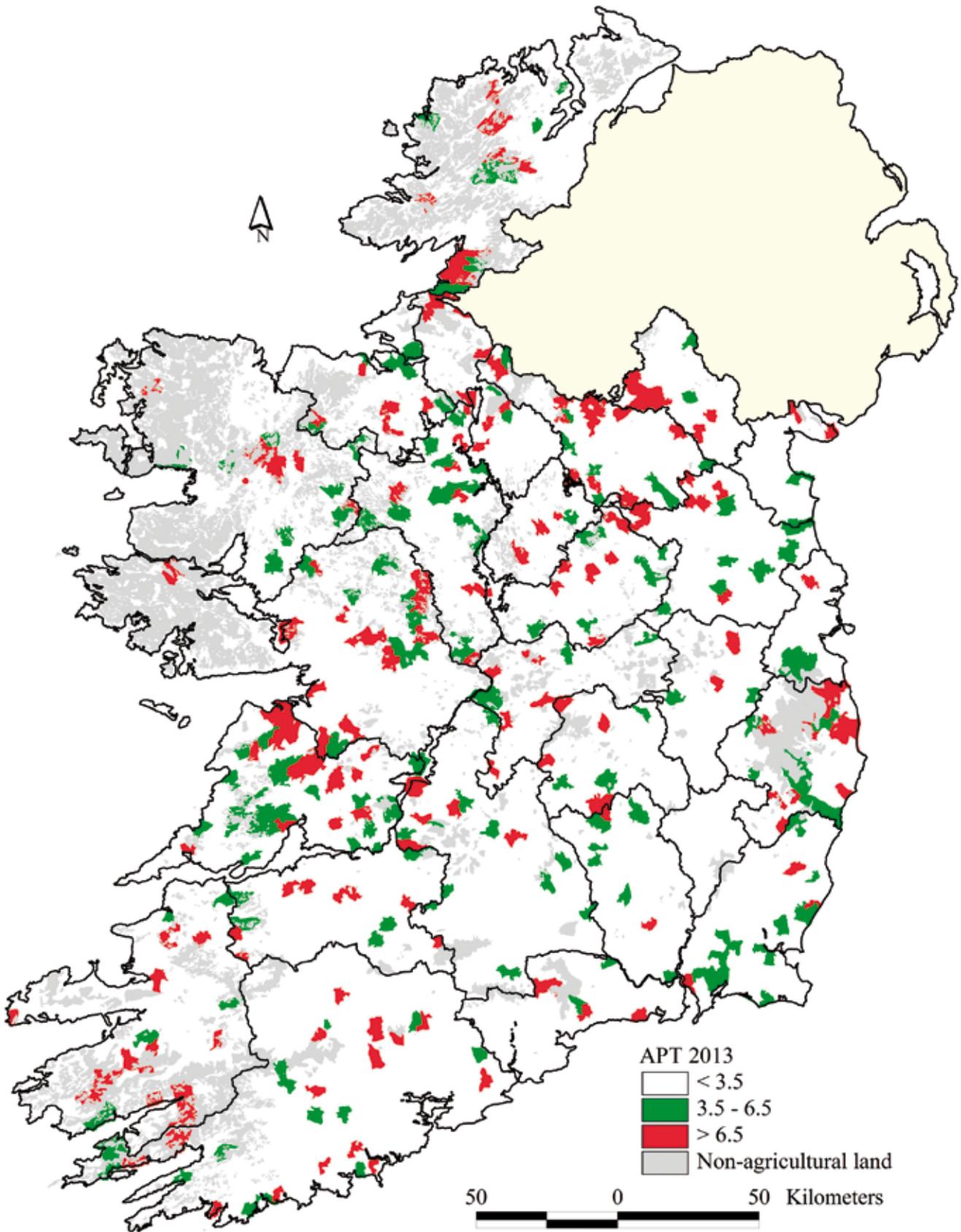


Density of TB incidence per square km during 2013 (kernel density with search radius at 10km)

## APT per DED



*APT (reactors per 1000 tests) per district electoral division, 2012*



*APT (reactors per 1000 tests) per district electoral division, 2013*





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## Non-regulatory cattle health issues

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## Biosecure diseases

### *Biosecurity*

#### Design of a model for prediction of the probability of introduction of infectious agents into animal populations

Geraghty, T.<sup>1</sup> et al.

<sup>1</sup> School of Veterinary Medicine, University of Glasgow, Glasgow, Scotland

The consequences of disease introduction into animal populations are increasingly understood. Quantitative risk assessment models for disease introduction have been described for national import risk analysis but their use at individual farm level is limited. We describe the design of a quantitative deterministic model to estimate the probability of introduction of infectious disease into susceptible individual farm populations.

#### Bioexclusion of diseases from dairy and beef farms: Risks of introducing infectious agents and risk reduction strategies

Mee, J.F.<sup>1</sup>, Geraghty, T.<sup>2</sup>, O'Neill, R.<sup>3</sup>, More, S.J.<sup>4,5</sup>

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#### **The Veterinary Journal 194, 143-150 (2012)**

Infectious disease represents a major threat to the productivity and welfare of cattle herds throughout the world. The introduction of infectious agents into dairy and beef farms may be through direct transmission (purchased cattle, reintroduced resident cattle and contact with contiguous cattle) or indirect transmission (fomites, visitors, other species, and biological materials) and this article reviews the evidence supporting these transmission routes. In the absence of eradication programmes for many endemic infectious diseases, bioexclusion is the key management process for risk reduction. Various ameliorative bioexclusion strategies have been recommended and the evidence supporting these protocols is considered.

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## Johne's disease

### Control of Johne's disease: an international review

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National bovine Johne's disease (JD) control programmes exist in several countries including Australia, Canada, Denmark, the Netherlands, the United Kingdom and the United States of America. Programme design varies with industry specific variables, the goals of the programme and the nature of the implementing body. Important differences also arise from the necessary subjective interpretation of incomplete scientific literature in areas including test reliability and epidemiology. Organisations developing new JD control programmes can benefit from the combined experiences of existing national control programmes. This article reviews the structure (laboratory and non-laboratory herd screening, herd classification, intervention guidelines, ability to respond to new scientific developments), implementation and limitations of existing JD control programmes to inform the development of a voluntary national programme in Ireland.

### Pan-genomic analysis of bovine monocyte-derived macrophage gene expression in response to *in vitro* infection with *Mycobacterium avium* subspecies *paratuberculosis*

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**Veterinary Research 43, 25 (2012)**

*Mycobacterium avium* subspecies *paratuberculosis* is the causative agent of Johne's disease, an intestinal disease of ruminants with major economic consequences. Infectious bacilli are phagocytosed by host macrophages upon exposure where they persist, resulting in lengthy subclinical phases of infection that can lead to immunopathology and disease dissemination. Consequently, analysis of the macrophage transcriptome in response to *M. avium* subsp. *paratuberculosis* infection can provide valuable insights into the molecular mechanisms that underlie Johne's disease. Here, we investigate pan-genomic gene expression in bovine monocyte-derived macrophages (MDM) purified from seven age-matched females, in response to *in vitro* infection with *M. avium* subsp. *paratuberculosis* (multiplicity of infection 2:1) at intervals of 2 hours, 6 hours and 24 hours post-infection (hpi). Differentially expressed genes were identified by comparing the transcriptomes of the infected MDM to the non-infected control MDM at each time point (adjusted *P*-value threshold  $\leq 0.10$ ). 1050 differentially expressed unique genes were identified 2 hpi, with 974 and 78 differentially expressed unique genes detected 6 and 24 hpi, respectively. Furthermore, in the infected MDM the number of upregulated genes exceeded the number of downregulated genes at each time point, with the fold-change in expression for the upregulated genes markedly higher than that for the downregulated genes. Inspection and systems biology analysis of the differentially expressed genes revealed an enrichment of genes involved in the inflammatory response, cell signalling pathways and apoptosis. The transcriptional changes associated with cellular signalling and the inflammatory response may reflect different immuno-modulatory mechanisms that underlie host-pathogen interactions during infection.

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## The effect of alternative testing strategies and bio-exclusion practices on Johne's disease risk in test-negative herds

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**Journal of Dairy Science 96, 1581-1590 (2013)**

Herd classification is a key component of national Johne's disease (JD) control programs. Herds are categorized on the basis of test results, and separate sub-programs are followed for test-positive and test-negative herds. However, a test-negative herd result does not necessarily equate to JD freedom for reasons relating to disease pathogenesis and available diagnostic tests. Thus, in several countries, JD control programs define test-negative herds as having a "low risk" of infection below a specified prevalence. However, the approach is qualitative, and little quantitative work is available on herd-level estimates of probability of freedom in test-negative herds. This paper examines the effect over time of alternative testing strategies and bio-exclusion practices on JD risk in test-negative herds. A simulation model was developed in the programming language R. Key model inputs included sensitivity and specificity estimates for 3 individual animal diagnostic tests (serum ELISA, milk ELISA, and fecal culture), design prevalence, testing options, and testing costs. Key model outputs included the probability that infection will be detected if present at the design prevalence or greater (herd sensitivity; *SeH*), the probability that infection in the herd is either absent or at very low prevalence (i.e., less than the design prevalence; *ProbF*), the probability of an uninfected herd producing a false-positive result [ $P(\text{False+})$ ], and mean testing cost (*HerdCost*) for different testing strategies. The output *ProbF* can be updated periodically, incorporating data from additional herd testing and information on cattle purchases, and could form the basis for an output-based approach to herd classification. A high *ProbF* is very difficult to achieve, reflecting the low sensitivity of the evaluated tests. Moreover, *ProbF* is greatly affected by any risk of introduction of infection, decreasing in herds with poor bio-exclusion practices despite ongoing negative test results. The value of  $P(\text{False+})$  was substantial when tests with imperfect specificity were used. Testing strategies can substantially influence testing costs but with little effect on test performance. This study illustrates an output-based approach to herd classification, with potential for national and field applications.

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## Evaluation of testing strategies to identify infected animals at a single round of testing within dairy herds known to be infected with *Mycobacterium avium* subspecies *paratuberculosis*

More, S.J.<sup>1,2</sup> et al.

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In herds known to be infected with *Mycobacterium avium* subsp. *paratuberculosis* (*Map*), testing strategies are used to identify individual animals for action, usually culling. However, due to the nature of currently available tests, this testing is unable to identify all infected animals at an early stage of infection, thereby risking ongoing within-herd transmission. As yet, there is limited understanding of the quality of different testing strategies to identify *Map* infected cattle in known infected herds. This study seeks to evaluate the effectiveness, cost and cost-effectiveness of different testing strategies to identify infected animals at a single round of testing within dairy herds known to be *Map* infected. Effectiveness is measured in terms of detection fraction (the proportion of cases detected), cost is based on both testing costs and costs associated with positive test results (assumed to be culling of animals), and cost-effectiveness as the cost per true positive detected.

## A national Johne's Disease serum survey and its use to evaluate targeted sub-sampling in Ireland

Mullowney, P.<sup>1</sup> et al.

<sup>1</sup> DAFM

Johne's Disease occurred sporadically in Ireland prior to 1992 when the advent of the Single European Market facilitated the free movement of animals within the EU. Subsequently, an increase in the prevalence of *Mycobacterium avium* subspecies *paratuberculosis* (*Map*) infection has been demonstrated. The primary objective of this study was to estimate the herd- and within-herd prevalence of *Map* infection in Irish cattle during 2009. In addition, we evaluated the effectiveness of targeted sub-sampling to detect *Map*-infected herds at a single screening, noting that this method has been suggested as a cost-effective alternative to testing of all adults.

## Bovine viral diarrhoea (BVD)

### Bovine viral diarrhoea virus seroprevalence and vaccination usage in dairy and beef herds in the Republic of Ireland

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**Irish Veterinary Journal 65, 16 (2012)**

Bovine viral diarrhoea (BVD) is an infectious disease of cattle with a worldwide distribution. Herd-level prevalence varies among European Union (EU) member states, and prevalence information facilitates decision-making and monitoring of progress in control and eradication programmes. The primary objective of the present study was to address significant knowledge gaps regarding herd BVD seroprevalence (based on pooled sera) and control on Irish farms, including vaccine usage. Preliminary validation of an indirect BVD antibody ELISA test (Svanova, Biotech AB, Uppsala, Sweden) using pooled sera was a novel and important aspect of the present study. Serum pools were constructed from serum samples of known seropositivity and pools were analysed using the same test in laboratory replicates. The output from this

indirect ELISA was expressed as a percentage positivity (PP) value. Results were used to guide selection of a proposed cut-off (PCO) PP. This indirect ELISA was applied to randomly constructed within-herd serum pools, in a cross-sectional study of a stratified random sample of 1,171 Irish dairy and beef cow herds in 2009, for which vaccination status was determined by telephone survey. The herd-level prevalence of BVD in Ireland (percentage positive herds) was estimated in non-vaccinating herds, where herds were classified positive when herd pool result exceeded PCO PP. Vaccinated herds were excluded because of the potential impact of vaccination on herd classification status. Comparison of herd-level classification was conducted in a subset of 111 non-vaccinating dairy herds using the same ELISA on bulk milk tank (BMT) samples. Associations between possible risk factors (herd size (quartiles)) and herd-level prevalence were determined using chi-squared analysis. Receiver Operating Characteristics Analysis of replicate results in the preliminary validation study yielded an optimal cut-off PP (Proposed Cut-off percentage positivity - PCO PP) of 7.58%. This PCO PP gave a relative sensitivity (Se) and specificity (Sp) of 98.57% and 100% respectively, relative to the use of the ELISA on individual sera, and was chosen as the optimal cut-off since it resulted in maximization of the prevalence independent Youden's Index. The herd-level BVD prevalence in non-vaccinating herds was 98.7% (95% CI - 98.3-99.5%) in the cross-sectional study with no significant difference between dairy and beef herds (98.3% vs 98.8%, respectively,  $p = 0.595$ ). An agreement of 95.4% was found on Kappa analysis of herd serological classification when bulk milk and serum pool results were compared in non-vaccinating herds. 19.2 percent of farmers used BVDV vaccine; 81% of vaccinated herds were dairy. A significant association was found between seroprevalence (quartiles) and herd size (quartiles) ( $p < 0.01$ ), though no association was found between herd size (quartiles) and herd-level classification based on PCO ( $p = 0.548$ ). The results from this study indicate that the true herd-level seroprevalence to Bovine Virus Diarrhoea (BVD) virus in Ireland is approaching 100%. The results of the present study will assist with national policy development, particularly with respect to the national BVD eradication programme which commenced recently.

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## Aspects of bovine herpesvirus 1 and bovine viral diarrhoea virus herd-level seroprevalence and vaccination in dairy and beef herds in Northern Ireland

Cowley, D.J.B.<sup>1</sup> et al.

<sup>1</sup> MSD Animal Health

Infections with bovine herpesvirus 1 and bovine-viral diarrhoea (BVD) virus cause diseases of cattle with a worldwide distribution. The primary objective of the present study was to describe aspects of herd-level BoHV-1 and BVDV seroprevalence (based on testing of pooled sera) and control on farms in Northern Ireland, including vaccine usage.

## Herd-level factors associated with the presence of bovine viral diarrhoea virus in herds participating in the voluntary phase of the Irish national eradication programme

Graham, D.A.<sup>1</sup>, Clegg, T.A.<sup>2</sup>, Lynch, M.<sup>3</sup>, More, S.J.<sup>2,4</sup>

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### Preventive Veterinary Medicine 112, 99-108 (2013)

A risk factor study was conducted to identify variables associated with initial positive or inconclusive results for bovine viral diarrhoea virus (BVDV) in ear punch samples collected from calves between 1st January and 15th July 2012 (the study period) as part of the voluntary phase of the Irish national BVD eradication programme based on testing of ear tag tissue samples from calves born in participating herds. Univariable analysis indicated significant associations with the following factors: herd type; the number of cows in the herd; the number of calves born in the study period; the number of calves tested in the study period; the number of cattle purchased in 2011, between 2009 and 2011 and between 2007 and 2011; the number of tested calves whose dams had been purchased within 9 months of their calving date; and the percentage of calf mortality within 28 days of birth. The percentage of the cows in each herd that was homebred, location (province), the number of separate land parcels used by each herd, the presence of an associated sheep enterprise and the purchase of cattle through marts were not found to be significant. An initial logistic regression model was developed to model the probability of a herd having one or more BVD virus-positive or inconclusive calves. When vaccination status was initially excluded, province, log of the numbers of cows in the herd, the number of cows purchased between 2009 and 2011, the number of tested calves whose dams had been purchased within 9 months of their calving date and calf mortality were significant. When vaccination status was included, using a subset of the data based on farmers responding to a survey on vaccination status, it was retained as a significant variable along with the same variables already listed, showing a significant 2-way interaction with the log of the number of cows. There was not a significant association between an initial positive or inconclusive result and the length of time for which herds had been vaccinating. The study provides a series of key communication messages relating to both the delivery of, and benefits from, the national eradication programme.

*Reprinted from Preventive Veterinary Medicine, 112, Graham, D.A., Clegg, T.A., Lynch, M., More, S.J., Herd-level factors associated with the presence of bovine viral diarrhoea virus in herds participating in the voluntary phase of the Irish national eradication programme, 99-108, Copyright 2013, with permission from Elsevier B.V.*

## A study into the retention of BVD virus positive calves

Graham D.<sup>1</sup> et al.

<sup>1</sup> Animal Health Ireland

The purpose of the current study is two-fold. Firstly, to examine whether there were any significant differences in survival/mortality between calves persistently infected (PI) with bovine viral diarrhoea (BVD) virus (cases) and their virus negative comrades in the same herd (control). Secondly, to examine the relationship between the duration of retention of PI calves in 2012 and the number of PI animals identified in the same herd during calf testing in the following year (2013).

## Predicted costs and benefits of eradicating BVDV from Ireland

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**Irish Veterinary Journal 65, 12 (2012)**

Bovine viral diarrhoea virus (BVDV) causes an economically important endemic disease (BVD) of cattle in Ireland and worldwide. Systematic eradication by detection and removal of infectious (BVDV carrier) cattle has been successful in several regions. We therefore assessed the benefits (disease losses avoided) and costs (testing and culling regime) of a potential eradication programme in Ireland. Published bio-economic models of BVDV spread in beef suckler herds and dairy herds were adapted to estimate potential benefits of eradication in Ireland. A simple model of BVDV spread in beef finisher herds was devised to estimate the benefits of eradication in this sector. A six year eradication programme consisting of 5 inter-related virological and serological testing programmes is outlined and costed. We found that the annualised benefits of BVDV eradication in Ireland exceeded the costs by a factor of 5 in the beef suckler sector and a factor of 14 in the dairy sector. Corresponding payback periods were 1.2 and 0.5 years respectively. These results highlight the significant economic impact of BVDV on the Irish cattle industry and suggest a clear economic benefit to eradication using the proposed approach. This type of cost-benefit analysis is considered an essential prerequisite prior to undertaking an eradication campaign of this magnitude.

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## Infectious bovine rhinotracheitis (IBR)

### Dynamics of individual animal Bovine Herpes Virus-1 antibody status on 9 commercial dairy herds

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**Research in Veterinary Science 93, 143-149 (2012)**

Bovine Herpes Virus 1 (BoHV-1) is an important viral disease of cattle worldwide. In endemically infected herds, there is an incomplete understanding of the epidemiology of BoHV-1 infection. We describe the dynamics of animal-level BoHV-1 antibody status on 9 endemically infected commercial dairy herds, based on the results of serial milk antibody testing. Results were used to identify primary exposure, secondary exposure (from re-activation or re-exposure) and development of test-negative latent carrier (TNLC) status. 4153 test results from 828 cow-lactations were analysed. Primary exposure occurred on two herds, secondary exposure occurred on all herds and development of TNLC status occurred in eight herds. Incidence of secondary exposure reduced over time and may have been related to increasing time since parturition. Regular secondary exposure is required to maintain measurable antibody status.

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## Leptospirosis

### Herd-level risk factors associated with *Leptospira* Hardjo seroprevalence in beef/suckler herds in the Republic of Ireland

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**Irish Veterinary Journal 65, 6 (2012)**

The aim of the present study was to investigate risk factors for herd seropositivity to *Leptospira* Hardjo in Irish suckler herds. Herds were considered eligible for the study if they were unvaccinated and contained  $\geq 9$  breeding animals of beef breed which were  $\geq 12$  months of age. The country was divided into six regions using county boundaries. Herd and individual animal prevalence data were available from the results of a concurrent seroprevalence study. Herds were classified as either "Free from Infection" or "Infected" based on a minimum expected 40% within-herd prevalence. Questionnaires were posted to 320 farmers chosen randomly from 6 regions, encompassing 25 counties, of the Republic of Ireland. The questionnaire was designed to obtain information about vaccination; reproductive disease; breeding herd details; the presence of recognized risk factors from previous studies; and husbandry on each farm. Data collected from 128 eligible herds were subjected to statistical analysis. Following the use of Pearson's Chi-Square Test, those variables associated with a herd being "infected" with a significance level of  $P < 0.2$  were considered as candidates for multivariable logistic regression modelling. Breeding herd size was found to be a statistically significant risk factor after multivariable logistic regression. The odds of a herd being positive for leptospiral infection were 5.47 times higher ( $P = 0.032$ ) in herds with 14 to 23 breeding animals compared with herds with  $\leq 13$  breeding animals, adjusting for Region, and 7.08 times higher ( $P = 0.033$ ) in herds with 32.6 to 142 breeding animals. Breeding herd size was identified as a significant risk factor for leptospiral infection in Irish suckler herds, which was similar to findings of previous studies of leptospirosis in dairy herds.

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## Seroprevalence of *Leptospira* Hardjo in the Irish suckler cattle population

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**Irish Veterinary Journal 65, 8 (2012)**

Prior to the present study, the seroprevalence of leptospirosis in Irish suckler herds was unknown. In this study, we describe the herd and animal-level prevalence of *Leptospira* Hardjo infection in the Irish suckler cattle population. For the purposes of the study, the 26 counties of the Republic of Ireland were divided into 6 regions from which a representative number of herds were selected. A herd was considered eligible for sampling if it was not vaccinating against leptospirosis and if it contained  $\geq 9$  breeding animals of beef breed  $\geq 12$  months of age. In total, 288 randomly selected herds were eligible for inclusion in the seroprevalence dataset analysis. Serological testing was carried out using a commercially available monoclonal antibody-capture ELISA, (sensitivity 100%; specificity 86.67%). Herds were categorised as either "Free from Infection" or "Infected" using the epidemiological software tool, *FreeCalc* 2.0. Using this classification, 237 herds were "Infected" (82.29%). The South West and South East regions had the highest herd prevalence. The regional effect on herd prevalence was largely mirrored by breeding herd size. A true animal-level prevalence of 41.75% was calculated using the epidemiological software tool, *TruePrev*. There was a statistically significant regional trend, with true prevalence being highest in the South East ( $P < 0.05$ ). The median Breeding Herd Size (BHS), when categorised into quartiles, had a statistically significant influence on individual animal true seroprevalence ( $P < 0.001$ ); true seroprevalence increased with increasing BHS. Leptospirosis is a widespread endemic disease in the Republic of Ireland. It is possible that economic losses due to leptospirosis in unvaccinated Irish suckler herds may be underestimated.

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## Non-biosecure diseases and conditions

### Milk quality

#### Investigating a dilution effect between somatic cell count and milk yield and estimating milk production losses in Irish dairy cattle

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**Journal of Dairy Science 96, 1477-1484 (2013)**

Increased somatic cell counts (SCC) are associated with reduced milk yield. Additionally, it has been hypothesized that as milk yield increases, SCC is diluted in cattle without an intramammary infection (IMI). If the hypothesis is correct, estimates of SCC from high-yielding cattle without an IMI are likely to be lower than those from low-yielding cattle without an IMI. The objectives of this paper were to investigate the presence of a potential dilution effect between SCC and milk yield, overall and by parity, and to estimate lactation milk production losses with increasing SCC in Irish dairy cattle. The data consisted of 100 randomly selected herds from all milk recording herds between 2008 and 2010. The data set comprised 8,229 cows, of which approximately 90% were Holstein or Holstein crossbred animals. Various adjustments were used to investigate the presence of a potential dilution effect between SCC and milk yield; additionally, lactation milk production losses with increasing SCC and parity were estimated. The data had an inherent hierarchical structure, with lactations nested within cows and cows within herds; thus, a linear mixed model with 2 random effects was used. We found no evidence of a dilution effect of SCC with increasing milk yield in Irish dairy cattle. Average milk production losses were estimated, and they increased with increasing SCC compared with the referent of  $\leq 50,000$  cells/mL. Additionally, for all SCC values for parities 1 to 3, this production loss increased significantly with increasing parity. Estimated milk losses for parities 4 and 5 did not differ, and differences between parities 3 and 4 were significant only for SCC values  $< 300,000$  cells/mL. The estimated milk loss with increasing SCC varies greatly across studies, with the results from the current study exceeding most previously published results (except for results from the UK). Several factors could explain these differences, including geographic factors such as milk yield and predominant mastitis pathogens. The dilution effect warrants further work, as does the effect of prior duration of increased SCC on milk yield and the potential for compensation of milk yield losses over a lactation.

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#### Opportunities and constraints to improving milk quality in Ireland: enabling change through collective action

Devitt, C.<sup>1</sup>, McKenzie, K.<sup>2</sup>, More, S.J.<sup>3,4</sup>, Heanue, K.<sup>5</sup>, McCoy, F.<sup>6</sup>

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**Journal of Dairy Science 96, 2661-2670 (2013)**

Ireland plays a key role in contributing to the global supply of dairy produce, and increasing international demand, as well as the abolition of milk quotas in the European Union in 2015, present opportunities for the Irish milk industry. Improving milk quality is required to maximize these opportunities. National action on milk quality is spearheaded by Animal Health Ireland, yet the potential for collective action at an industry level is undermined by the inability of

individual stakeholders to accept responsibility for action. In-depth qualitative interviews were conducted with n = 12 stakeholder representatives. The theoretical concepts of collective action (i.e., when a group of people with a shared interest undertake some kind of voluntary common action in pursuit of that shared interest) is applied to understanding the results and identifying a collective way forward. Though consensus is apparent on the need to improve milk quality, differences exist about individual responsibility and the best way to achieve higher quality standards. The propensity for collective action is undermined by shifting responsibility to other stakeholders, stakeholder positions, trust concerns, and concerns over the commitment of other stakeholders to cooperate. Understanding how collective action works provides Animal Health Ireland with a knowledge framework in which to build stakeholder consensus. The paper concludes with practical examples of how Animal Health Ireland continues to apply this understanding by bringing individual stakeholders together to achieve milk quality improvement.

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## Mapping milk production in Ireland

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

This project will present a national map of milk production based on data supplied by the Irish Cattle Breeding Federation for milk recording herds. A Geographical Information System will be employed to generate a triangular irregular network to create a surface that will be representative of the entire country based on a sample of approximately 6,000 herds.

## The effect of somatic cell count data adjustment and interpretation, as outlined in European Union legislation, on herd eligibility to supply raw milk for processing of dairy products

More, S.J.<sup>1,2</sup>, Clegg, T.A.<sup>1</sup>, Lynch, P.J.<sup>3</sup>, O'Grady, L.<sup>2</sup>

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**Journal of Dairy Science 96, 3671-3681 (2013)**

Somatic cell count (SCC) limits are a key component of national and international regulation for milk quality. As yet, very limited work has been published on SCC regulatory standards, including on the effect of different approaches to SCC data adjustment and interpretation. This study examines the effect of SCC data adjustment and interpretation, as outlined in current European Union (EU) legislation, on herd eligibility to supply raw milk for processing of dairy products for human consumption, using Irish data for illustration. The study used Irish milk-recording data as a proxy for bulk tank SCC (BTSCC) data, to calculate an unadjusted monthly SCC value for each herd during each month of participation. Subsequently, 4 data adjustments were applied, as outlined in EU and national legislation: seasonal adjustment; 3-mo rolling geometric average, without accounting for a break in the supply; 3-mo rolling geometric average, after accounting for a break in the supply; and seasonal adjustment and 3-mo rolling geometric average combined, after accounting for a break in the supply. Analyses were conducted to examine the effect, during the period from 2004 to 2010, of data adjustment on the percentage of herds with herd SCC >400,000 cells/mL. In all, 4 interpretation scenarios, incorporating different data adjustment combinations, were used to estimate herd eligibility (compliant, under warning, or suspended, as defined by legislation) to supply raw milk for processing. The 4 methods of data adjustment each led

to a sizable reduction (6.7, 5.0, 5.3, and 11.1 percentage points, respectively, compared with the unadjusted data) in the percentage of herds exceeding a herd SCC of 400,000 cells/mL. Herd eligibility varied by interpretation scenarios, in particular those incorporating seasonal adjustment. The study provides new perspectives on the effect of data adjustment on herd SCC and of interpretation scenarios on herd eligibility. The results provide an illustrative, rather than definitive, picture of this effect, as national authorities use BTSCC data when determining herd eligibility, whereas this study was conducted using milk-recording data as a proxy. Some aspects of the primary EU legislation are unclear, which may lead to differences in interpretation and application. The potential impact of data adjustment and milk purchaser pricing on farm-level mastitis control in Ireland is considered.

*Reprinted from Journal of Dairy Science, 96, More, S.J., Clegg, T.A., Lynch, P.J., O'Grady, L., The effect of somatic cell count data adjustment and interpretation, as outlined in European Union legislation, on herd eligibility to supply raw milk for processing of dairy products, 3671-3681, Copyright 2013, with permission from American Dairy Science Association.*

## Insights into udder health and intramammary antibiotic usage on Irish dairy farms during 2003-2010

More, S.J.<sup>1,2</sup>, Clegg, T.A.<sup>1</sup>, O'Grady, L.<sup>2</sup>

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Veterinary Medicine

**Irish Veterinary Journal 65, 7 (2012)**

By international standards, Ireland is a relatively small dairy producer. However, the industry plays a critical role to the national economy, accounting for approximately 3% of national gross domestic product. This paper presents insights into udder health and intramammary antibiotic usage on Irish dairy farms during 2003-2010, based on data from several sources. Three data sources were used, including data on milk recording data, intramammary antibiotic sales and animal health assessment. The milk recording data included a single unadjusted herd-level somatic cell count (SCC) value for each herd at each milk recording, being the arithmetic mean of cow-level SCC of each cow at that recording, weighted by cow-level yield. These data were used to calculate the percentage of herds each month where the unadjusted herd SCC exceeded 200,000 and 400,000 cells/mL. Two logistic generalised estimating-equations (GEE) models were developed, the outcome variable being either the probability that the monthly SCC of a herd was greater than 400,000 cells/mL or less than or equal to 200,000 cells/mL. Spring herds had a lower probability of a high SCC (> 400,000 cells/mL) during February to October compared to non-Spring herds but a higher probability between November to January. The odds of a high SCC were greater in 2005, 2006, 2009 and 2010 but less in 2007 and 2008 compared to 2004. Smaller herds had higher odds of having a high SCC compared to larger herds. We present the number of intramammary tubes and the quantity of active substance (kg) sold annually in Ireland during 2003-2010. We infer an incidence of clinical mastitis of 54.0 cases per 100 cow-years at risk, assuming 4 tubes per treatment regime, one affected quarter per cow, tubes restricted to clinical cases only and 100% of treated cases considered new cases, based on data collected on sales of in-lactation intra-mammary antibiotics. With differing assumptions, this estimate varied between 25.8 and 77.0 cases per 100 cow-years at risk. Using data on sales of dry cow therapy intra-mammary antibiotics, we also infer that most Irish dairy farmers use blanket dry cow therapy. It is important that Ireland has an objective understanding of current levels of udder health, to facilitate benchmarking and improvement into the future. Udder health is a concern on a number of Irish dairy farms. High SCC results were present throughout the year, but more marked towards the start and end of each milking season. Animal Health Ireland recently commenced a major national programme, *CellCheck*, in collaboration with a broad range of stakeholders, to support national SCC improvement. In this paper, relevant European and national legislation is also reviewed.

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## Is the rise in somatic cell count at the start and the end of lactation in Ireland due to physiological or pathological causes?

More, S.J.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Veterinary Medicine

In Ireland, there is a marked temporal trend in the percentage of dairy herds exceeding 400,000 cells/mL, based on unadjusted herd somatic cell count (SCC) results derived from milk recording. This percentage is much higher at the start and end of the year, compared with other times. Until recently, this effect was attributed to a physiological effect, driven by changes in milk volume, coincident with the start and end of lactation in the predominantly spring-calving national herd. However, based on the results of recent research, there is no evidence of a dilution effect in Irish dairy cattle. Therefore, the aim of this study is to clarify the relative importance of physiological and pathological factors in the observed temporal trend in herd SCC.

### *Fertility*

## Breeding soundness evaluation of 50 bulls with reduced reproductive performance: a retrospective study

Beltman, M.E.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

The objective of this study was to determine the fertility status of 50 bulls presented with a history of reduced reproductive performance to University Veterinary Hospital, University College Dublin between 27/11/2006 and 14/03/2011.

## Characterisation of abnormal ovaries with follicular structures in mares

Beltman, M.E.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

The objective of this study was to characterise the composition of the follicular fluid from mares with distinct cystic follicles or Granulosa Cell Tumors (GCTs).

## The influence of cow and management factors on reproductive performance of Irish seasonal calving dairy cows

Lane, E.A.<sup>1</sup>, Crowe, M.A.<sup>2</sup>, Beltman, M.E.<sup>2</sup>, More, S.J.<sup>1, 2</sup>

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Veterinary Medicine

### Animal Reproduction Science 141, 34-41 (2013)

Herd management record analysis facilitates accurate assessment of the current herd reproductive status; a crucial decision making tool to implement effective change. To determine the relative importance of cow and management factors on reproductive indices in moderate-yielding Irish seasonal-calving dairy herds, breeding records of 1173 cows were collected from 10 seasonal calving herds between 2007 and 2009. Backward-stepwise multivariable logistic regression analysis was utilised to determine the effect of cow factors including parity, calving timing, days post partum, heat detection accuracy and herd factors including herd size and heat detection efficiency on key reproductive indices. Mean farm six-week pregnancy and end of season not-in-calf rate were 46% (range 14–72%) and 22% (range 3–40%), respectively. Oestrous detection efficiency ( $P < 0.001$ ), timing of calving ( $P < 0.001$ ) relative to start of breeding, history of abnormal repeat intervals ( $P < 0.001$ ) and length of post partum interval ( $P < 0.001$ ) were each associated with lower six-week pregnancy rates. Timing of calving ( $P < 0.001$ ) and history of abnormal repeat intervals ( $P < 0.001$ ) were associated with higher not-in-calf rates. Herd size and cow parity were not associated ( $P > 0.05$ ) with either outcome when factors including existing calving pattern and heat detection accuracy and efficiency were accounted for. The existing spread in calving pattern, heat detection quality and length of voluntary waiting period were the most influential factors that reduced fertility performance in seasonal-calving herds.

*Reprinted from Animal Reproduction Science, 141, Lane, E.A., Crowe, M.A., Beltman, M.E., More, S.J., The influence of cow and management factors on reproductive performance of Irish seasonal calving dairy cows, 34-41, Copyright 2013, with permission from Elsevier B.V.*

## Addressing reproductive performance in Irish seasonal-calving dairy herds: A review

Lane, E.A.<sup>1, 2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Dairy cow fertility is decreasing worldwide associated with concomitant increases in milk production. Infertility is an important economic constraint restricting farm expansion. Dairy herds must realize reproductive targets to ensure economic feasibility. This study reviews strategies and resources available in Ireland and elsewhere to address infertility in the national dairy herd.

## Key factors affecting fertility in seasonal-calving Irish dairy herds

Lane, E.A.<sup>1, 2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Development of a national strategy to improve dairy herd reproductive performance should be based on the analysis of current performance. This study was undertaken to determine the relative importance of herd, cow and management factors on reproductive indices in Irish seasonal-calving dairy herds.



OTHER ANIMAL HEALTH AND WELFARE ISSUES



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## Animal welfare

### *Bovine welfare*

#### Veterinary certificates for emergency or casualty slaughter bovine animals in the Republic of Ireland: are the welfare needs of certified animals adequately protected?

Cullinane, M.<sup>1</sup>, O'Sullivan, E.<sup>2</sup>, Collins, G.<sup>1</sup>, Collins, D.M.<sup>3</sup>, More, S.J.<sup>3,4</sup>

<sup>1</sup> DAFM, <sup>2</sup> Cork County Council, <sup>3</sup> UCD CVERA, <sup>4</sup> UCD School of Veterinary Medicine

#### **Animal Welfare 21, 61-67 (2012)**

All emergency and casualty bovines in the Republic of Ireland that are deemed to be fit for human consumption must be accompanied to the slaughterhouse by an official veterinary certificate (VC). Cullinane et al. (2010) conducted a review of bovine cases consigned under veterinary certification to emergency (ES) and casualty (CS) slaughter in the Republic of Ireland during 2006 to 2008. The current paper further evaluates these results, with emphasis on the period of validity, transport distance and transport conditions, and considers whether the current VC adequately protects welfare. Of 1,255 veterinary certificates, the median time between certification and slaughter was 1 (minimum 0, maximum 452) day, with one-fifth in excess of three days. The median straight-line distance between farm and slaughterhouse was 22 km; 82 and 98% study animals were transported distances of no more than 40 and 100 km, respectively. In 27% of VCs, no slaughterhouse was designated; hence the transport distance was not limited. In 77% of all cases, the disability/injury was related to the locomotor system, including 35% with limb fractures. Veterinary certification of the latter as being fit for transport appears to have been in contravention of animal transport and welfare legislation. The welfare of animals would be improved if each VC included a certified period of validity. In future, veterinary certificates should state clearly a maximum period of validity between certification and slaughter, a maximum distance that the animal should be transported and a minimum level of comfort under which the animal must be transported. Historically, in the Republic of Ireland, there was no suitable non-transport alternative available to cattle producers wanting to salvage an otherwise healthy animal that had suffered an accident or injury resulting in acute pain. An alternative is now available, with the introduction of an on-farm emergency slaughter policy.

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#### Investigating social and health factors impacting on farm animal welfare incidents in Ireland: methodological challenges

Devitt, C.<sup>1</sup> et al.

<sup>1</sup> Glendalough, Co. Wicklow

There is growing recognition in the animal welfare sciences of the benefit of an interdisciplinary approach with the social sciences. In 2012, qualitative research methods were used to investigate social, health, and psychological factors impacting on farm animal welfare in Ireland. A number of challenges were encountered. These related to conducting sensitive research, as herd owners were requested to talk about social, health and psychological difficulties, as well as animal welfare incidents on their farm. Challenges were also encountered in the study design and participant recruitment. Experiences from this study show that when conducting sensitive research, the study design must aim to minimize the potential risks for all participants involved, including the researcher. Understanding what these risks are is crucial to conducting sensitive research.

## An investigation into social, health and psychological factors impacting on farm animal welfare in Ireland

Devitt, C.<sup>1</sup> et al.

<sup>1</sup> Glendalough, Co. Wicklow

A previous study on key performance indicators for animal welfare incidents in Ireland provided anecdotal evidence to suggest that farm animal welfare standards are often underpinned by social, health, and psychological factors among herd owners. This study took an exploratory approach to identify these factors and how they contributed to farm animal welfare incidents.

## Professional dilemmas experienced by government veterinarians when responding to farm animal welfare incidents in Ireland

Devitt, C.<sup>1</sup> et al.

<sup>1</sup> Glendalough, Co. Wicklow

In Ireland, an Early Warning System, which brings together relevant agencies, is in place to identify and prevent farm animal welfare problems before they become critical. This paper identifies the professional dilemmas experienced by government veterinarians during their investigations of farm animal welfare incidents that involve social, health or psychological difficulties experienced by herd owners.

## Veterinary challenges to providing a multi-agency response to the human aspect of farm animal welfare problems in Ireland

Devitt C.<sup>1</sup>, Kelly P.<sup>2</sup>, Blake M.<sup>2</sup>, Hanlon A.<sup>3</sup>, More S.J.<sup>3,4</sup>

<sup>1</sup> Glendalough, Co. Wicklow, <sup>2</sup> DAFM, <sup>3</sup> UCD School of Veterinary Medicine, <sup>4</sup> UCD CVERA

**Revue Scientifique et Technique / Office International des Épizooties  
(OIE Scientific and Technical Review) 32, 657-668 (2013)**

In 2012, the authors reported that social, health and attitudinal factors, and mental health problems contribute to farm animal welfare incidents in Ireland. An Early Warning System involving relevant agencies is in place to identify and prevent farm animal welfare problems before they become critical. The literature provides examples of private veterinarians linking with support services where there are indicators of animal and human abuse. Yet, there are no research examples of government or private veterinarians linking with support services to resolve farm animal welfare cases where there are herd owner social/health/psychological-related difficulties. Four focus groups were conducted with government veterinarians (n = 18) and three with private veterinarians (n = 12). Contact with support services was made by government veterinarians when seeking advice on how best to respond to the human element of farm animal welfare incidents, or when seeking support for the herd owner. Contact between government and private veterinarians was driven by the former. Communication between agencies was influenced by individual efforts and personal contacts. Formal structures and guidelines, perceived professional capabilities in determining herd owner needs, and client confidentiality concerns among support services and private veterinarians was of lesser influence. Fear of losing clients and the financial implications of this was also cited by private veterinarians. Family, neighbours and local support groups assisted in reaching an on-farm solution. The paper concludes the requirements for a multi-agency approach in Ireland: the provision of tailored information and guidelines targeting government and

private veterinarians and support services, and a comprehensive structure for relationship-building, planning, and cross-reporting between all relevant agencies.

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## A review of key design features of six on-farm voluntary quality assurance programmes relevant to cattle welfare

Dineen, A.M.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

On-farm quality assurance programmes relevant to animal welfare have been evaluated in different ways. To date, there appears to be no published studies evaluating programme design features. This study reviews six on-farm voluntary quality assurance programmes (each relevant to cattle welfare and based in Europe) for key design features relating to farmer participation, changed farmer behaviour and programme evaluation.

## Farmers' self-reported perceptions and behavioural impacts of a welfare scheme for suckler beef cattle in Ireland

Dwane, A.M.<sup>1</sup>, More, S.J.<sup>1,2</sup>, Blake, M.<sup>3</sup>, McKenzie, K.<sup>4</sup>, Hanlon, A.J.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> UCD CVERA, <sup>3</sup> DAFM, <sup>4</sup> UCD School of Public Health, Physiotherapy and Population Science

**Irish Veterinary Journal 66, 1 (2013)**

To date, there have been a limited number of studies on the impact of government-incentivised farm animal welfare programmes or 'schemes', and on farmers' attitudes regarding such schemes. In this study, focus groups were used to gain insight into Irish farmers' perceptions of such a scheme for suckler cattle and its behavioural impacts on farmers. The findings were categorised into 46 codes and ultimately yielded two Global themes: 1) Beliefs and Evidence and 2) Logic and Logistics. The former theme covered farmers' attitudes and observations regarding the Scheme. The latter dealt with factors such as workload and costs. The Global themes allowed for comprehensive reporting of the strongest messages from focus groups. There was consensus that Scheme measures for the minimum calving age and for weaning had a positive impact on welfare. Two aspects criticized by participants were firstly disbudding, due to the logistics for anaesthetic application, and secondly the administrative workload associated with data capture and utilisation. The majority anticipated that data being collected via the Scheme would help to inform farm management decisions in future. Farm animal welfare schemes, which incentivise participants to implement certain practices, aspire to long-term behavioural change after scheme conclusion. Our research showed that this Scheme increased farmer awareness of the benefits of certain practices. It also demonstrated the importance of stakeholder participation in the design stages of welfare initiatives to ensure scheme measures are practical and relevant, to address any perceived controversial measures, and to plan for training and adding value to schemes.

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## Validation of key indicators in cattle farms at high risk of animal welfare problems: a qualitative case-control study

Kelly, P.C.<sup>1</sup>, More, S.J.<sup>2,3</sup>, Blake, M.<sup>1</sup>, Higgins, I.<sup>2</sup>, Clegg, T.A.<sup>2</sup>, Hanlon, A.J.<sup>3</sup>

<sup>1</sup> DAFM, <sup>2</sup> UCD CVERA, <sup>3</sup> UCD School of Veterinary Medicine

### Veterinary Record 172, 314 (2013)

The objective of this study was to validate four key farmer performance indicators (KFPI), identified in a previous study, as indicators of on-farm cattle welfare incidents in Ireland, through comparison of the distribution of these KPFIs in the national herd (n=109,925) and in case herds (n=18), where welfare incidents were previously studied. The KPFIs identified were late registrations, and exits from the herd by on-farm burial, by moves to knackeries and by moves to 'herd unknown'. Data were extracted from two Department of Agriculture, Food and the Marine databases for the national herd and the case herds. All four KPFIs differed significantly between the case herds and the national herd, and one further KFPI was identified, namely moves to factories. The data for these KPFIs are routinely stored on national databases, which were established in order to comply with Regulation (EC) 1760/2000. Based on the results obtained in this study, it may be possible in the future to use routine data capture to improve strategy towards on-farm animal welfare. At this point, however, based on calculated specificities and sensitivities, none of these five KPFIs, at the cut-offs investigated and using several combinations, are able to distinguish herds with and without on-farm animal welfare problems at an accuracy suitable for routine national use in Ireland.

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## Farm animal welfare in Ireland: From Humanity Dick to the new Animal Health and Welfare Bill

Kelly, P.C.<sup>1</sup> et al.

<sup>1</sup> DAFM

The first documented piece of legislation in relation to animal welfare anywhere in the English-speaking world was in Ireland. It was recorded in 1635 and is known as the 'Act against Plowing by the Tayle, and Pulling the Wooll off Living Sheep'. In 1821, an Irishman called Richard Martin introduced 'The Treatment of Horses Bill' in the British House of Commons, whilst serving as a Member of the British Parliament. In 1822, Martin became known as Humanity Dick when he put a further bill through Parliament offering protection to cattle, horses and sheep from cruelty. This was one of the first major pieces of legislation in the world aimed at the welfare of animals. In 1824 he became one of the founder members of the Society for the Prevention of Cruelty of Animals in 1824. In this paper, we review the literature, including this early work, on farm animal welfare, with particular reference to Ireland.

## Equine welfare

### Use of qualitative methods to identify solutions to selected equine welfare problems in Ireland

Collins, J.A.<sup>1</sup>, More, S.J.<sup>1,2</sup>, Hanlon, A.<sup>1</sup>, Wall, P.G.<sup>3</sup>, McKenzie, K.<sup>3</sup>, Duggan, V.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> UCD CVERA, <sup>3</sup> UCD School of Public Health, Physiotherapy and Population Science

**Veterinary Record 170, 442 (2012)**

This paper explores the views of those in the Irish equine industry, organisations and government regarding necessary improvements to equine welfare in Ireland at unregulated gatherings and during the disposal process. Three qualitative research methods were employed, namely semi-structured interviews, focus groups and a structured, facilitated workshop. Representatives from industry, welfare societies, socially disadvantaged groupings and government engaged with this process and shared their views regarding horse welfare and implementable solutions with merit to address welfare problems. A consensus was achieved that equine welfare in Ireland could be improved by the development of a comprehensive identification system, a Code of Practice for horse gatherings, a horse licensing scheme, ring-fenced funding to promote responsible, humane horse disposal and better means of raising awareness of the value of safeguarding horse welfare for the benefit of all parties.

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### A description of equine impoundments under the Control of Horses Act 1996 in the Munster region of Ireland during 2005 to 2012

Cullinane, M.<sup>1</sup> et al.

<sup>1</sup> DAFM

There has been an increase in the number of unwanted and stray horses throughout Europe since the onset of the current economic downturn. In Ireland, the Control of Horses Act (COH) 1996 allows for the seizure of equines under specified circumstance, such as stray or nuisance horses. The Act is implemented by Local Authorities. There are a number of outcomes following seizure and impoundment, including re-claiming of the horse by the owner, the rehoming of the horse or euthanasia. This paper describes the characteristics and outcomes of all equine impoundments under the COH Act 1996 in the Munster region of Ireland during 2005-2012.

### A retrospective study of horses investigated for weight loss despite a good appetite (2002-2011)

Metcalfe, L.V.A.<sup>1</sup>, More, S.J.<sup>1,2</sup>, Duggan, V.<sup>1</sup>, Katz, L.M.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> UCD CVERA

**Equine Veterinary Journal 45, 340-345 (2013)**

Weight loss despite a good appetite is a frequent diagnostic challenge for equine veterinarians; however, there are few objective reports and little descriptive information regarding risk factors and prognostic indicators. To provide a descriptive epidemiological analysis of horses evaluated for weight loss despite a good appetite and evaluate relationships

between historical and clinicopathological findings and final outcome (survival vs. nonsurvival) to identify risk factors and prognostic indicators. Medical records of horses referred for investigation of weight loss despite a good appetite were reviewed. Data collated included history, case details, clinical and diagnostic findings, diagnoses and outcome. Univariable associations were evaluated with a Mann–Whitney *U* test (continuous data), Fisher’s exact test (categorical or binary data) or Pearson’s rank correlation (continuous data), with  $P \leq 0.05$  significant. Forty cases met the inclusion criteria. Total protein ( $P = 0.004$ ) and albumin concentrations ( $P = 0.0008$ ) at admission were higher in survivors than nonsurvivors, with total protein ( $r^2 = 0.31$ ;  $P = 0.002$ ) and albumin ( $r^2 = 0.36$ ;  $P = 0.0002$ ) positively correlated with outcome. Hypoproteinaemic ( $P = 0.008$ , odds ratio (OR) = 12, 95% confidence interval (CI) = 1.99–72.4) and hypoalbuminaemic ( $P = 0.0009$ , OR = 28, 95% CI = 2.94–266.6) animals were at greater odds for nonsurvival. Body condition score was positively correlated with total protein ( $r^2 = 0.16$ ;  $P = 0.05$ ) and albumin ( $r^2 = 0.53$ ;  $P < 0.0001$ ) concentrations at admission and duration of clinical signs ( $r^2 = 0.19$ ;  $P = 0.03$ ). The severity of hypoproteinaemia and hypoalbuminaemia were related with nonsurvival. Body condition score and albumin concentration could potentially be used as prognostic indicators for survival. These findings highlight the importance of body condition assessment in conjunction with clinicopathological evaluation in horses with weight loss despite a good appetite.

*Reprinted from Equine Veterinary Journal, 45, Metcalfe, L.V.A., More, S.J., Duggan, V., Katz, L.M., A retrospective study of horses investigated for weight loss despite a good appetite (2002-2011), 340-345, Copyright 2013, with permission from EVJ Ltd.*

## Porcine welfare

### Good animal welfare makes economic sense: potential of pig abattoir meat inspection as a welfare surveillance tool

Harley, S.<sup>1</sup>, More, S.J.<sup>1,2</sup>, Boyle, L.<sup>3</sup>, O’Connell, N.<sup>4</sup>, Hanlon, A.<sup>1</sup>

<sup>1</sup> UCD School of Veterinary Medicine, <sup>2</sup> UCD CVERA, <sup>3</sup> Teagasc Moorepark, <sup>4</sup> Queens University Belfast, Belfast, Northern Ireland

**Irish Veterinary Journal 65, 11 (2012)**

During abattoir meat inspection pig carcasses are partially or fully condemned upon detection of disease that poses a risk to public health or welfare conditions that cause animal suffering e.g. fractures. This incurs direct financial losses to producers and processors. Other health and welfare-related conditions may not result in condemnation but can necessitate ‘trimming’ of the carcass e.g. bruising, and result in financial losses to the processor. Since animal health is a component of animal welfare these represent a clear link between suboptimal pig welfare and financial losses to the pig industry. Meat inspection data can be used to inform herd health programmes, thereby reducing the risk of injury and disease and improving production efficiency. Furthermore, meat inspection has the potential to contribute to surveillance of animal welfare. Such data could contribute to reduced losses to producers and processors through lower rates of carcass condemnations, trimming and downgrading in conjunction with higher pig welfare standards on farm. Currently meat inspection data are under-utilised in the EU, even as a means of informing herd health programmes. This includes the island of Ireland but particularly the Republic. This review describes the current situation with regard to meat inspection regulation, method, data capture and utilisation across the EU, with special reference to the island of Ireland. It also describes the financial losses arising from poor animal welfare (and health) on farms. This review seeks to contribute to efforts to evaluate the role of meat inspection as a surveillance tool for animal welfare on-farm, using pigs as a case example.

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## Evaluating the prevalence of tail biting and carcass condemnations in slaughter pigs in the Republic and Northern Ireland, and the potential of abattoir meat inspection as a welfare surveillance tool

Harley, S.<sup>1</sup>, More, S.J.<sup>1,2</sup>, O'Connell, N.E.<sup>3</sup>, Hanlon, A.<sup>1</sup>, Teixeira, D.<sup>4</sup>, Boyle, L.<sup>4</sup>

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### Veterinary Record 171, 621 (2012)

Despite extensive utilisation in epidemiological investigations of animal health, to date there has been little consideration of the value of abattoir meat inspection as a pig welfare surveillance tool. This study measured the prevalence of tail-docking, tail biting, carcass condemnations and associated financial losses of the latter (Northern Ireland only) in 36,963 pigs slaughtered in six abattoirs from the Republic of Ireland and Northern Ireland in July and August 2010. Over 99 per cent of inspected pigs had been tail-docked, while 58.1 per cent and 1.03 per cent had detectable and severe tail lesions, respectively. Producer losses resulting from carcass condemnation were estimated to be €0.37 per pig slaughtered. Enhanced capture and utilisation of meat inspection data for use in animal welfare surveillance schemes has the potential to drive improvements in production efficiency and animal welfare. However, significant differences were detected in the prevalence of carcass condemnation conditions between abattoirs and judiciaries (Republic and Northern Ireland). This reflects variation in the criteria and methods of data capture used in meat inspection in different abattoirs. Thus, the meat inspection process needs to be standardised and reformed before it can be reliably utilised in large-scale pig welfare surveillance schemes.

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## Assessment of prevalence, associations and financial implications of health and welfare conditions in slaughter pigs

Harley, S.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

As public concern about animal welfare continues to grow, there is an increasing need for better surveillance of animal welfare across the EU. It is widely acknowledged that this should incorporate animal-based measurements. Abattoir meat inspection is a continuous process during which pathological carcass lesions are detected. By expanding this process to incorporate animal-based measurements, a significant contribution could be made to animal welfare surveillance. Hence the aim of this study was to incorporate animal-based welfare measurements into the meat inspection process and to determine the prevalence of several welfare-related lesions, and the association of these lesions with carcass condemnations, carcass weight and financial losses.

## Emergency issues

### An outbreak of piroplasmosis in horses in Ireland

Bailey, D.<sup>1</sup> et al.

<sup>1</sup> DAFM

An outbreak of piroplasmosis (caused by *Theileria equi*) occurred in horses in Ireland during 2009. The objective of this paper is to describe the outbreak, the transmission of *T. equi* within Ireland and aspects of outbreak management.



## Transmissible spongiform encephalopathy (TSE)

### Factors contributing to sample quality for the BSE active surveillance programme in the Republic of Ireland

Cahill, A.<sup>1</sup> et al.

<sup>1</sup> DAFM

The Republic of Ireland's active surveillance programme for BSE involves the collection of brain stem tissue samples from certain categories of cattle, including cattle which die on farm (so-called 'fallen cattle'). Some of these samples are of poor quality due to autolysis, with implications for accurate BSE diagnosis. The Republic of Ireland is obliged under EU law to take measures to minimise sample autolysis. Data on the degree of autolysis of all samples taken between 2007 and 2011 have been captured on the AHCS (Animal Health Computer System). The objective of this study is to identify risk factors for poor sample quality in fallen animals in the Republic of Ireland.

### The epidemiology of bovine spongiform encephalopathy in the Republic of Ireland before and after the reinforced feed ban

Ryan, E.<sup>1</sup>, McGrath, G.<sup>2</sup>, Sheridan, H.<sup>3</sup>, More, S.J.<sup>2,4</sup>, Aznar, I.<sup>2</sup>

<sup>1</sup> DAFM Veterinary Laboratory Service, <sup>2</sup> UCD CVERA, <sup>3</sup> DAFM, <sup>4</sup> UCD School of Veterinary Medicine

#### Preventive Veterinary Medicine 105, 75-84 (2012)

Bovine spongiform encephalopathy (BSE) is a prion disease spread by the inclusion in cattle feed of meat and bone meal made from cattle infected with the BSE agent. In the Republic of Ireland, a reinforced feed ban on mammalian meat and bone meal (MMBM) was introduced on 17th October 1996 to stop further infection of cattle. Between then and July 2010, 44 cases of BSE from 40 herds have been born, termed "born after the reinforced ban" or "BARB" cases. The objectives of this project were: (a) to describe the epidemiology of these BARB cases, (b) to determine area-level risk factors for BSE herds and how they related to the stage of the BSE epidemic, and (c) to evaluate whether the spatial pattern of BSE cases was non-random and had changed over time. The BSE epidemic was divided into three phases: cases born prior to 1991, born 1991–October 1996 and BARB cases. To determine the area level risk factors for BSE herds, a case–control study was conducted for each phase of the epidemic. We selected four control herds for each herd with one or more BSE cases. A grid of hexagons of 10 km diameter was created covering the territory of the Republic of Ireland and BSE herds and control herds were assigned to a hexagon. The numbers of cattle herds, dairy herds, piggeries and poultry holdings within the hexagons containing these case and control herds were enumerated. To evaluate the spatial pattern of BSE cases, standardised mortality ratios were calculated for each hexagon, and Oden's I<sub>pop</sub> was used to investigate clustering. The descriptive analysis showed "feeding of concentrates" as the only common factor to all BARB cases for which information existed. The case–control study identified being a dairy herd as a risk factor during the pre-1991 phase of the BSE epidemic. Dairy herd type, a large proportion of local herds which were dairy and large numbers of piggeries and poultry holdings locally were also risk factors during the 1991–1996 phase. For the post-October 1996 phase (BARBs), dairy herd type and large numbers of other herds locally were risk factors. The spatial pattern of BSE cases changed over the three phases of the epidemic and was non-random, with evidence of clustering. The evidence supports the hypothesis that BARB cases do not arise spontaneously but rather are caused by the same food-borne infectious route as other BSE cases.

*Reprinted from Preventive Veterinary Medicine, 105, Ryan, E., McGrath, G., Sheridan, H., More, S.J., Aznar, I., The epidemiology of bovine spongiform encephalopathy in the Republic of Ireland before and after the reinforced feed ban, 75-84, Copyright 2012, with permission from Elsevier B.V.*

## Q fever

### Q fever in humans and farm animals in four European countries, 1982 to 2010

Georgiev, M.<sup>1</sup>, Afonso, A.<sup>2</sup>, Neubauer, H.<sup>3</sup>, Needham, H.<sup>4</sup>, Thiéry, R.<sup>5</sup>, Rodolakis, A.<sup>6</sup>, Roest, H.J.<sup>7</sup>, Stärk, K.D.<sup>8</sup>, Stegeman, J.A.<sup>9</sup>, Vellema, P.<sup>10</sup>, van der Hoek, W.<sup>11</sup>, More, S.J.<sup>12, 13</sup>

<sup>1</sup> Royal Veterinary College (RVC), London, England, <sup>2</sup> European Food Safety Authority (EFSA), Parma, Italy, <sup>3</sup> Friedrich-Loeffler-Institute, Institute for Bacterial Infections and Zoonoses, Jena, Germany, <sup>4</sup> European Centre for Disease Prevention and Control (ECDC), Stockholm, Sweden, <sup>5</sup> ANSES, Laboratoire de Sophia-Antipolis, Unité pathologie des ruminants, Sophia-Antipolis, France, <sup>6</sup> Institut National de la Recherche Agronomique (INRA), Infectiologie Animale et Santé Publique, Nouzilly, France, <sup>7</sup> Department of Bacteriology and TSEs, Central Veterinary Institute, part of Wageningen UR, Lelystad, Netherlands, <sup>8</sup> SAFOSO, Safe Food Solutions Inc., Bern, Switzerland, <sup>9</sup> University of Utrecht, Dept. Farm Animal Health, Utrecht, the Netherlands, <sup>10</sup> Department of Small Ruminant Health, Animal Health Service GD Deventer, Deventer, Netherlands, <sup>11</sup> Centre for Infectious Disease Control, National Institute for Public Health and the Environment, Bilthoven, Netherlands, <sup>12</sup> UCD CVERA, <sup>13</sup> UCD School of Veterinary Medicine

#### Eurosurveillance 18, 20407 (2013)

Q fever is a disease of humans, caused by *Coxiella burnetii*, and a large range of animals can be infected. This paper presents a review of the epidemiology of Q fever in humans and farm animals between 1982 and 2010, using case studies from four European countries (Bulgaria, France, Germany and the Netherlands). The Netherlands had a large outbreak between 2007 and 2010, and the other countries a history of Q fever and Q fever research. Within all four countries, the serological prevalence of *C. burnetii* infection and reported incidence of Q fever varies broadly in both farm animals and humans. Proximity to farm animals and contact with infected animals or their birth products have been identified as the most important risk factors for human disease. Intrinsic farm factors, such as production systems and management, influence the number of outbreaks in an area. A number of disease control options have been used in these four countries, including measures to increase diagnostic accuracy and general awareness, and actions to reduce spill-over (of infection from farm animals to humans) and human exposure. This study highlights gaps in knowledge, and future research needs.

Georgiev M, Afonso A, Neubauer H, Needham H, Thiéry R, Rodolakis A, Roest HJ, Stärk KD, Stegeman JA, Vellema P, van der Hoek W, More SJ. Q fever in humans and farm animals in four European countries, 1982 to 2010. *Euro Surveill.* 2013;18(8):pii=20407. Available online: <http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=20407>

## Companion animal epidemiology

### Neutering of cats and dogs in Ireland; pet owner self-reported perceptions of enabling and disabling factors in the decision to neuter

Downes, M.J.<sup>1</sup> et al.

<sup>1</sup> Centre for Evidence-based Veterinary Medicine, School of Veterinary Medicine and Science, The University of Nottingham, Nottingham, England

Failure among pet owners to neuter their pets results in increased straying and overpopulation problems. Variations in neutering levels can be explained by cultural differences, differences in economic status in rural and urban locations, and owner perceptions about their pet. This paper identified the perceptions of Irish cat and dog owners that influenced their decisions on pet neutering. Understanding how pet owners feel about topics such as pet neutering can help improve initiatives aimed at emphasising the responsibility of population control of cats and dogs.

### Understanding the context for pet obesity; self-reported beliefs and factors influencing pet feeding and exercise behaviour among Irish pet owner

Downes, M.J.<sup>1</sup> et al.

<sup>1</sup> Centre for Evidence-based Veterinary Medicine, School of Veterinary Medicine and Science, The University of Nottingham, Nottingham, England

Pet obesity contributes to increased risk of various diseases, such as cancer and diabetes mellitus as well as worsening of orthopaedic problems, and a reduction in survival rate. Changes in feeding regimes and increased amounts of exercise have been an important component of weight management programs. This study identifies the self-reported beliefs and factors that influence owner behaviour around feeding and exercising their pet. Understanding owner behaviours on feeding and exercise allows for a more targeted approach to preventing and treating pet obesity.

### Understanding the reasons for pet ownership; providing a context for understanding pet care?

Downes, M.J.<sup>1</sup> et al.

<sup>1</sup> Centre for Evidence-based Veterinary Medicine, School of Veterinary Medicine and Science, The University of Nottingham, Nottingham, England

Pets have fulfilled a number of roles for humans including; hunting, protection, pest control, companionship and for the benefit of the children in the household. Little research has been done to explore pet ownership in qualitative manor. In this study, we explore the reasons for choosing a pet and the possible outcomes this may have on other aspects of pet ownership.

# Cadmium exposure in cattle

## Cadmium and other heavy metal concentrations in bovine kidneys in the Republic of Ireland

Canty, M.J.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Cadmium (Cd) is a naturally occurring heavy metal with no known biological function in either animals or humans. In Europe, maximum limits (ML) for Cd in foodstuffs are set by Commission Regulation No. 1881/2006, including 1.0 mg/kg in kidneys. High Cd concentrations in European topsoil are mainly a result of intensive agricultural use of phosphate fertilisers and sewage sludge, except in several countries, including Ireland, where naturally occurring high levels are found. In this study, we determine the concentration of Cd and other heavy metals (As, Hg and Pb) in kidneys collected from cattle at slaughter in Ireland.

### Cadmium review

Lane, E.A.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

No biological role has been described for cadmium (Cd) in animals and its presence in animal tissue is considered unnecessary. This paper reviews the literature pertaining to Cd exposure and consequences for farmed animal health and production.



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## International collaboration

### Epidemiological characteristics of bovine brucellosis in Korea, 2000-2004

Nam, H.-M.<sup>1</sup>, Yoon, H.<sup>1</sup>, Kim, C.-H.<sup>2</sup>, More, S.J.<sup>3,4</sup>, Kim, S.J.<sup>1</sup>, Lee, B.-Y.<sup>1</sup>, Park, C.-K.<sup>1</sup>, Jeon, J.-M.<sup>1</sup>, Wee, S.-H.<sup>1</sup>

<sup>1</sup> Animal, Plant and Fisheries Quarantine and Inspection Agency, Anyang, Korea, <sup>2</sup> Food Safety and Sanitation Division, Ministry for Food, Agriculture, Forestry and Fisheries, Gwacheon, Korea, <sup>3</sup> UCD CVERA, <sup>4</sup> UCD School of Veterinary Medicine

**Korean Journal of Veterinary Research 52, 19-24 (2012)**

This paper describes the epidemiological characteristics of bovine brucellosis in Korea during January 2000-September 2004, which encompasses the period when the incidence of bovine brucellosis increased abruptly. Data from the National Animal Infectious Disease Data Management System were used for this study. A range of epidemiological measures was calculated including annual herd and animal incidence. During the study period, there were 1,183 outbreaks on 638 farms. In beef cattle, annual herd incidence increased from 0.2 (2000) to 11.5 (2004, to September) outbreaks per 10,000 and annual animal incidence varied between 3.4 (2000) and 105.8 (2004, to September) per 100,000, respectively. On 401 (62.9%) infected farms during this period, infection was eradicated without recurrence. Recurrence of infection was significantly higher on farms where abortion was reported (53.3%), compared to farms where it was not (30.0%). On beef cattle farms, infection was introduced most frequently through purchased cattle (46.2%). Based on the results of this study, the establishment and spread of brucellosis in the Korean beef cattle population were mainly due to incomplete or inappropriate treatment of aborted materials and the movement of infected cattle.

*Reproduced from Korean Journal of Veterinary Research, 52, Nam, H.-M., Yoon, H., Kim, C.-H., More, S.J., Kim, S.J., Lee, B.-Y., Park, C.-K., Jeon, J.-M., Wee, S.-H., 19-24, Copyright 2012, with permission from Korean Journal of Veterinary Research.*



## Marine health

### Risk factors associated with increased mortality of farmed Pacific oysters in Ireland during 2011

Clegg, T.A.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

The Pacific oyster, *Crassostrea gigas*, plays a significant role in the aquaculture industry in Ireland. Episodes of increased mortality in *C. gigas* have been described in many countries, and in Ireland since 2008. The cause of mortality events in *C. gigas* spat and larvae is suspected to be multifactorial, with ostreid herpesvirus 1 (OsHV-1, in particular OsHV-1  $\mu$ var) considered a necessary, but not sufficient, cause. The objectives of the current study were to describe mortality events that occurred in *C. gigas* in Ireland during the summer of 2011 and to identify any associated environmental, husbandry and oyster endogenous factors.

### Epidemiological studies on infectious pancreatic necrosis in the Irish salmon farming industry

Yatabe-Rodríguez, T.<sup>1</sup> et al.

<sup>1</sup> University of California, Davis, California, USA

Infectious Pancreatic Necrosis Virus (IPNV) has become a very significant agent in Ireland causing severe disease and mortalities in recent years, due to an increased number of clinical outbreaks, especially during the 2003-2006 period, where several sea sites experienced outbreaks in the three month window following stocking. A range of studies are planned, including: describing the epidemiology and space-time distribution of IPN in Ireland, modeling the spread of the IPN virus in the Irish salmon farming industry, estimating the association between IPN and epidemiological factors at the farm level and financial analysis of the impact of the disease and cost-benefit analysis of alternative mitigation strategies.

## Equine health

### Key factors affecting reproductive success of mares on well managed stud-farms

Crowe, M.A.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

This study is being conducted to evaluate factors contributing to fertility success of Thoroughbred mares. The results indicate that Thoroughbreds can be effectively managed to achieve high reproductive performance in a commercial setting.

### Development of a bio-security assessment tool and its application at equine events in Ireland

Johnson, J.P.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

There is the potential for disease transmission wherever horses gather in groups. The inconsistent application of disease control measures across the horse industries in Ireland, the highly contagious nature of many of the equine infectious diseases, the potential for the spread of disease from sub-clinically infected horses and increased transport of horses to international events together mean that all horses are put at risk of disease transmission, particularly in the event of an outbreak of an exotic equine disease. The objectives of this study were to develop a bio-security assessment tool for use at equine events, to apply the tool in the investigation of the potential for contagious disease transmission at equine events in Ireland, and to determine the influence of the degree of regulation of event on risk of disease transmission.

## Miscellaneous

### Seroprevalence of Louping Ill virus (LIV) antibodies in sheep submitted for post mortem examination in the North West of Ireland in 2011

Barrett, D.<sup>1</sup>, Collins, D.M.<sup>2</sup>, McGrath, G.<sup>2</sup>, Ó Muireagain, C.<sup>1</sup>

<sup>1</sup> DAFM Veterinary Laboratory Service, <sup>2</sup> UCD CVERA

**Irish Veterinary Journal 65, 20 (2012)**

Blood samples were collected opportunistically at routine post mortem examination from 199 sheep which came from 152 flocks. The location of each submitting flock was mapped. Sera were tested using a goose blood haemagglutination inhibition assay for louping ill virus. There was an animal level prevalence of 8.5%, and a flock level prevalence of 9.8%. The greatest proportion of seropositive animals was identified among the animals older than 24 months of age. The elevation of the land associated with positive flocks was greater than that of negative flocks. Lesions of non-suppurative meningoencephalitis were observed in three of the 199 animals.

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### Examination of factors affecting the submission of bovine carcasses to the Regional Veterinary Laboratories (RVLs) in the Republic of Ireland between 2009 and 2013

Barrett, D.<sup>1</sup> et al.

<sup>1</sup> DAFM Veterinary Laboratory Service

There has been an increase in the number of carcasses submitted for post mortem examination to the RVLs in recent years. This has led to increased demands on resources in a period when resources have become more limited. The objective of this study is to assess seasonal, weather and economic factors affecting the submission of carcasses for post mortem examination during the study period.

### A case control study of Schmallerberg disease in Irish sheep flocks

Barrett, D.<sup>1</sup> et al.

<sup>1</sup> DAFM Veterinary Laboratory Service

Schmallerberg virus is an emerging viral disease of ruminants. In sheep it causes abortion and foetal deformities. It is generally considered a low impact disease (< 5% prevalence of deformities), but significant losses have been described in some Irish flocks. The objective of this study is to determine factors associated with the occurrence of Schmallerberg virus in Irish sheep flocks and determine the impact of infection on productivity.

## Prevalence and distribution of exposure to Schmallenberg virus in Irish cattle during 2012/13

Bradshaw, B.<sup>1</sup> et al.

<sup>1</sup> DAFM Veterinary Laboratory Service

Schmallenberg virus (SBV) was first identified in plasma samples from cattle on a farm in Germany in November 2011. Since its discovery, evidence of infection of livestock with this virus has been found across Northern Europe with the first report in Ireland in October 2012. Prior to this study, little was known of the extent of exposure to SBV infection in Ireland after this date. In this study, we describe the prevalence and distribution of exposure to SBV in Irish cattle during 2012/13.

## Ergot alkaloid intoxication associated with perennial ryegrass (*Lolium perenne*): an emerging animal health concern in Ireland?

Canty, M.J.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Animals grazing or consuming conserved forages can encounter problems if forages are infected with an endophyte, which produces toxins which are harmful to animals. Endophytes are fungi that live within a plant and the relationship between a grass and its endophyte is symbiotic. The grass provides the nutrients and the endophyte produces toxins that fend off insects, diseases and grazing animals. Endophytes are transmitted only through grass seed. Different species of endophyte fungus infect different species of grass. Principally we are concerned with the fungus *Neotyphodium coenophialum*, which produces over 32 toxic alkaloids including 17 ergot alkaloids that affect livestock. The principal toxin is ergovaline, which amongst other alkaloids, causes fescue toxicosis in livestock. These toxins are vasoconstrictors, they constrict blood vessels and reduce circulation to the body extremities, interfering with the animal's ability to regulate body temperature and causing conditions called 'fescue foot' in cold weather and 'summer slump' in hot weather. The objective of this study is to determine the role of the endophyte ergovaline on a number of farms where poor animal performance had been reported.

## Graduate Certificate in Dairy Herd Health

Cashman, D.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

Online learning is growing in popularity as a method to deliver lifelong learning to veterinary professionals, as many are unable to commit to full-time, on-campus educational programmes. The number of academic staff engaging in this method of educational delivery is low, however. There are challenges to the development and delivery of high quality online learning programmes, recent reductions in university resources, both human and financial. The Dairy Herd Health group in the University College of Dublin, aimed to overcome these hurdles, and set out to develop and deliver an online graduate certificate in dairy herd health. Targeted at veterinarians out in practice, practitioners will be equipped with tools for herd data analysis, practical herd evaluation skills, and an ability to integrate the multiple facets of dairy herd health for the development of holistic herd level solutions that are set in context with regard to herd profitability and animal health and welfare. The Certificate was successfully delivered in 2011 and again in 2013. This paper offers a framework for the development of online graduate programmes with limited resources and novice academic staff new to online delivery of programmes. We reflect on the challenges that academic staff members encountered in the design and delivery of their online teaching strategies. Finally we provide recommendations on how to overcome these teaching and learning challenges.

## Panmictic structure of the *Cryptosporidium parvum* population in Irish calves: Influence of prevalence and host movement

De Waele, V.<sup>1,2,3</sup>, Van den Broeck, F.<sup>3,4</sup>, Huyse, T.<sup>3,4</sup>, McGrath, G.<sup>5</sup>, Higgins, I.<sup>5</sup>, Speybroeck, N.<sup>6</sup>, Berzano, M.<sup>1</sup>, Raleigh, P.<sup>1</sup>, Mulcahy, G.<sup>2</sup>, Murphy, T.<sup>1</sup>

<sup>1</sup> DAFM Veterinary Laboratory Service, <sup>2</sup> UCD School of Veterinary Medicine, <sup>3</sup> Department of Biomedical Sciences, Institute of Tropical Medicine, Antwerp, Belgium, <sup>4</sup> Laboratory of Biodiversity and Evolutionary Genomics, University of Leuven, Leuven, Belgium, <sup>5</sup> UCD CVERA, <sup>6</sup> Institut de Recherche Santé et Société (IRSS), Université catholique de Louvain, Brussels, Belgium

### Applied and Environmental Microbiology 79, 2534-2541 (2013)

In total, 245 *Cryptosporidium parvum* specimens obtained from calves in 205 Irish herds between 2003 and 2005 were subtyped by sequencing the glycoprotein gene *gp60* and performing multilocus analysis of seven markers. The transmission dynamics of *C. parvum* and the influence of temporal, spatial, parasitic, and host-related factors on the parasite (sub)populations were studied. The relationship of those factors to the risk of cryptosporidiosis was also investigated using results from 1,368 fecal specimens submitted to the veterinary laboratories for routine diagnosis during 2005. The prevalence was greatest in the northwest and midwest of the country and on farms that bought in calves. The panmixia (random mating) detected in the *C. parvum* population may relate to its high prevalence, the cattle density, and the frequent movement of cattle. However, local variations in these factors were reflected in the *C. parvum* subpopulations. This study demonstrated the importance of biosecurity in the control of bovine cryptosporidiosis (e.g., isolation and testing of calves before introduction into a herd). Furthermore, the zoonotic risk of *C. parvum* was confirmed, as most specimens possessed GP60 and MS1 subtypes previously described in humans.

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## Risk factors for lameness on 10 dairy farms in Ireland

Doherty, N.<sup>1</sup> et al.

<sup>1</sup> UCD School of Veterinary Medicine

Lameness is an important welfare issue for dairy cows and has significant economic implications. The aim of this investigation was to evaluate risk factors for lameness on 10 dairy farms in Ireland.

## Integrated Constructed Wetlands (ICW) working at the landscape scale: The Anne Valley project, Ireland

Harrington, R.<sup>1</sup>, O'Donovan, G.<sup>2</sup>, McGrath, G.<sup>3</sup>

<sup>1</sup> Waterford County Council, <sup>2</sup> Broadview Ecological Consultants, Gloucestershire, England, <sup>3</sup> UCD CVERA

### Ecological Informatics 14, 104–107 (2013)

Availability of clean water in Europe has become a topic of great concern. The Water Framework Directive (WFD) is putting pressure on EU Member States to provide water quality of a high standard throughout the Union. An effective way of tackling this problem is to use Integrated Constructed Wetlands (ICWs) at the landscape scale. Over the last 23 years, 15 ICWs have been constructed within the Anne Valley catchment in Waterford, Ireland, to address both point-source and diffuse pollution at the catchment scale. ICWs address a diversity of pollution problems including the treatment of sewage effluent from small villages, wastewater from livestock and waste material from creameries. A series of aerial photographs shows the development of these wetlands within the catchment over time. A catchment scale GIS is currently being developed in Ireland to address the WFD concerns. The integration of ICWs into these catchment models will provide a mechanism for measuring their effectiveness at the landscape scale and for identifying strategic sites for their implementation.

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## Small area study/milk recording data

Lane, E.A.<sup>1,2</sup> et al.

<sup>1</sup> UCD CVERA, <sup>2</sup> DAFM

Milk recording data are a valuable resource, providing insights into milk production over defined geographical areas. In this study, we use these data to provide insights into the influence of local industry on milk production in surrounding farms.

## Farm mineral maps

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

This study will involve performing a spatial analysis on the Geological Survey of Ireland's soil mineral survey in an attempt to give an approximate interpolation of the soil mineral values of all farms in Ireland. This information could be used by farmers as a possible indicator of mineral deficiencies or excesses in their grass with subsequent impact on animal nutrition.

## Movement in the national herd

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

This study seeks to create a series of animations displaying actual movements of animals within the National Herd at daily/weekly intervals in Ireland. A previous cohort study looked at movements from County Kerry. This was summarised by the lifetime of the cohort. However, a static image cannot convey the intensity of national movement. In the absence of a true network analysis, an animation showing movements on a daily or weekly basis per video frame would be a valuable visualisation to emphasise the extent to which herds are connected through the transfer of animals.

## Spatial structure of farms in Ireland

McGrath, G.<sup>1</sup> et al.

<sup>1</sup> UCD CVERA

Most research into transmissible diseases in the National Herd makes reference to the fact that farms are often fragmented into multiple disparate parcels, occurring at varying distances away from the 'home farm'. Farms will also have a differing number of neighbours depending on their size and the shape of their perimeters. This study will attempt to analyse and describe the extent of farm fragmentation in Ireland. The number of neighbours and the length of shared boundary with neighbours will also be presented. This will provide a reference point for future epidemiological studies.

## Evidence is at the core of scientific method: A challenge for clinicians

More, S.J.<sup>1,2</sup>

<sup>1</sup> UCD CVERA, <sup>2</sup> UCD School of Veterinary Medicine

### **The Veterinary Journal 191, 11-12 (2012)**

Evidence ('... facts tending to prove or disprove any conclusion') is at the core of the scientific method, providing the basis for acquiring new and correcting and consolidating existing knowledge. Within the disciplines of veterinary medicine, evidence is generally gathered through experimentation and/or observation, each with its strengths and limitations, with conclusions then being drawn using inductive and/or deductive reasoning. This Guest Editorial focuses on two key issues relating to scientific evidence and veterinary clinicians: the presentation of scientific evidence to end-users, and the use of this evidence by veterinary clinicians.

*Adapted from The Veterinary Journal, 191, More, S.J., Evidence is at the core of scientific method: A challenge for clinicians, 11-12, Copyright 2012, with permission from Elsevier Ltd.*





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## Scientific support

- Epidemiological support* ..... 90
- Statistical support* ..... 92
- Geographic Information Systems (GIS) support* ..... 93
- Database support* ..... 95

CVERA works to generate scientific information in support of national policy decision-making. This work is conducted in two ways, either as:

- defined *scientific projects* (as outlined in earlier sections of this Biennial Report [Bovine tuberculosis; Non-regulatory cattle health issues; Other animal health and welfare issues]),  
or
- as more-general *scientific support*.

Each accounts for approximately 50% of available resources.

CVERA provides scientific support to both *ad hoc* and ongoing activities, and to a range of national bodies including the Department of Agriculture, Food and the Marine, University College Dublin and Animal Health Ireland. In each case, the work draws on expertise within CVERA in epidemiology, statistics, geographic information systems and database maintenance and interrogation.

The following provide a broad, non-exhaustive overview of scientific support provided by CVERA during 2012 and 2013.

## Epidemiological support

Simon More, Inma Aznar, Mary Canty & Liz Lane

### *Department of Agriculture, Food and the Marine*

- Membership of the Scientific Advisory Committee on Animal Health and Welfare and the bTB/BR North/South Working Group
- Epidemiological support on a range of issues including:
  - Emergency disease management
  - General study design
  - Heavy metals, including cadmium
  - National animal disease surveillance
  - National bTB eradication programme
  - Non-regulatory animal health issues (including Johnes's disease, bovine viral diarrhoea and mastitis)

### *University College Dublin*

#### Teaching

- Undergraduate, including Agricultural Science (ANSC30130), Veterinary Medicine (VETS30170, VETS30290) and Medicine (MDSA10210)
- Postgraduate, including Agricultural Science (AESC40020), Dairy Herd Health (VETS40180), and Infection Biology (Thematic PhD)

#### Postgraduate supervision/support

- Finalised during 2013: Valerie De Waele (PhD, veterinary parasitology), Andrea Dwane (MVSc) [animal welfare], Paddy Kelly (MVSc) [animal welfare], Pat Meskell (MBA) [bTB], Eoin Ryan (DipECBHM) [leptospirosis]
- Ongoing: Inma Aznar (PhD Wageningen) [bTB], Tracy Clegg (PhD University of Bolton) [bTB], Martin Downes (DipECVPH) [milk quality], Martin Gallagher (MVSc) [bTB], Lucy Metcalfe (DipECEIM) [equine medicine], Tadaishi Rodríguez-Yatabe (PhD UC Davis) [fish epidemiology], Paul White (PhD Wageningen) [bTB], Renhao Jin (PhD) [bTB]

- Commencing: Damien Barrett (PhD) [Schmallenberg epidemiology], Sara Cabaço (PhD Universidade de Lisboa) [mastitis]

## Other

### Animal Health Ireland

- Chair of the Technical Working Groups on Johne's disease and mastitis

### Anses (French Agency for Food, Environmental and Occupational Health & Safety)

- Membership of the Groupe de travail 'Avis de l'Anses relatif à l'utilisation de certains tests de diagnostic de la tuberculose bovine'

### Australian and New Zealand College of Veterinary Scientists

- Head subject examiner (Fellowship, veterinary epidemiology)

### Department of Environment, Food and Rural Affairs, UK

- Membership of the Epidemiology & Wildlife Risks Programme Advisory Sub-Group, bTB Science Advisory Body

### European Food Safety Authority

- Chair of the Animal Health and Welfare (AHAW) Panel and member of several working groups
- Membership of the Scientific Committee

### Food Safety Authority of Ireland

- Membership of the Biological Safety Sub-Committee and the AMR working subgroup

### FP7 RISKSUR project

- Membership of the Scientific Advisory Board member

### General scientific community

- Scientific Advisory Board, *The Veterinary Journal*
- Deputy Editor, *Irish Veterinary Journal*
- Independent referee (ongoing), numerous international peer reviewed journals
- Thesis examination (MVSc, PhD, *Doctor Medicinae Veterinariae*), several universities



## Statistical support

Tracy Clegg

### *Department of Agriculture, Food and the Marine*

- Statistical support on a range of issues including:
  - Bovine spongiform encephalopathy.
  - Leptospirosis.
  - Estimation of the potency of tuberculin supplied to Ireland.
  - Selection of a random sample of herds for the surveillance of freedom from Bluetongue.
  - Statistical support to assist in the quantitative comparison of the performance of private veterinary practitioners (PVPs) in relation to SICTT testing for bovine tuberculosis.
  - Serum tests for colostrum absorption in calves.
  - Schmallerberg - sample size selection.
  - PVP quality control study.

### *University College Dublin*

- Statistical support for a range of studies, including:
  - Metcalfe et al., 2013. A retrospective study of horses investigated for weight loss despite a good appetite (2002-2011). *Equine Veterinary Journal* 45, 340-345.
  - Harley et al., 2012. Evaluating the prevalence of tail biting and carcass condemnations in slaughter pigs in the Republic and Northern Ireland, and the potential of abattoir meat inspection as a welfare surveillance tool. *Veterinary Record* 171, 621.
  - Huuskonen et al., 2012. Intratesticular lidocaine reduces the response to surgical castration in dogs. *Veterinary Anaesthesia and Analgesia* 40, 74-82.
  - Schneeweiss et al., 2012. Comparison of ultrasound-guided vs. 'blind' techniques for intra-synovial injections of the shoulder area in horses: Scapulohumeral joint, bicipital and infraspinatus bursae. *Equine Veterinary Journal* 44, 674-678.

### *Other*

- Statistical support for a range of studies, including:
  - Study design and preparation for analysis of the 2012 Oyster data, in collaboration with the Marine Institute.
  - Downes et al., 2013. Methods used to estimate the size of the owned cat and dog population: a systematic review. *BMC Veterinary Research* 9, 121.
  - Sleeman et al., 2012. What proportion of badgers (*Meles meles*) are killed on roads in rural areas in the Republic of Ireland? *Mammal Notes* 6, 1-4.

# Geographic Information Systems (GIS) support

Guy McGrath, Daniel Collins

## *Department of Agriculture, Food and the Marine*

- Wildlife Administration Unit
  - Daily approvals and monthly/yearly reports.
  - End of year progress maps for each DVO.
  - Area treated calculations are submitted on a regular basis in compliance with NPWS.
  - Resources for problem areas.
- Foot and Mouth disease modelling. CVERA is currently upgrading to a new dispersal model and inter-herd disease dissemination management tool in support of DAFM's National Disease Control Centre.
- A current 'most complete' version of LPIS is maintained continuously within CVERA
- GIS support for a broad range of studies, including:
  - DAFM Veterinary Laboratory Service. CVERA performed a preliminary analysis on the inverse relationship between submissions to a specific laboratory and the distance to the laboratory.
  - Vaccine trial areas. GIS were used initially to define the current vaccine trial areas, with support continuing throughout the study period.
  - Spatial support for testing and surveillance programs e.g. bluetongue and Schmallenberg.
  - Spatial statistics on sett distance to index herds.
  - Provided spatial statistics on DVO catchment areas for administrative decision making.
  - Clegg et al., 2013. The impact of animal introductions during herd restrictions on future herd-level bovine tuberculosis risk. *Preventive Veterinary Medicine* 109, 246-257.
  - White et al., 2013. The importance of 'neighbourhood' in the persistence of bovine tuberculosis in Irish cattle herds. *Preventive Veterinary Medicine* 110, 346-355.
  - Sheridan et al., in press. The impact of an integrated wildlife and bovine tuberculosis eradication programme in Ireland.
  - Martin et al. Galway vaccine area dual carriageway project.

## *University College Dublin*

- GIS support for a range of studies, including:
  - De Waal et al. Spatio-temporal modelling of parasite distribution and abundance at the local, regional and area-wide scale.
  - De Waele et al. Epidemiological studies on *Cryptosporidium parvum* excreted by cattle in Ireland. PhD thesis.
  - Zintl et al. National survey for *Babesia divergens* prevalence and predictive model.

## Other

- GIS support for a range of studies, including:
  - Graham et al, 2013. Herd-level factors associated with the presence of bovine viral diarrhoea virus in herds participating in the voluntary phase of the Irish national eradication programme. *Preventive Veterinary Medicine* 112, 99-108.
  - O'Doherty et al., 2013. Temporal trends in bulk milk antibodies to *Salmonella*, *Neospora caninum* and *Leptospira interrogans* serovar *hardjo* in Irish dairy herds. *Preventive Veterinary Medicine* 109, 343-348.
  - Sayers et al., 2013. Implementing biosecurity measures on dairy farms in Ireland. *The Veterinary Journal* 197, 259-267.
  - Clegg et al., in press. Risk factors associated with increased mortality of farmed Pacific oysters in Ireland during 2011. *Preventive Veterinary Medicine*.
  - Bloemhoff et al. Determination of the prevalence of *Ostertagia ostertagi*, *Fasciola hepatica* and *Dictyocaulus viviparus* in Irish dairy herds using bulk milk analysis and examination of the impact of these parasites on the productivity of those herds.
  - Kelly et al. Seasonal and geographical bodyweight trends in British and Irish badgers.
  - Moran et al. Estimating the current deer population in Ireland and examining the potential deer to livestock overlap.
  - Animal Health Ireland, BVD analysis.
  - Programme maps for Animal Health Ireland.



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## Database support

Isabella Higgins

### *Department of Agriculture, Food and the Marine*

- Creation of episode-based data for 1989-2013 for inclusion in DAFM documentation, user guides and reports. Episode program validation with AHCS breakdowns from 2005 onwards.
- Maintenance and conversion of DAFM data (AHCS & AIMS) to SAS format for projects.
- Generation of data for use in annual APT and bTB incidence maps.
- Update of national summary tables for bTB from 1989-2013.
- Validation of data for a project entitled 'Factors contributing to sample quality for the BSE active surveillance programme in the Republic of Ireland'.
- Provision of badger capture data for Parliamentary questions.
- *Ad-hoc* reports on laboratory tests, episode duration validation re-coding of oedema in bTB file.
- Calf wastage study.
- Data for a 'Retrospective study to examine temporal trends in bTB over a 20 year period in Ireland from 1993 to 2012'.
- Data for a 'Retrospective qualitative and quantitative study to investigate changing characteristics of bTB episodes over a 20 year period in Ireland from 1993 to 2012'.

### *Other*

- Database support for a range of studies, including:
  - More et al., 2013. The effect of alternative testing strategies and bio-exclusion practices on Johne's disease risk in test-negative herds. *Journal of Dairy Science* 96, 1581-1590.
  - Provision of data to the European Food Safety Authority for a project on "Within herd bTB prevalence in infected herds in Ireland" – episode and reactor criteria were used for identification.
  - Provision of data to Teagasc for a project that will identify regions of the bovine genome associated with susceptibility to bTB in cattle to include beef animals in order to elucidate breed effects for the years 2000 to 2012.
  - Data for a SFI Genetics project relating to bovine genetic variation and disease susceptibility.
  - Provision of data for an investigation of the outcomes for animals detected as BVD antigen positives during 2010.
  - Data support for a project focusing on Johne's Disease modelling.



PUBLICATIONS

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## Publications

<i>During 2012 - 2013</i> .....	98
<i>Between 2004 - 2011</i> .....	105

## During 2012 - 2013

### Peer reviewed papers

Abernethy, D.A., Upton, P., Higgins, I.M., McGrath, G., Goodchild, A.V., Rolfe, S.J., Broughan, J.M., Downs, S.H., Clifton-Hadley, R., Menzies, F.D., de la Rúa-Domenech, R., Blissitt, M.J., Duignan, A., More, S.J., 2013. Bovine tuberculosis trends in the UK and the Republic of Ireland, 1995–2010. *Veterinary Record* 172, 312.

Aznar, I., More, S.J., Frankena, K., de Jong, M.C.M., 2013. Estimating the power of a *Mycobacterium bovis* vaccine trial in Irish badgers. *Preventive Veterinary Medicine* 111, 297-303.

Barrett, D., Collins, D.M., McGrath, G., Ó Muireagain, C., 2012. Seroprevalence of Louping Ill virus (LIV) antibodies in sheep submitted for post mortem examination in the North West of Ireland in 2011. *Irish Veterinary Journal* 65, 20.

Berrian, A.M., O’Keeffe, J., White, P.W., Norris, J., Litt, J., More, S.J., Olea-Popelka, F.J., 2012. Risk of bovine tuberculosis for cattle sold out from herds during 2005 in Ireland. *Veterinary Record* 170, 620.

Boland, F., Kelly, G.E., Good, M., More, S.J., 2012. Bovine tuberculosis and udder health in Irish dairy herds. *The Veterinary Journal* 192, 71-74.

Boland, F., O’Grady, L., More, S.J., 2013. Investigating a dilution effect between somatic cell count and milk yield and estimating milk production losses in Irish dairy cattle. *Journal of Dairy Science* 96, 1477-1484.

Byrne, A.W., O’Keeffe, J., Green, S., Sleeman, D.P., Corner, L.A.L., Gormley, E., Murphy, D., Martin, S.W., Davenport, J., 2012. Population estimation and trappability of the European badger (*Meles meles*): implications for tuberculosis management. *PLoS One* 7, e50807.

Byrne, A.W., O’Keeffe, J., Sleeman, D.P., Davenport, J., Martin, S.W., 2013. Impact of culling on relative abundance of the European badger (*Meles meles*) in Ireland. *European Journal of Wildlife Research* 59, 25-37.

Byrne, A.W., O’Keeffe, J., Sleeman, D.P., Davenport, J., Martin, S.W., 2013. Factors affecting European badger (*Meles meles*) capture numbers in one county in Ireland. *Preventive Veterinary Medicine* 109, 128-135.

Byrne, A.W., Sleeman, D.P., O’Keeffe, J., Davenport, J., 2012. The ecology of the Eurasian badger (*Meles meles*) in Ireland: a review. *Biology and Environment: Proceedings of the Royal Irish Academy* 112B, 105-132.

Clegg, T.A., Blake, M., Healy, R., Good, M., Higgins, I.M., More, S.J., 2013. The impact of animal introductions during herd restrictions on future herd-level bovine tuberculosis risk. *Preventive Veterinary Medicine* 109, 246-257.

Collins, J.A., More, S.J., Hanlon, A., Wall, P.G., McKenzie, K., Duggan, V., 2012. Use of qualitative methods to identify solutions to selected equine welfare problems in Ireland. *Veterinary Record* 170, 442.

Corner, L.A.L., Gormley, E., 2012. Mycobacterial infections in multiple species: Implications for diagnosis and control. *The Veterinary Journal* 191, 141-142.

Corner, L.A.L., Gormley, E., Pfeiffer, D.U., 2012. Primary isolation of *Mycobacterium bovis* from bovine tissues: conditions for maximising the number of positive cultures. *Veterinary Microbiology* 156, 162-171.

Corner, L.A.L., O’Meara, D., Costello, E., Lesellier, S., Gormley, E., 2012. The distribution of *Mycobacterium bovis* infection in naturally infected badgers. *The Veterinary Journal* 194, 166-172.

Cowley, D.J.B., Clegg, T.A., Doherty, M.L., More, S.J., 2012. Bovine viral diarrhoea virus seroprevalence and vaccination usage in dairy and beef herds in the Republic of Ireland. *Irish Veterinary Journal* 65, 16.

Cullinane, M., O'Sullivan, E., Collins, G., Collins, D.M., More, S.J., 2012. Veterinary certificates for emergency or casualty slaughter bovine animals in the Republic of Ireland: are the welfare needs of certified animals adequately protected? *Animal Welfare* 21, 61-67.

De Waele, V., Van den Broeck, F., Huyse, T., McGrath, G., Higgins, I., Speybroeck, N., Berzano, M., Raleigh, P., Mulcahy, G., Murphy, T., 2013. Panmictic structure of the *Cryptosporidium parvum* population in Irish calves: Influence of prevalence and host movement. *Applied and Environmental Microbiology* 79, 2534-2541.

Devitt, C., Kelly, P., Blake, M., Hanlon, A., More, S.J., 2013. Veterinary challenges to providing a multi-agency response to the human aspect of farm animal welfare problems in Ireland. *Revue scientifique et technique / Office international des épizooties (OIE Scientific and Technical Review)* 32, 657-668.

Devitt, C., McKenzie, K., More, S.J., Heanue, K., McCoy, F., 2013. Opportunities and constraints to improving milk quality in Ireland: enabling change through collective action. *Journal of Dairy Science* 96, 2661-2670.

Duignan, A., Good, M., More, S.J., 2012. Quality control in the national bovine tuberculosis control programme in Ireland. *Revue scientifique et technique / Office international des épizooties (OIE Scientific and Technical Review)* 31, 845-860.

Dwane, A.M., More, S.J., Blake, M., McKenzie, K., Hanlon, A.J., 2013. Farmers' self-reported perceptions and behavioural impacts of a welfare scheme for suckler beef cattle in Ireland. *Irish Veterinary Journal* 66, 1.

Finlay, E.K., Berry, D.P., Wickham, B., Gormley, E., Bradley, D.G., 2012. A genome wide association scan of bovine tuberculosis susceptibility in Holstein-Friesian dairy cattle. *PLoS One* 7, e30545.

Furphy, C., Costello, E., Murphy, D., Corner, L.A., Gormley, E., 2012. DNA typing of *Mycobacterium bovis* isolates from badgers (*Meles meles*) culled from areas in Ireland with different levels of tuberculosis prevalence. *Veterinary Medicine International* 2012, 742478.

Gallagher, M.J., Higgins, I.M., Clegg, T.A., Williams, D.H., More, S.J., 2013. Comparison of bovine tuberculosis recurrence in Irish herds between 1998 and 2008. *Preventive Veterinary Medicine* 111, 237-244.

Georgiev, M., Afonso, A., Neubauer, H., Needham, H., Thiéry, R., Rodolakis, A., Roest, H.J., Stärk, K.D., Stegeman, J.A., Vellema, P., van der Hoek, W., More, S.J., 2013. Q fever in humans and farm animals in four European countries, 1982 to 2010. *Eurosurveillance* 18, 20407.

Geraghty, T., O'Neill, R., More, S.J., O'Grady, L., 2012. Dynamics of individual animal Bovine Herpes Virus-1 antibody status on 9 commercial dairy herds. *Research in Veterinary Science* 93, 143-149.

Gormley, E., Corner, L.A.L., 2013. Control strategies for wildlife tuberculosis in Ireland. *Transboundary and Emerging Diseases* 60, S1, 128-135.

Gormley, E., Doyle, M., Duignan, A., Good, M., More, S.J., Clegg, T.A., 2013. Identification of risk factors associated with disclosure of false positive bovine tuberculosis reactors using the gamma-interferon (IFN $\gamma$ ) assay. *Veterinary Research* 44, 117.

Graham, D.A., Clegg, T.A., Lynch, M., More, S.J., 2013. Herd-level factors associated with the presence of bovine viral diarrhoea virus in herds participating in the voluntary phase of the Irish national eradication programme. *Preventive Veterinary Medicine* 112, 99-108.

Harrington, R., O'Donovan, G., McGrath, G., 2013. Integrated Constructed Wetlands (ICW) working at the landscape scale: The Anne Valley project, Ireland. *Ecological Informatics* 14, 104-107.

Harley, S., More, S.J., Boyle, L., O'Connell, N., Hanlon, A., 2012. Good animal welfare makes economic sense: potential of pig abattoir meat inspection as a welfare surveillance tool. *Irish Veterinary Journal* 65, 11.

Harley, S., More, S.J., O'Connell, N.E., Hanlon, A., Teixeira, D., Boyle, L., 2012. Evaluating the prevalence of tail biting and carcass condemnations in slaughter pigs in the Republic and Northern Ireland, and the potential of abattoir meat inspection as a welfare surveillance tool. *Veterinary Record* 171, 621.

Jin, R., Good, M., More, S.J., Sweeney, C., McGrath, G., Kelly, G., 2013. An association between rainfall and bovine TB in Wicklow, Ireland. *Veterinary Record* 173, 452.

Kelly, D.J., Robertson, A., Murphy, D., Fitzsimons, T., Costello, E., Gormley, E., Corner, L.A.L., Marples, N.M., 2012. Trophic enrichment factors for blood serum in the European badger (*Meles meles*). *PLoS ONE* 7, e53071.

Kelly, P.C., More, S.J., Blake, M., Higgins, I., Clegg, T.A., Hanlon, A.J., 2013. Validation of key indicators in cattle farms at high risk of animal welfare problems: a qualitative case-control study. *Veterinary Record* 172, 314.

Lane, E.A., Crowe, M.A., Beltman, M.E., More, S.J., 2013. The influence of cow and management factors on reproductive performance of Irish seasonal calving dairy cows. *Animal Reproduction Science* 141, 34-41.

MacHugh, D.E., Taraktoglou, M., Killick, K.E., Nalpas, N.C., Browne, J.A., Park, S.D., Hokamp, K., Gormley, E., Magee, D.A., 2012. Pan-genomic analysis of bovine monocyte-derived macrophage gene expression in response to *in vitro* infection with *Mycobacterium avium* subspecies *paratuberculosis*. *Veterinary Research* 43, 25.

Magee, D.A., Taraktoglou, M., Killick, K.E., Nalpas, N.C., Browne, J.A., Park, S.D., Conlon, K.M., Lynn, D.J., Hokamp, K., Gordon, S.V., Gormley, E., MacHugh, D.E., 2012. Global gene expression and systems biology analysis of bovine monocyte-derived macrophages in response to *in vitro* challenge with *Mycobacterium bovis*. *PLoS One* 7, e32034.

Mee, J.F., Geraghty, T., O'Neill, R., More, S.J., 2012. Bioexclusion of diseases from dairy and beef farms: Risks of introducing infectious agents and risk reduction strategies. *The Veterinary Journal* 194, 143-150.

Meskell, P., Devitt, C., More, S.J., 2013. Challenges to quality testing for bovine tuberculosis in Ireland: perspectives from major stakeholders. *Veterinary Record* 173, 94.

Metcalf, L.V.A., More, S.J., Duggan, V., Katz, L.M., 2013. A retrospective study of horses investigated for weight loss despite a good appetite (2002-2011). *Equine Veterinary Journal* 45, 340-345.

More, S.J., 2012. Evidence is at the core of scientific method: A challenge for clinicians. *The Veterinary Journal* 191, 11-12.

More, S.J., Clegg, T.A., Lynch, P.J., O'Grady, L., 2013. The effect of somatic cell count data adjustment and interpretation, as outlined in European Union legislation, on herd eligibility to supply raw milk for processing of dairy products. *Journal of Dairy Science* 96, 3671-3681.

More, S.J., Clegg, T.A., O'Grady, L., 2012. Insights into udder health and intramammary antibiotic usage on Irish dairy farms during 2003-2010. *Irish Veterinary Journal* 65, 7.

More, S.J., Sergeant, E.S.G., Strain, S., Cashman, W., Kenny, K., Graham, D., 2013. The effect of alternative testing strategies and bio-exclusion practices on Johne's disease risk in test-negative herds. *Journal of Dairy Science* 96, 1581-1590.

Murray, D., Clegg, T.A., More, S.J., 2012. Evaluation of single reactor bovine tuberculosis breakdowns based on analysis of reactors slaughtered at an Irish export meat plant. *Veterinary Record* 170, 516.

Nalpas, N.C., Park, S.D., Magee, D.A., Taraktoglou, M., Browne, J.A., Conlon, K.M., Rue-Albrecht, K., Killick, K.E., Hokamp, K., Lohan, A.J., Loftus, B.J., Gormley, E., Gordon, S.V., MacHugh, D.E., 2013. Whole-transcriptome, high-throughput RNA sequence analysis of the bovine macrophage response to *Mycobacterium bovis* infection *in vitro*. *BMC Genomics* 14, 230.

Nam, H.-M., Yoon, H., Kim, C.-H., More, S.J., Kim, S.J., Lee, B.-Y., Park, C.-K., Jeon, J.-M., Wee, S.-H., 2012. Epidemiological characteristics of bovine brucellosis in Korea, 2000-2004. *Korean Journal of Veterinary Research* 52, 19-24.

Olea-Popelka, F.J., Freeman, Z., White, P., Costello, E., O'Keeffe, J., Frankena, K., Martin, S.W., More, S.J., 2012. Relative effectiveness of Irish factories in the surveillance of slaughtered cattle for visible lesions of tuberculosis, 2005-2007. *Irish Veterinary Journal* 65, 2.

Palmer, M.V., Thacker, T.C., Waters, W.R., Gortázar, C., Corner, L.A.L., 2012. *Mycobacterium bovis*: A model pathogen at the interface of livestock, wildlife and humans. *Veterinary Medicine International* 2012, 236205.

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Ryan, E.G., Leonard, N., O'Grady, L., Doherty, M.L., More, S.J., 2012. Herd-level risk factors associated with *Leptospira* Hardjo seroprevalence in beef/suckler herds in the Republic of Ireland. *Irish Veterinary Journal* 65, 6.

Ryan, E.G., Leonard, N., O'Grady, L., More, S.J., Doherty, M.L., 2012. Seroprevalence of *Leptospira* Hardjo in the Irish suckler cattle population. *Irish Veterinary Journal* 65, 8.

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White, P.W., Martin, S.W., de Jong, M.C.M., O'Keeffe, J., More, S.J., Frankena, K., 2013. The importance of 'neighbourhood' in the persistence of bovine tuberculosis in Irish cattle herds. *Preventive Veterinary Medicine* 110, 346-355.

## Scientific opinions

*S.J. More [UCD CVERA] with other members of the Panel on Animal Health and Welfare (AHAW) of the European Food Safety Authority [EFSA]*

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on the use of animal-based measures to assess welfare in pigs. *EFSA Journal* 10, 2512.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Guidance on risk assessment for animal welfare. *EFSA Journal* 10, 2513.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on the use of animal-based measures to assess welfare of dairy cows. *EFSA Journal* 10, 2554.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on swine vesicular disease and vesicular stomatitis. *EFSA Journal* 10, 2631.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on foot-and-mouth disease in Thrace. *EFSA Journal* 10, 2635.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on the welfare of cattle kept for beef production and the welfare in intensive calf farming systems. *EFSA Journal* 10, 2669.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on the electrical requirements for water-bath stunning equipment applicable for poultry. *EFSA Journal* 10, 2757.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on Review of the European Union Summary Report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2009 and 2010 specifically for the data related to bovine tuberculosis, Echinococcus, Q fever, brucellosis and non-food borne diseases. *EFSA Journal* 10, 2765.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Statement on the use of animal-based measures to assess the welfare of animals. *EFSA Journal* 10, 2767.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on the use of animal-based measures to assess welfare of broilers. *EFSA Journal* 10, 2774.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on animal health risk mitigation treatments as regards imports of animal casings. *EFSA Journal* 10, 2820.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on infectious salmon anaemia (ISA). *EFSA Journal* 10, 2971.

EFSA Panel on Animal Health and Welfare (AHAW), 2012. Scientific opinion on the use of a gamma interferon test for the diagnosis of bovine tuberculosis. *EFSA Journal* 10, 2975.

EFSA Panel on Animal Health and Welfare (AHAW), 2013. Scientific opinion on Review of the European Union Summary Report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks - Terms of reference 2 to 7. *EFSA Journal* 11, 3074.

EFSA Panel on Animal Health and Welfare (AHAW), 2013. Scientific opinion on the risk of entry of *Aethina tumida* and *Tropilaelaps* spp. in the EU. *EFSA Journal* 11, 3128.

EFSA Panel on Animal Health and Welfare (AHAW), 2013. Scientific opinion on Rift Valley Fever. *EFSA Journal* 11, 3180.

EFSA Panel on Animal Health and Welfare (AHAW), 2013. Scientific opinion on the electrical parameters for the stunning of lambs and kid goats. *EFSA Journal* 11, 3249.

EFSA Panel on Animal Health and Welfare (AHAW), 2013. Scientific opinion on the use of carbon dioxide for stunning rabbits. *EFSA Journal* 11, 3250.

EFSA Panel on Animal Health and Welfare (AHAW), European Centre for Disease Prevention and Control, European Medicines Agency, 2013. Scientific opinion on the possible risks posed by the influenza A (H3N2v) virus for animal health and its potential spread and implications for animal and human health. *EFSA Journal* 11, 3383.

EFSA Panel on Animal Health and Welfare (AHAW), 2013. Scientific opinion on monitoring procedures at slaughterhouses for bovines. *EFSA Journal* 11, 3460.

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*Simon More [UCD CVERA] and Eamonn Gormley [UCD TB Diagnostics and Immunology Research Centre] with other members of a working group ('Tuberculose/test de diagnostic par dosage de l'interféron gamma') at Anses (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail [the French Agency for Food, Environmental and Occupational Health & Safety]).*

Avis de l'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses) relatif à l'utilisation de certains tests de diagnostic de la tuberculose bovine

- a. Premier avis (sur deux) consacré aux caractéristiques intrinsèques des tests IFN $\gamma$ , à leurs seuils de positivité et à l'estimation du risque lié à l'utilisation «en série» du test IFN $\gamma$
- b. Deuxième partie: proposition d'un protocole décisionnel simplifié et utilisable sur l'ensemble du territoire français métropolitain

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