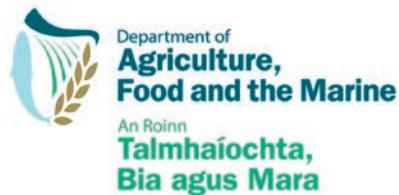


The Centre for Veterinary Epidemiology and Risk Analysis

The TB Diagnostics and Immunology Research Centre

The Badger Vaccine Project

Biennial Report, 2014-15



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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 2014 and 2015.

Simon J. More
Eamonn Gormley
Leigh Corner
UCD School of Veterinary Medicine
University College Dublin
Belfield, Dublin 4, Ireland

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 2014-15:

University College Dublin

- UCD School of Veterinary Medicine
- UCD School of Biology and Environmental Science

Rest of the Republic of Ireland

- DAFM State Veterinary Service
- DAFM Veterinary Laboratory Service
- Animal Health Ireland
- Enfer Scientific
- Forenaghts Stud
- Growth from Knowledge, GfK-Ireland
- Irish Cattle Breeding Federation
- Irish Equine Centre
- Marine Harvest Ireland
- Marine Institute
- MSD Animal Health
- Private consultants
- TCD Smurfit Institute of Genetics
- Teagasc
- The Veterinary Department of Cork County Council
- UCC School of Biological, Earth and Environmental Sciences

United Kingdom

- Agri-Food and Biosciences Institute, Belfast, Northern Ireland
- Animal Health & Welfare Northern Ireland, Dungannon, Northern Ireland
- Growth from Knowledge, GfK Kynetec Ltd., Berkshire, England
- Institute for Global Food Security, Northern Ireland Technology Centre, Queens University Belfast, Belfast, Northern Ireland
- School of Veterinary Science, University of Liverpool, Neston, Cheshire, England
- Scottish Centre for Production Animal Health and Food Safety, University of Glasgow Veterinary School, Glasgow, Scotland
- Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, Tubney, Abingdon, England

Rest of the world

- AusVet Animal Health Services Pty Ltd., Lyon, France
- Biosecurity Advisory Service, Australia
- Centre for Applied Health Economics, Menzies Health Institute Queensland, Griffith University, Queensland, Australia
- CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBio Laboratório Associado, Universidade do Porto, Portugal
- College of Veterinary Medicine, Iowa State University, Ames, USA

- Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PEI, Canada
- Department of Medicine & Epidemiology, School Veterinary Medicine, University of California, Davis, USA
- Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada
- Escola Universitária Vasco da Gama, Coimbra, Portugal
- Greencross Vets, Brisbane, Queensland, Australia
- Private consultant, Howard Springs, Northern Territory, Australia
- INRA, Oniris, LUNAM Université, Biologie, Epidémiologie et Analyse de Risque en Santé Animale, Nantes, France
- Quantitative Veterinary Epidemiology Group, Wageningen Institute of Animal Sciences, Wageningen University, Wageningen, The Netherlands
- SaBio IREC, Instituto de Investigación en Recursos Cinegéticos (CSIC-UCLM-JCCM), Ciudad Real, Spain
- School of BioSciences, University of Birmingham, Valeilles, France
- University of Guelph, Guelph, Ontario, Canada
- Asia-Pacific Centre for Animal Health, Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, VIC, Australia

The TB Diagnostics and Immunology Research Centre

Staff from the UCD laboratory acknowledge the help and support of District Veterinary Office (DVO) staff in providing samples for the IFN- γ 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 and Plant Health Association (APHA, Weybridge, England) are also thanked for contributing technical expertise for the research programme.

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Personnel

The UCD Centre for Veterinary Epidemiology and Risk Analysis

Board of management

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- Simon J. More (UCD)

School, College and University representatives

- Vice-President for Research, Innovation and Impact
- 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 (until Summer 2015)

Staff

Simon J. More (UCD) (Director)

Inma Aznar (DAFM)

Andrew Byrne (UCD) (until Summer 2014)

Tracy A. Clegg (UCD)

Daniel M. Collins (UCD)

Isabella Higgins (UCD) (until Summer 2014)

Erik Houtsma (UCD) (from September 2014)

Guy McGrath (UCD)

Jamie Tratalos (UCD) (from September 2014)

Associates

Damien Barrett (DAFM Veterinary Laboratory Service)

Rob Doyle (DAFM)

Anthony Duignan (DAFM)

David Graham (Animal Health Ireland)

Elizabeth Lane (DAFM)

Gerard Murray (DAFM)

Jarlath O'Connor (DAFM)

Luke O'Grady (UCD School of Veterinary Medicine)

James O'Keeffe (DAFM)

Fiona Reardon (Animal Health Ireland)

Eoin Ryan (UCD School of Veterinary Medicine)

Paul White (DAFM)

Tadaishi Yatabe (University of California, Davis, CA, USA)

Consultants

Wayne Martin, University of Guelph, Canada

Francisco Olea-Popelka, Department of Clinical Sciences, Colorado State University, United States of America

Mart de Jong and Klaas Frankena, University of Wageningen, The Netherlands

The TB Diagnostics and Immunology Research Centre

Eamonn Gormley

Tara Fitzsimons

Mairéad Doyle

Kevina McGill

The Badger Vaccine Project

Eamonn Gormley

Naomi Fogarty

Leigh Corner

Julianne Molloy

Deirdre Ní Bhuachalla

Anthony Duignan (DAFM)

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, including the national eradication programme for bovine tuberculosis;
- Work in support of Animal Health Ireland (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, Schmallenberg viral infection), 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. Over the course of nine studies with captive badgers, we have demonstrated as proof of principle 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 licensing of the vaccine as a veterinary medicine. In our most recent captive badger studies we have shown that lower doses of oral BCG vaccine are equally effective at protecting badgers against experimental challenge, compared with the standard dose (10^7 colony forming units). This has implications for cost of manufacture of an oral vaccine. We have also conducted a study to investigate the distribution of BCG in orally vaccinated badgers over a period of twelve weeks. This is one of a series of pre-regulatory studies required to address the safety of oral BCG vaccination in badgers. Complementary studies are being carried out by collaborating groups at APHA UK and ANSES / DGAL, Office for Animal Health (France). 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 completed. The data is being compiled and analysed with a view to publication in 2016. In addition to the vaccination research programme, the UCD laboratory is also contributing to the development and validation of new serological tests, and in evaluating advanced transcriptomic tests to better understand the specific immune responses to vaccination and infection.

TB Diagnostics and Immunology Research Centre

The gamma-interferon (IFN- γ) assay is used as a tool by ERAD to assist in the eradication of bovine tuberculosis from the national cattle herd. While the first stage of the assay is currently conducted at UCD and the Sligo Regional Veterinary Laboratory, all of the second stage ELISA testing is carried out in the laboratory based at UCD. In the period 2014-2015, approx. 52,000 blood samples were submitted to the laboratory for testing. This represents close to a 100% increase compared with submission numbers for the previous two years. The samples originated mainly from:

- bovine reactor re-test herds, where the IFN- γ test was used to diagnose infected animals that were missed by the SICTT (false negatives). Approximately 20% of all samples submitted were positive to IFN- γ .
- SICTT reactor animals where the IFN- γ test was used to confirm the exposure status of SICTT positive animals. The correlation between positive SICTT result and positive IFN- γ results exceeds 80%, and provides a useful measure of the quality of the skin test. The IFN- γ testing on skin test reactors was conducted as part of the ERAD Quality Assurance programme (lead by Anthony Duignan SVI).

The laboratory continues to conduct research with a view to improving the performance of the assay under Irish conditions. Having investigated the risk factors associated with disclosure of false positive reactors using the IFN- γ assay, the laboratory is initiating studies to investigate the underlying causes of false positive results in the skin test and IFN- γ assay. As the decline in overall reactor numbers continues these false positives will constitute a higher proportion of the reactor population and may be a serious impediment to future eradication of the disease in cattle. The laboratory is also involved in studies using the IFN- γ assay to estimate the potency of tuberculin. This will be important when the pool of reactor animals suitable for skin test evaluation of tuberculin potency declines to low numbers.

Further information

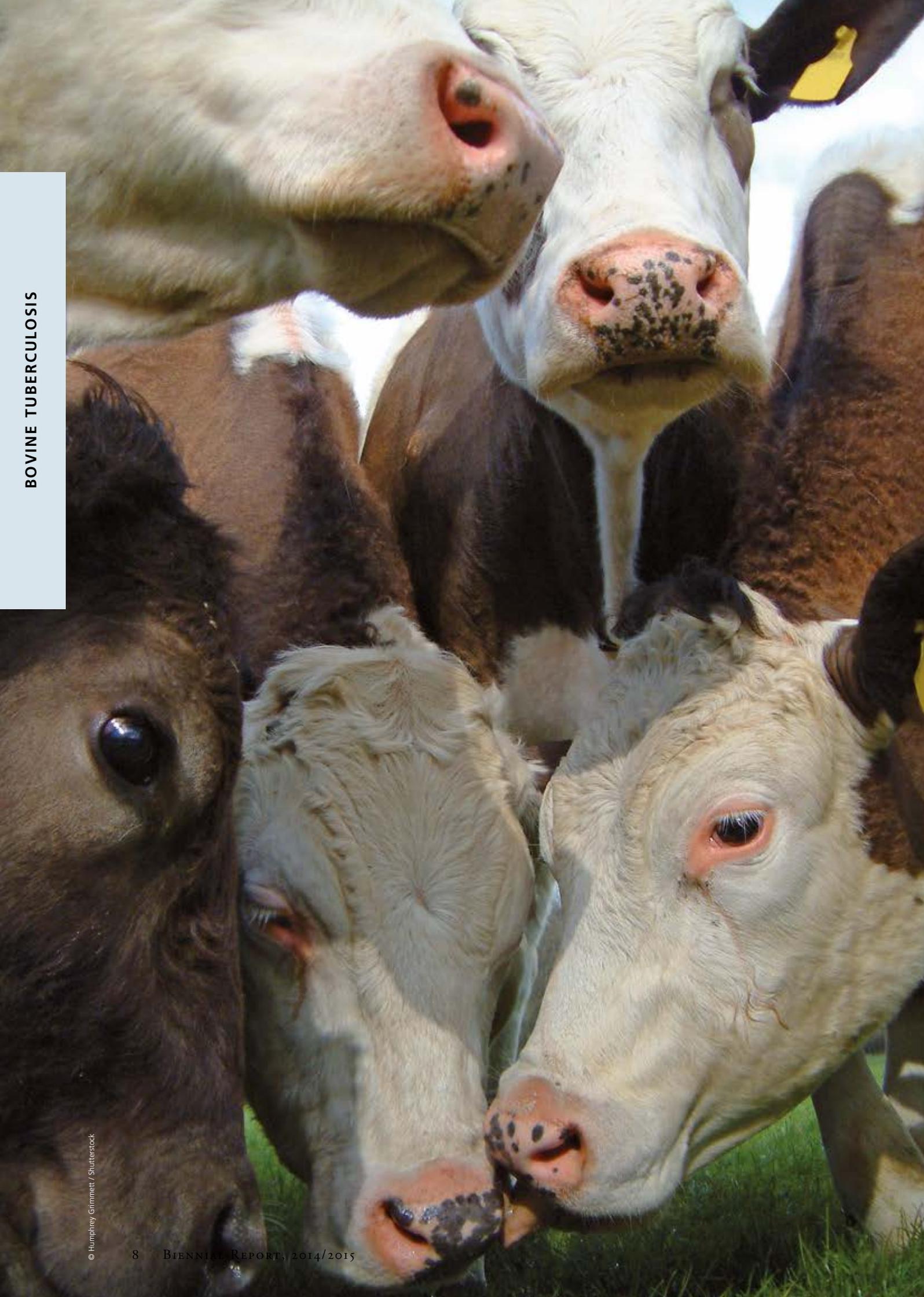
In this report, projects are either:

- Complete, which includes those projects where relevant peer-reviewed papers, or equivalent, have been published in 2014/15, 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. Guidelines for the transparent reporting of specific study types (for example, the CONSORT statement for transparent reporting of trials, 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.

BOVINE TUBERCULOSIS





Bovine tuberculosis

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Improving surveillance

Field-based surveillance

The temporal and spatial distribution of singleton reactors in Ireland: exploring the spatial variation in specificity of the TB test

McGrath, G. et al.

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.

Factory-based surveillance

Risk factors for animals presenting with a confirmed bTB lesion at slaughter, from herds with no evidence of within-herd transmission

Clegg, T.A. et al.

UCD CVERA

A substantial number of confirmed bovine tuberculosis (bTB) lesions are detected in non-reactor animals, from Officially Tuberculosis Free (OTF) herds at slaughter. It is anticipated that at least some are presenting with residual, possibly latent, infection. Further, it is uncertain whether some of these could have been detected sooner. In this study we investigate risk factors for non-reactor animals presenting with a confirmed bTB lesion at slaughter, but with no evidence of within-herd transmission. In particular we are interested in whether these animals could have been infected, and potentially detected, during earlier field surveillance.

Monitoring the relative effectiveness of Irish factories in the surveillance of slaughtered cattle for visible lesions of tuberculosis: An update for years 2008-2010

Olea-Popelka, F. et al.

College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, USA

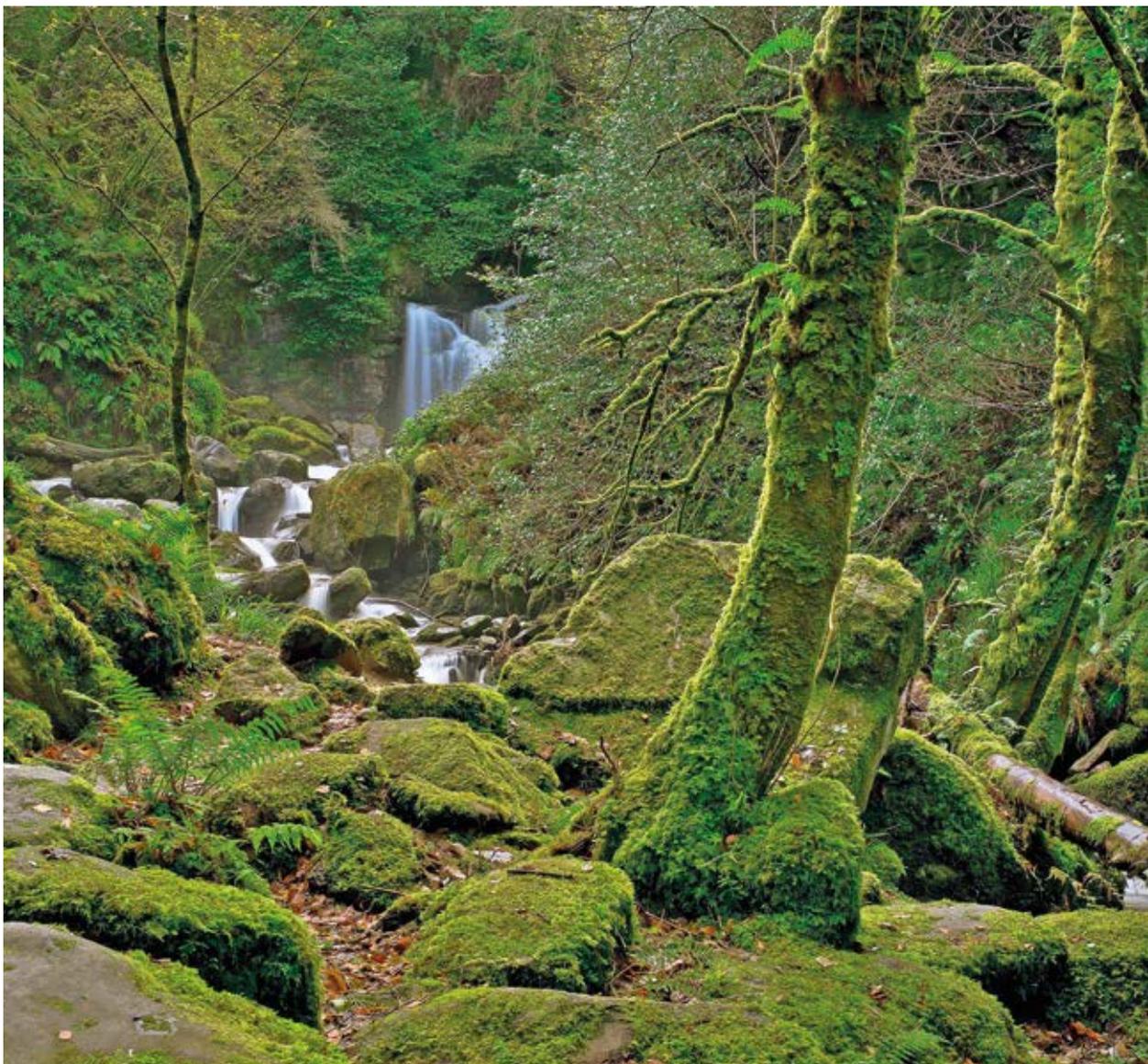
In Ireland, every animal is examined at slaughter for its fitness for human consumption. The detection of gross (visible) tuberculous lesions at slaughter has proved to be an essential component of the overall bovine tuberculosis (TB) surveillance system for the cattle population. The aim of this study has been to monitor and determine the relative effectiveness of factories in submitting and subsequently in having suspect lesions confirmed as bovine tuberculosis (TB) lesions from cattle from attested herds (i.e. herds classified free of bovine TB). Thus, this study provides an update for the period 2008-2010 that serves as comparison to previous years (2005-2007).

Estimating the impact of potential changes to meat inspection on the sensitivity of abattoir surveillance for bovine tuberculosis in Ireland

Willeberg, P. et al.

Department of Epidemiology, National Veterinary Institute, Technical University of Denmark, Copenhagen, Denmark

The European Food Safety Authority (EFSA) has recently published a series of opinions to assess the impact of changing from the current meat inspection procedures (CMI) to alternative visual-only inspection (VOI) procedures. These proposed changes seek to increase the safety of products from the main meat-producing species by minimizing the risk of microbiological cross-contamination, e.g. caused by palpation and incision of carcasses. Potential negative effects of these changes for animal health surveillance have also been evaluated. Some EU countries, including Ireland, do not have OTF (Official Tuberculosis Freedom) status, and field-testing and routine meat inspection (MI) are both used to detect cases of bovine tuberculosis (bTB). Concern has been raised that changes from CMI to VOI will adversely affect the effectiveness of bTB surveillance in these countries. This study seeks to estimate the impact of proposed changes from CMI to VOI on the probability of detecting one or more animals with a confirmed bTB lesion in non-restricted herds in Ireland.



Improving management of high risk herds

Evaluating the use of gamma-interferon in the national bTB eradication programme

Clegg, T.A. et al.

UCD CVERA

The gamma-interferon assay (IFN γ) is often used as an ancillary diagnostic test alongside the single intradermal comparative tuberculin test (SICTT) in order to detect *Mycobacterium bovis* infected cattle. The IFN γ assay has higher test sensitivity but lower specificity than SICTT. As a consequence, and particularly due to the potential for disclosing false-positive results, the γ IFN test is generally applied to known heavily infected herds in Ireland, to identify infected animals that are missed by the SICTT, and where residual infection is suspected. The aim of this study was to assess whether comprehensive use of the IFN γ during a severe bovine tuberculosis breakdown can reduce the length of a restriction and decrease the risk of future breakdowns.

Future risk of single intradermal test positive animals in high risk herds

Lane, E.A. et al.

DAFM

Bovine tuberculosis (bTB) is an important infectious disease of cattle that constitutes a public health risk due to its zoonotic potential and is subject to regulatory in many countries. The single intradermal tuberculin test (SIT) and the single intradermal comparative tuberculin test (SICTT) are widely used, the latter to address non-specific sensitisation due to exposure to other mycobacteria. Previous unpublished work suggested that 34 % (in 2009) and 38 % (2012) of Irish herds considered bTB-free based on the use of the SICTT would have been classified positive if the SIT had been used. This study will seek to determine the future bTB risk of these SIT responder animals within Irish cattle herds.

Risk of bovine tuberculosis at the animal level in Ireland

Olea-Popelka, F. et al.

College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, USA

The national bovine TB control programme in Ireland is primarily herd-based, and most actions (including most relating to surveillance and control) are focused on the herd rather than the individual animals. Understandably, most studies in Ireland have also focused on the herd, with few being conducted to assess the risk of bovine TB at the animal level. The current study seeks to provide new information of the role of animal movements in future disease risk at the animal level. In this study, we will expand previously published work (Berrian et al., 2012) to quantify and compare the risk of bovine TB among animals sold out from attested Irish herds with different bovine TB history including past breakdowns severity as well as including the outputs of ecological research on badgers, to assess the impact of badger population dynamics on bovine TB among cattle.

Supporting studies

Genetics, milk production

Bacteriological diagnosis and molecular strain typing of *Mycobacterium bovis* and *Mycobacterium caprae*

Gormley, E.¹, Corner, L.A.L.¹, Costello, E.², Rodriguez-Campos, S.³

¹ UCD School of Veterinary Medicine, ² DAFM Veterinary Laboratory Service, ³ Institute of Veterinary Bacteriology, Vetsuisse Faculty, University of Bern, Bern, Switzerland

Research in Veterinary Science 97 (suppl.), S30-S43 (2014)

The primary isolation of a *Mycobacterium sp.* of the *Mycobacterium tuberculosis* complex from an infected animal provides a definitive diagnosis of tuberculosis. However, as *Mycobacterium bovis* and *Mycobacterium caprae* are difficult to isolate, particularly for animals in the early stages of disease, success is dependent on the optimal performance of all aspects of the bacteriological process, from the initial choice of tissue samples at post-mortem examination or clinical samples, to the type of media and conditions used to cultivate the microorganism. Each step has its own performance characteristics, which can contribute to sensitivity and specificity of the procedure, and may need to be optimized in order to achieve the gold standard diagnosis. Having isolated the slow-growing mycobacteria, species identification and fine resolution strain typing are keys to understanding the epidemiology of the disease and to devise strategies to limit transmission of infection. New technologies have emerged that can now even discriminate different isolates from the same animal. In this review we highlight the key factors that contribute to the accuracy of bacteriological diagnosis of *M. bovis* and *M. caprae*, and describe the development of advanced genotyping techniques that are increasingly used in diagnostic laboratories for the purpose of supporting detailed epidemiological investigations.

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Key hub and bottleneck genes differentiate the macrophage response to virulent and attenuated *Mycobacterium bovis*

Killick, K.E.^{1,2}, Magee, D.A.¹, Park, S.D.E.^{1,3}, Taraktoglou, M.^{1,4}, Browne, J.A.¹, Conlon, K.M.^{5,6}, Nalpas, N.C.¹, Gormley, E.⁵, Gordon, S.V.^{5,7}, MacHugh, D.E.^{1,7}, Hokamp, K.⁸

¹ Animal Genomics Laboratory, UCD School of Agriculture and Food Science, ² Systems Biology Ireland, UCD Conway Institute of Biomolecular and Biomedical Research, ³ IdentiGEN Ltd., ⁴ Biological Agents Unit, Health and Safety Executive, Leeds, United Kingdom, ⁵ UCD School of Veterinary Medicine, ⁶ Science Foundation Ireland, ⁷ UCD Conway Institute of Biomolecular and Biomedical Research, ⁸ TCD Smurfit Institute of Genetics

Frontiers in Immunology 5, 422 (2014)

Mycobacterium bovis is an intracellular pathogen that causes tuberculosis in cattle. Following infection, the pathogen resides and persists inside host macrophages by subverting host immune responses via a diverse range of mechanisms. Here, a high-density bovine microarray platform was used to examine the bovine monocyte-derived macrophage transcriptome response to *M. bovis* infection relative to infection with the attenuated vaccine strain, *M. bovis* Bacille Calmette–Guérin. Differentially expressed genes were identified (adjusted *P*-value ≤ 0.01) and interaction networks generated across an infection time course of 2, 6, and 24 h. The largest number of biological interactions was observed in the 24-h network, which exhibited scale-free network properties. The 24-h network featured a small number of key

hub and bottleneck gene nodes, including *IKBKE*, *MYC*, *NFKB1*, and *EGR1*, that differentiated the macrophage response to virulent and attenuated *M. bovis* strains, possibly via the modulation of host cell death mechanisms. These hub and bottleneck genes represent possible targets for immuno-modulation of host macrophages by virulent mycobacterial species that enable their survival within a hostile environment.

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Innate cytokine profiling of bovine alveolar macrophages reveals commonalities and divergence in the response to *Mycobacterium bovis* and *Mycobacterium tuberculosis* infection

Magee, D.A.¹, Conlon, K.M.², Nalpas, N.C.¹, Browne, J.A.¹, Pirson, C.³, Healy, C.², McLoughlin, K.E.¹, Chen, J.², Vordermeier, H.M.³, Gormley, E.², MacHugh, D.E.^{1,4}, Gordon, S.V.^{2,4}

¹ Animal Genomics Laboratory, UCD School of Agriculture and Food Science, ² UCD School of Veterinary Medicine, ³ Department of Bacteriology, Animal Health and Veterinary Laboratories Agency, New Haw, Addlestone, Surrey, United Kingdom, ⁴ UCD Conway Institute of Biomolecular and Biomedical Research

Tuberculosis 94, 441–450 (2014)

Despite sharing >99.9% genome sequence similarity at the nucleotide level, *Mycobacterium tuberculosis* and *Mycobacterium bovis* — the causative agents of human and bovine tuberculosis, respectively—exhibit distinct host preferences. *M. bovis* can cause disease in both cattle and humans yet rarely transmits between immuno-competent human hosts, while *M. tuberculosis* is a highly successful pathogen of humans that does not sustain in animal populations. Based on the key role played by alveolar macrophages during mycobacterial infection, we hypothesised that the immunological and pathological differences observed in cattle infected with virulent *M. bovis* and *M. tuberculosis* may have a basis in innate immune mechanisms; these differences, in turn, would be reflected at the macrophage mRNA and protein level. To investigate this, we have analysed the transcriptional profile of innate immune genes in bovine alveolar macrophages following 24 and 48 h infection with the genome-sequenced strains, *M. bovis* AF2122/97 and *M. tuberculosis* H37Rv. A bespoke multiplex ELISA was also used to quantify corresponding cytokine secretion in supernatants from the same infected alveolar macrophages. All cytokines showed similar significant patterns of expression (*i.e.* up- or down-regulation) at both the mRNA and protein levels in infected macrophages relative to parallel non-infected controls at the two time points ($P \leq 0.05$). However, significant upregulation and downregulation of several innate immune genes—including *TLR2*, *FOS*, *PIK3IP1*, *CCL4*, *IL1B*, *IL6* and *TNF*—and the CCL-4 protein was observed in the *M. bovis*-infected macrophages relative to the *M. tuberculosis*-infected macrophages 48 h post-infection ($P \leq 0.05$). These results support the hypothesis that the divergent virulence of *M. bovis* and *M. tuberculosis* in cattle has a basis in innate immune mechanisms, which may contribute to host preference within the *M. tuberculosis* complex of strains.

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RNA sequencing provides exquisite insight into the manipulation of the alveolar macrophage by tubercle bacilli

Nalpas, N.C.¹, Magee, D.A.¹, Conlon, K.M.², Browne, J.A.¹, Healy, C.², McLoughlin, K.E.¹, Rue-Albrecht, K.^{1,2}, McGettigan, P.A.¹, Killick, K.E.³, Gormley, E.², Gordon, S.V.^{2,4,5,6}, MacHugh, D.E.^{1,6}

¹ Animal Genomics Laboratory, UCD School of Agriculture and Food Science, ² UCD School of Veterinary Medicine, ³ Systems Biology Ireland, UCD Conway Institute of Biomolecular and Biomedical Research, ⁴ UCD School of Medicine and Medical Science, ⁵ UCD School of Biomolecular and Biomedical Science, ⁶ UCD Conway Institute of Biomolecular and Biomedical Research

Scientific Reports 5, 13629 (2015)

Mycobacterium bovis, the agent of bovine tuberculosis, causes an estimated \$3 billion annual losses to global agriculture due, in part, to the limitations of current diagnostics. Development of next-generation diagnostics requires a greater understanding of the interaction between the pathogen and the bovine host. Therefore, to explore the early response of the alveolar macrophage to infection, we report the first application of RNA-sequencing to define, in exquisite detail, the transcriptomes of *M. bovis*-infected and non-infected alveolar macrophages from ten calves at 2, 6, 24 and 48 hours post-infection. Differentially expressed sense genes were detected at these time points that revealed enrichment of innate immune signalling functions, and transcriptional suppression of host defence mechanisms (e.g., lysosome maturation). We also detected differentially expressed natural antisense transcripts, which may play a role in subverting innate immune mechanisms following infection. Furthermore, we report differential expression of novel bovine genes, some of which have immune-related functions based on orthology with human proteins. This is the first in-depth transcriptomics investigation of the alveolar macrophage response to the early stages of *M. bovis* infection and reveals complex patterns of gene expression and regulation that underlie the immunomodulatory mechanisms used by *M. bovis* to evade host defence mechanisms.

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RNA-seq transcriptional profiling of peripheral blood leukocytes from cattle infected with *Mycobacterium bovis*

McLoughlin, K.E.¹, Nalpas, N.C.¹, Rue-Albrecht, K.¹, Browne, J.A.¹, Magee, D.A.¹, Killick, K.E.¹, Park, S.D.E.¹, Hokamp, K.², Meade, K.G.³, O'Farrelly, C.⁴, Gormley, E.⁵, Gordon, S.V.^{5,6}, MacHugh, D.E.^{1,6}

¹ Animal Genomics Laboratory, UCD School of Agriculture and Food Science, ² TCD Smurfit Institute of Genetics, ³ Teagasc, ⁴ Comparative Immunology Group, School of Biochemistry and Immunology, Trinity Biosciences Institute, Trinity College Dublin, ⁵ UCD School of Veterinary Medicine, ⁶ UCD Conway Institute of Biomolecular and Biomedical Research

Frontiers in Immunology 5, 396 (2014)

Bovine tuberculosis, caused by infection with *Mycobacterium bovis*, is a major endemic disease affecting cattle populations worldwide, despite the implementation of stringent surveillance and control programs in many countries. The development of high-throughput functional genomics technologies, including gene expression microarrays and RNA-sequencing (RNA-seq), has enabled detailed analysis of the host transcriptome to *M. bovis* infection, particularly at the macrophage and peripheral blood level. In the present study, we have analyzed the peripheral blood leukocyte (PBL) transcriptome of eight natural *M. bovis*-infected and eight age- and sex-matched non-infected control Holstein-Friesian animals using RNA-seq. In addition, we compared gene expression profiles generated using RNA-seq with those previously generated using the high-density Affymetrix® GeneChip® Bovine Genome Array platform from the same PBL-extracted RNA. A total of 3,250 differentially expressed (DE) annotated genes were detected in the *M. bovis*-infected samples relative to the controls (adjusted P-value ≤ 0.05), with the number of genes displaying decreased relative expression (1,671) exceeding those with increased relative expression (1,579). Ingenuity® Systems Pathway Analysis (IPA) of all DE genes revealed enrichment for genes with immune function. Notably, transcriptional suppression was observed among several of the top-ranking canonical pathways including *Leukocyte Extravasation Signaling*. Comparative platform analysis demonstrated that RNA-seq detected a larger number of annotated DE genes (3,250) relative to the microarray (1,398), of which 917 genes were common to both technologies and displayed the same direction of expression. Finally, we show that RNA-seq had an increased dynamic range compared to the microarray for estimating differential gene expression.

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Variance components for susceptibility to *Mycobacterium bovis* infection in dairy and beef cattle

Richardson, I.W.^{1,2}, Bradley, D.G.¹, Higgins, I.M.³, More, S.J.^{3,4}, McClure, J.⁵, Berry, D.P.²

¹ Smurfit Institute of Genetics, Trinity College Dublin, ² Teagasc, ³ UCD CVERA, ⁴ UCD School of Veterinary Medicine, ⁵ Irish Cattle Breeding Federation

Genetics Selection Evolution 46, 77 (2014)

Infection of livestock with bovine tuberculosis (bTB; *Mycobacterium bovis*) is of major economical concern in many countries; approximately 15000 to 20000 cattle are infected per year in Ireland. The objective of this study was to quantify the genetic variation for bTB susceptibility in Irish dairy and beef cattle. A total of 105914 cow, 56904 heifer and 21872 steer single intra-dermal comparative tuberculin test records (i.e., binary trait) collected from the years 2001 to 2010 from dairy and beef herds were included in the analysis. Only animal level data pertaining to periods of herd bTB infection were retained. Variance components for bTB were estimated using animal linear and threshold mixed models and co-variances were estimated using sire linear mixed models. Using a linear model, the heritability for susceptibility to bTB in the entire dataset was 0.11 and ranged from 0.08 (heifers in dairy herds) to 0.19 (heifers in beef

herds) among the sub-populations investigated. Differences in susceptibility to bTB between breeds were clearly evident. Estimates of genetic correlations for bTB susceptibility between animal types (i.e., cows, heifers, steers) were all positive (0.10 to 0.64), yet different from one. Furthermore, genetic correlations for bTB susceptibility between environments that differed in herd prevalence of bTB ranged from 0.06 to 0.86 and were all different from one. Genetic trends for bTB susceptibility observed in this study suggest a slight increase in genetic susceptibility to bTB in recent years. Since bTB is of economic importance and because all animals are routinely tested at least once annually in Ireland and some other countries, the presence of genetic variation for bTB susceptibility suggests that bTB susceptibility should be included in a national breeding program to halt possible deterioration in genetic susceptibility to bTB infection.

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A genome wide association study for genetic susceptibility to *Mycobacterium bovis* infection in dairy cattle identifies a susceptibility QTL on chromosome 23

Richardson, I.W. et al.

TCD Smurfit Institute of Genetics & Teagasc

Bovine tuberculosis (bTB; caused by infection with *Mycobacterium bovis*) in cattle is a significant economic concern in many countries, with annual bTB control costs to of bTB costing the UK and Irish governments of approximately €190 million and €63 million, respectively. A genome wide association study for genetic susceptibility to *M. bovis* infection in dairy cattle identifies a susceptibility QTL on chromosome 23. The objective of the present study was to detect regions of the bovine genome associated with bTB susceptibility in Irish dairy cattle and elucidate any likely candidate genes and pathways contributing to these putative quantitative trait loci (QTLs).



Improved understanding of ecology and TB epidemiology

Badger ecology

Estimating badger social-group abundance in the Republic of Ireland using cross-validated species distribution modelling

Byrne, A.W.^{1,2}, Acevedo, P.^{3,4}, Green, S.², O’Keeffe, J.^{1,5}

¹ UCD CVERA, ² Teagasc, ³ CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBio Laboratório Associado, Universidade do Porto, Portugal, ⁴ SaBio IREC, Instituto de Investigación en Recursos Cinegéticos (CSIC-UCLM-JCCM), Ciudad Real, Spain, ⁵ DAFM

Ecological Indicators 43, 94–102 (2014)

The badger (*Meles meles*) is an important wildlife host for bovine tuberculosis (bTB), and is a reservoir of infection to cattle. Reliable indicators of badger abundance at large spatial scales are important for informing epidemiological investigation. Thus, we aimed to estimate badger social group abundance from a large-scale dataset to provide useful information for the management of bTB in the Republic of Ireland (ROI). Robust estimates of species abundance require planned systematic surveying. This is often unfeasible at large spatial scales, resulting in inadequate (biased) data collection. We employed species distributional modelling (SDM) using 7724 badger main-sett (burrow) locations across the ROI at a 1 ha scale. This dataset was potentially biased as surveying was directed towards areas with cattle bTB-breakdowns. In order to manage sampling bias, we developed a model where the environment was sampled using pseudoabsences geographically constrained to the potential survey area only (constrained model), in addition to a model where all of the ROI was sampled (non-constrained model). Models predictive performance 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 (755 km²). Finally, the relationship between predicted probability and observed abundance at local-scale was used to infer number of social-groups at the national level. The geographically constrained model showed moderate discriminatory power, but good calibration in both the internal and external validations. The non-constrained model resulted in higher discrimination but poorer calibration in the internal validation, indicating a limitation for national-scale predictions. Interestingly, there was a strong cubic relationship between predicted probability-classes and observed sett density in the local-area ($R^2 = 0.85$ and 0.96 ; for the non-constrained and the constrained models, respectively). At the national-scale, the preferred model predicted a total of 19,200 (95% Confidence Interval: 12,200–27,900) social groups. Our analyses demonstrated that under a critical perspective large-scale potentially biased datasets can be used to estimate variations in species abundance. The abundance predictions are in keeping with recent independent estimations of the badger population, and will be a valuable index of species abundance for epidemiology (e.g. risk mapping), species management (e.g. informing vaccine strategies) and conservation planning (e.g. assessing population viability).

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Spatial and temporal analyses of metrics of tuberculosis infection in badgers (*Meles meles*) from the Republic of Ireland: Trends in apparent prevalence

Byrne, A.W.^{1,2}, Kenny, K.³, Fogarty, U.⁴, O’Keeffe, J.J.^{1,5}, More, S.J.^{1,6}, McGrath, G.¹, Teeling, M.³, Martin, S.W.⁷, Dohoo, I.R.⁸

¹ UCD CVERA, ² Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast, Northern Ireland, ³ DAFM Veterinary Laboratory Service, ⁴ Irish Equine Centre, ⁵ DAFM, ⁶ UCD School of Veterinary Medicine, ⁷ University of Guelph, Guelph, Ontario, Canada, ⁸ Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PEI, Canada

Preventive Veterinary Medicine 122, 345–354 (2015)

Badgers are a wildlife host of *Mycobacterium bovis*, the causative agent of bovine tuberculosis (bTB), and an important contributor to the epidemiology of bTB in cattle in Ireland and Britain. Repeated culling of badgers in high prevalence cattle bTB areas has been used in the Republic of Ireland as one tool to reduce intra- and interspecific transmission of *M. bovis*. We assessed factors that influenced infection prevalence of culled badgers from 2009 to 2012 ($n = 4948$) where spatial, temporal and intrinsic factor data were available using multivariable modelling. Prevalence appeared higher in western areas than eastern areas of Ireland and badgers were more likely to be test-positive if caught at a sett (burrow system) which was close to other infected setts (spatial clustering of infection). There was a significant positive association between badger test-status and cattle prevalence of *M. bovis* infection at a spatial scale of 1 km around setts. Badgers were more likely to be deemed test positive if they were male (OR: 1.9) or a parous female (OR: 1.7), compared to a female who had never conceived. Our results are consistent with different groups within badger populations having differential exposures and therefore infection risk (for example, parous vs. non-parous females). Furthermore, bTB clusters within the badger population, with greater risk to badgers in setts that are closest to other infected setts. The effective scale of the association of bTB risk between badger and cattle populations may be relatively large in Ireland. Our data indicate that the overall trend in prevalence of *M. bovis* infection in badgers has decreased in Ireland ($P < 0.001$) while controlling for significant confounders over the study period, and follows a longer temporal trend from 2007 to 2013, where unadjusted apparent prevalence declined from 26% to 11% during 2007 to mid-2011, followed by a stable trend between 9 and 11% thereafter ($n = 10,267$).

Preventive Veterinary Medicine, 122, Byrne et al., *Spatial and temporal analyses of metrics of tuberculosis infection in badgers (Meles meles) from the Republic of Ireland: Trends in apparent prevalence*, 345-354, Copyright © 2015, with permission from Elsevier B.V.

Tuberculosis in badgers (*Meles meles*)

Chambers, M.A.¹, Gormley, E.², Corner, L.A.L.², Smith, G.C.¹, Delahay, R.J.¹

¹ Animal and Plant Health Agency, United Kingdom; University of Surrey, Guildford, United Kingdom, ² UCD School of Veterinary Medicine

In Tuberculosis, leprosy and mycobacterial diseases of man and animals: the many hosts of mycobacteria, 296-312 (2015)

This chapter is published in the book “*Tuberculosis, leprosy and mycobacterial diseases of man and animals: the many hosts of mycobacteria*”. The chapter outlines a number of aspects relating to tuberculosis in badgers including badger ecology, the pathogenesis of TB, diagnostic techniques and their application, the epidemiology of *M. bovis* infection in badgers, disease transmission to cattle and various disease control strategies.

Chambers, M.A., Gormley, E., Corner, L.A.L., Smith, G.C., Delahay, R.J. (Authors)/Mukundan, H., Chambers, M., Waters, R., Larsen, M. (Editors); 2015; Tuberculosis in badgers (Meles meles); In Tuberculosis, leprosy and mycobacterial diseases of man and animals: the many hosts of mycobacteria; Published by CAB International, Wallingford, UK.

Reproductive biology including evidence for superfetation in the European badger *Meles meles* (Carnivora: Mustelidae)

Corner, L.A.¹, Stuart, L.J.², Kelly, D.J.^{2,3}, Marples N.M.^{2,3}

¹ UCD School of Veterinary Medicine, ² TCD Department of Zoology, ³ TCD Centre for Biodiversity Research

PLoS One 10, e0138093 (2015)

The reproductive biology of the European badger (*Meles meles*) is of wide interest because it is one of the few mammal species that show delayed implantation and one of only five which are suggested to show superfetation as a reproductive strategy. This study aimed to describe the reproductive biology of female Irish badgers with a view to increasing our understanding of the process of delayed implantation and superfetation. We carried out a detailed histological examination of the reproductive tract of 264 female badgers taken from sites across 20 of the 26 counties in the Republic of Ireland. The key results show evidence of multiple blastocysts at different stages of development present simultaneously in the same female, supporting the view that superfetation is relatively common in this population of badgers. In addition we present strong evidence that the breeding rate in Irish badgers is limited by failure to conceive, rather than failure at any other stages of the breeding cycle. We show few effects of age on breeding success, suggesting no breeding suppression by adult females in this population. The study sheds new light on this unusual breeding strategy of delayed implantation and superfetation, and highlights a number of significant differences between the reproductive biology of female Irish badgers and those of Great Britain and Swedish populations.

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Discovery of a polyomavirus in European badgers (*Meles meles*) and the evolution of host range in the family *Polyomaviridae*

Hill, S.C.¹, Murphy, A.A.², Cotten, M.³, Palser, A.L.³, Benson, P.², Lesellier, S.⁴, Gormley, E.⁵, Richomme, C.⁶, Grierson, S.⁷, Ni Bhuachalla, D.⁵, Chambers, M.^{4,8}, Kellam, P.^{3,9}, Boschioli, M.-L.¹⁰, Ehlers, B.¹¹, Jarvis, M.A.², Pybus, O.G.¹

¹ Department of Zoology, University of Oxford, United Kingdom, ² School of Biomedical and Healthcare Sciences, Plymouth University, United Kingdom, ³ Wellcome Trust Sanger Institute, United Kingdom, ⁴ Bacteriology Department, Animal and Plant Health Agency, United Kingdom, ⁵ UCD School of Veterinary Medicine, ⁶ ANSES, Nancy Laboratory for Rabies and Wildlife, France, ⁷ Department of Virology, Animal and Plant Health Agency, United Kingdom, ⁸ School of Veterinary Medicine, University of Surrey, United Kingdom, ⁹ MRC/UCL Centre for Medical Molecular Virology, University College London, United Kingdom, ¹⁰ University Paris-Est, ANSES, Laboratory for Animal Health, Bovine Tuberculosis National Reference Laboratory, France, ¹¹ Robert Koch Institute, Division ¹² 'Measles, Mumps, Rubella and Viruses Affecting Immunocompromised Patients', Germany

Journal of General Virology 96, 1411-1422 (2015)

Polyomaviruses infect a diverse range of mammalian and avian hosts, and are associated with a variety of symptoms. However, it is unknown whether the viruses are found in all mammalian families and the evolutionary history of the polyomaviruses is still unclear. Here, we report the discovery of a novel polyomavirus in the European badger (*Meles meles*), which to our knowledge represents the first polyomavirus to be characterized in the family Mustelidae, and within a European carnivoran. Although the virus was discovered serendipitously in the supernatant of a cell culture inoculated with badger material, we subsequently confirmed its presence in wild badgers. The European badger polyomavirus was tentatively named *Meles meles* polyomavirus 1 (MmelPyV1). The genome is 5187 bp long and encodes proteins typical of polyomaviruses. Phylogenetic analyses including all known polyomavirus genomes consistently group MmelPyV1 with California sea lion polyomavirus 1 across all regions of the genome. Further evolutionary analyses revealed phylogenetic discordance amongst polyomavirus genome regions, possibly arising from evolutionary rate heterogeneity, and a complex association between polyomavirus phylogeny and host taxonomic groups.

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Seasonal variation in the biotic and abiotic influences on bodyweight of a seasonal mammal, the European badger (*Meles meles*)

Kelly, D. et al.

TCD

Many seasonal mammals are known to undergo dramatic changes in physical appearance and/or physiology across the year, in order to cope with seasonality. This study aims to analyse bodyweight during three discrete physiological stages in the annual life cycle of badgers; bodyweight increase (September - November), bodyweight decrease (December - March) and lean bodyweight maintenance (April - August). The data set is comprised of 11,000 badgers recorded in England and Ireland.

The impact of local weather on European badger (*Meles meles*) capture success: implications for bovine tuberculosis management

Martin, L. et al.

College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, USA

In the Republic of Ireland, badgers have been managed through culling to control bovine TB, but vaccination using the Bacillus Calmette-Guérin (BCG) vaccine is becoming the new goal. However, for vaccination to be effective, badger trapping success must be high to deliver vaccines to a large proportion of badgers in a given population (coverage). In this study, we examined the effect of local weather on badger capture success. We compiled data from 1,985 badger captures during 2010-2013 as part of a bovine TB badger vaccine trial in County Kilkenny. In our preliminary analysis, we found that badger captures were significantly higher in drizzle, rain, and heavy rain, and significantly lower in snow compared to dry weather. Badger captures were significantly higher at setts with activity scores of 4 as compared to setts with activity scores of 3.

Tri-axial accelerometers quantify behaviour in the Eurasian badger (*Meles meles*): towards an automated interpretation of field data

McClune, D.W.¹, Marks, N.J.¹, Wilson, R.P.², Houghton, J.D.R.¹, Montgomery, I.W.¹, McGowan, N.E.¹, Gormley, E.³, Scantlebury, M.¹

¹ School of Biological Sciences, Institute for Global Food Security, Queen's University Belfast, Northern Ireland, ² Biological Sciences, Institute of Environmental Sustainability, Swansea University, Wales ³ UCD School of Veterinary Medicine

Animal Biotelemetry 2, 5 (2014)

The popularity of tri-axial accelerometer data loggers to quantify animal activity through the analysis of signature traces is increasing. However, there is no consensus on how to process the large data sets that these devices generate when recording at the necessary high sample rates. In addition, there have been few attempts to validate accelerometer traces with specific behaviours in non-domesticated terrestrial mammals. We fitted a collar with a tri-axial accelerometer to a tame captive Eurasian badger (*Meles meles*). The animal was allowed to move freely in an outside enclosure and artificial sett whilst movements were recorded using a video camera. Data were analysed using custom-written software in terms of magnitude of movement, posture and periodicity using spectral analysis, a principal component analysis, the *k*-nearest neighbour algorithm and a decision tree to facilitate the automated classification of behaviours. We have demonstrated that various discrete behaviours (walking, trotting, snuffling and resting) can be differentiated using tri-axial accelerometer data. Classification accuracy ranged between 77.4% and 100% depending on the behaviour and classification method employed. These results are an important step in defining how accelerometer data code for the behaviour of free-ranging mammals. The classification methods outlined here have the potential to be used in the construction of a behavioural database and to generate behaviour-time budgets of hitherto unparalleled detail for wild animals. This would be invaluable for studies of nocturnal, subterranean or difficult-to-observe species that are particularly sensitive to human intrusion.

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The role of badgers in the epidemiology of *Mycobacterium bovis* infection (tuberculosis) in cattle in the United Kingdom and the Republic of Ireland: current perspectives on control strategies

Ní Bhuachalla, D.¹, Corner, L.A.L.¹, More, S.J.^{1,2}, Gormley, E.¹

¹ UCD School of Veterinary Medicine, ² UCD CVERA

Veterinary Medicine: Research and Reports 6, 27-38 (2015)

Bovine tuberculosis (TB), caused by infection with *Mycobacterium bovis*, is a persistent problem in cattle herds in Ireland and the United Kingdom, resulting in hardship for affected farmers and substantial ongoing national exchequer expenditure. There is irrefutable scientific evidence that badgers are a reservoir of *M. bovis* infection and are implicated in the transmission of infection to cattle. A range of options for the control of TB in badgers is currently available or under development including culling of badgers, vaccination of badgers and cattle, and improved biosecurity to limit contact between the two species. It is unlikely that the eradication of TB from cattle will be achieved without the reservoir of *M. bovis* infection in badgers being controlled. The chances of success will, however, improve with greater knowledge of the disease in both species and an understanding of the epidemiological drivers of the transmission of infection between badgers and cattle.

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Where and when badger (*Meles meles*) road casualties occurred in the Four Area Study

Sleeman, D.P.¹, Collins, D.M.², Davenport, J.¹

¹ UCC School of Biological, Earth and Environmental Sciences, ² UCD CVERA

Irish Naturalists' Journal 33, 119-123 (2014)

The locations and season of seventy six badger road casualties found in the Irish Four Area Project (FAP) over a five year period are reported and discussed. The casualties were highly seasonal, but with similar numbers of males and females. The casualties tended to be at the outskirts of the removal areas, suggesting that they were dispersing animals.

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Infection control strategies

Badger removal

Effect of culling and vaccination on bovine tuberculosis infection in a European badger (*Meles meles*) population by spatial simulation modelling

Abdou, M. et al.

Quantitative Veterinary Epidemiology Group, Wageningen University, Wageningen, The Netherlands

The control of bovine tuberculosis (bTB) in cattle herds in the Republic of Ireland (ROI) is partially hindered by spill-back infection from wild badgers (*Meles meles*). The aim of this study was to determine the relative effects of interventions (combinations of culling and/or vaccination) on bTB dynamics in an Irish badger population. A spatial agent-based stochastic simulation model was developed to evaluate the effect of various control strategies for bovine tuberculosis in badgers: single control strategies (culling, selective culling, vaccination, and vaccine baits), and combined strategies (Test vaccinate/cull (TVC)), split area approaches using culling and vaccination, or selective culling and vaccination, and mixed scenarios where culling was conducted for five years and followed by vaccination or by a TVC strategy. The effect of each control strategy was evaluated over a 20-year period. This model will be a useful tool to assess the potential impacts of future proposed interventions.

Risk of tuberculosis cattle herd breakdowns in Ireland: effects of badger culling effort, density and historic large-scale interventions

Byrne, A.W.^{1,2}, White, P.W.^{1,3}, McGrath, G.¹, O’Keeffe, J.^{1,3}, Martin, S.W.⁴

¹ UCDC CVERA, ² Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast, Northern Ireland,

³ DAFM, ⁴ University of Guelph, Guelph, Ontario, Canada

Veterinary Research 45, 109 (2014)

Bovine tuberculosis (bTB) continues to be a problem in cattle herds in Ireland and Britain. It has been suggested that failure to eradicate this disease is related to the presence of a wildlife reservoir (the badger). A large-scale project was undertaken in the Republic of Ireland during 1997-2002 to assess whether badger removal could contribute to reducing risk of cattle herd breakdowns in four areas. During the period of that “four area” study, there was a significant decrease in risk in intensively culled (removal) areas relative to reference areas. In the present study, we revisit these areas to assess if there were any residual area effects of this former intervention a decade on (2007-2012). Over the study period there was an overall declining trend in bTB breakdown risk to cattle herds. Cattle herds within former removal areas experienced significantly reduced risk of breakdown relative to herds within former reference areas or herds within non-treatment areas (OR: 0.53; $P < 0.001$). Increased herd breakdown risk was associated with increasing herd size (OR: 1.92-2.03; $P < 0.001$) and herd bTB history (OR: 2.25-2.40; $P < 0.001$). There was increased risk of herd breakdowns in areas with higher badger densities, but this association was only significant early in the study (PD*YEAR interaction; $P < 0.001$). Badgers were culled in areas with higher cattle bTB risk (targeted culling). Risk tended to decline with cumulative culling effort only in three counties, but increased in the fourth (Donegal). Culling badgers is not seen as a viable long-term strategy. However, mixed policy options with biosecurity and badger vaccination, may help in managing cattle breakdown risk.

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Large-scale movements in European badgers: has the tail of the movement kernel been underestimated?

Byrne, A.W.^{1,2,3}, Quinn, J.L.², O’Keeffe, J.^{3,4}, Green, S.¹, Sleeman, D.P.², Martin, S.W.⁵, Davenport, J.²

¹ Teagasc, ² UCC School of Biological, Earth and Environmental Sciences, ³ UCD CVERA, ⁴ DAFM, ⁵ University of Guelph, Guelph, Ontario, Canada

Journal of Animal Ecology 83, 991-1001 (2014)

Characterizing patterns of animal movement is a major aim in population ecology, and yet doing so at an appropriate spatial scale remains a major challenge. Estimating the frequency and distances of movements is of particular importance when species 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 their potential to spread bovine tuberculosis in parts of their range. Considerable uncertainty surrounds the movement potential of badgers, and this may be related to the spatial scale of previous empirical studies. We conducted a large-scale mark-recapture study (755 km²; 2008-2012; 1935 capture events; 963 badgers) to investigate movement patterns in badgers, and undertook a comparative meta-analysis using published data from 15 European populations. The dispersal movement (>1 km) kernel followed an inverse power-law function, with a substantial ‘tail’ indicating the occurrence of rare long-distance dispersal attempts during the study period. The mean recorded distance from this distribution was 2.6 km, the 95 percentile was 7.3 km and the longest recorded was 22.1 km. Dispersal frequency distributions were significantly different between genders; males dispersed more frequently than females, but females made proportionally more long-distance dispersal attempts than males. We used a subsampling approach to demonstrate that the appropriate minimum spatial scale to characterize badger movements in our study population was 80 km², substantially larger than many previous badger studies. Furthermore, the meta-analysis indicated a significant association between maximum movement distance and study area size, while controlling for population density. Maximum long-distance movements were often only recorded by chance beyond the boundaries of study areas. These findings suggest that the tail of the badger movement distribution is currently underestimated. The implications of this for understanding the spatial ecology of badger populations and for the design of disease intervention strategies are potentially significant.

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Monitoring trap-related injury status during large-scale wildlife management programmes: an adaptive management approach

Byrne, A.W.^{1,2}, O’Keeffe, J.^{1,3}, Fogarty, U.⁴, Rooney, P.³, Martin, S.W.⁵

¹ UCD CVERA, ² Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast, Northern Ireland, ³ DAFM, ⁴ Irish Equine Centre,

⁵ University of Guelph, Guelph, Ontario, Canada

European Journal of Wildlife Research 61, 445-455 (2015)

Wildlife management and research programmes often rely on the capturing of live animals. All capture methods for wildlife involve a risk of injury. For that reason, monitoring of injuries should be completed concurrently, and efficiently, throughout the intervention programme, or study period, to uphold welfare standards. Here, we present a practical adaptive management system to monitor trap-related injuries as a component of broader attempts to maintain welfare standards. The monitoring system described is part of a large-scale tuberculosis-control management programme of European badgers (*Meles meles*) in the Republic of Ireland. Badgers were captured in stopped cable restraints. A standardised operating procedure was developed to allow for the necropsy of large numbers of badgers ($N = 18,596$) by a veteri-

nary pathologist. As part of this programme, badger injury status was evaluated using a categorical severity scale ranging from 0 (no impact due to capture) to 6 (death) for badgers captured in restraints. No restraint-related deaths were recorded over the study period. Eighty-four percent of captured badgers exhibited no impact or only superficial hair/skin compression (scale 0–1). Logistic models indicated that injury severity was significantly influenced by year, season, age class, gender, weight and the body position where the badger was captured. Despite the low prevalence of severe injuries recorded, the proportion of animals with a minor injury type (skin oedema; scale 2) increased during the study period. This highlights the need for continual sensitive welfare vigilance during prolonged programmes. We suggest improvements to the current programme and additional adjustments for future vaccination campaigns. We contend that this type of monitoring, coupled with adaptive management strategies, is essential for wildlife programmes to maintain high animal welfare standards, at least in terms of injuries, but also highlight that trap injuries are only one component of animal welfare. We suggest that this adaptive management system could serve as a template for other similar wildlife programmes.

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In situ adaptive response to climate and habitat quality variation: spatial and temporal variation in European badger (*Meles meles*) body weight

Byrne, A.W.^{1,2}, Fogarty, U.³, O’Keeffe, J.^{1,4}, Newman, C.⁵

¹UCD CVERA, ²Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast, Northern Ireland, ³Irish Equine Centre, ⁴DAFM, ⁵Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, Tubney, Abingdon, United Kingdom

Global Change Biology 21, 3336-3346 (2015)

Variation in climatic and habitat conditions can affect populations through a variety of mechanisms, and these relationships can act at different temporal and spatial scales. Using post-mortem badger body weight records from 15 878 individuals captured across the Republic of Ireland (7224 setts across ca. 15 000 km²; 2009–2012), we employed a hierarchical multilevel mixed model to evaluate the effects of climate (rainfall and temperature) and habitat quality (landscape suitability), while controlling for local abundance (unique badgers caught/sett/year). Body weight was affected strongly by temperature across a number of temporal scales (preceding month or season), with badgers being heavier if preceding temperatures (particularly during winter/spring) were warmer than the long-term seasonal mean. There was less support for rainfall across different temporal scales, although badgers did exhibit heavier weights when greater rainfall occurred one or 2 months prior to capture. Badgers were also heavier in areas with higher landscape habitat quality, modulated by the number of individuals captured per sett, consistent with density-dependent effects reducing weights. Overall, the mean badger body weight of culled individuals rose during the study period (2009–2012), more so for males than for females. With predicted increases in temperature, and rainfall, augmented by ongoing agricultural land conversion in this region, we project heavier individual badger body weights in the future. Increased body weight has been associated with higher fecundity, recruitment and survival rates in badgers, due to improved food availability and energetic budgets. We thus predict that climate change could increase the badger population across the Republic of Ireland. Nevertheless, we emphasize that, locally, populations could still be vulnerable to extreme weather variability coupled with detrimental agricultural practice, including population management.

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Randomised Badger Culling Trial: interpreting the results

More, S.J.^{1,2}, McGrath, G.¹

¹ UCD CVERA, ² UCD School of Veterinary Medicine

Veterinary Record 177, 128-129 (2015)

The Randomised Badger Culling Trial (RBCT) was conducted in England between 1998 and 2005 to evaluate the effectiveness of badger culling as a control strategy for bovine tuberculosis (bTB) in cattle in Britain (Donnelly and others 2007). It has generated intense discussion in the general press. As yet, however, there has been almost no critique of the RBCT results in the scientific literature (More and others 2007). This is surprising, given the one-off nature of the trial, and the pivotal role of this work in subsequent science and policy in the UK. Epidemiological studies seek to provide accuracy in estimation, either of disease frequency or of the effect of exposure on the occurrence of disease in a study population (Rothman and others 2008). In this context, accuracy encompasses both validity and precision (the absence of systematic error [bias] and random error, respectively). Frequently, epidemiological studies also seek estimates that can be generalised beyond the study population. In the RBCT, the authors sought accurate estimates of the impact of badger culling on herd bTB incidence in local cattle. Here, we outline four issues that we believe may adversely affect the validity of the results.

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County Laois targeted badger removal study: revisited

Olea-Popelka, F. et al.

College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, USA

The data used to investigate the impact of targeted removal of badgers on the subsequent bovine tuberculosis status in cattle herds in county Laois, Ireland (Olea-Popelka et al., 2009) were re-analyzed to measure the impact of badger removal activities since the beginning of the removal activities rather than at the end of the removal activities as originally conducted. Additionally, the risks of bovine TB for herds in four different geographical zones within county Laois were investigated. The main conclusion of this study using the time-at-risk since the opening of the badger removal license was that targeted badger removal had a beneficial impact on the survival time to future bovine TB episodes in herds in areas where badgers were removed.

Temporal association between badger presence and herd bTB risk in Co. Monaghan, Ireland

White, P.W. et al.

UCD CVERA & DAFM

In Ireland, badgers are culled in response to herd breakdowns of bovine tuberculosis (bTB), where implicated following an epidemiological investigation of the 'index herd' episode. Our goal is to quantify relative temporal trends in bTB risk before and after culling of badgers from the land of surrounding herds (those with 33% of land area within 500m of an affected sett) in county Monaghan during 2004-2011.

Progress towards a badger vaccine

Badger tuberculosis vaccine

Ní Bhuachalla, D.¹, Duignan, A.², Corner, L.A.L.¹ Gormley, E.¹

¹ UCD School of Veterinary Medicine, ² DAFM

a. Vaccine development (studies with captive badgers)

Persistence and distribution of oral Mycobacterium bovis BCG vaccine in European badgers (Meles meles).

The BCG vaccine is a live vaccine and is the most widely applied in the world. It has an exemplary safety record with only rare complications recorded. Where reactions to BCG do occur (mostly in immune-compromised humans), they are usually self-limiting and of short duration. We previously published a comprehensive review on the safety of BCG vaccination in human, veterinary and wildlife in the international journal 'Tuberculosis'. Our colleagues at APHA – UK also published the results of a formal study investigating safety and adverse reactions to intra-muscular injection of BCG into badgers. Only minimal effects of short-duration were recorded. The conclusion reached was that the BCG is safe to use in badgers. We have carried out several studies with oral BCG vaccination in our captive badgers and have not noted any reactions. We have also investigated faecal shedding of BCG following oral vaccination and found it to be intermittent, of very short duration (a few days) and very low bacillary numbers involved. The risk of transfer to non-target species is considered inconsequential and even if it does occur it is not likely to cause any problems.

In order to understand how the immune system primes the protective immune response we set out to determine where the BCG is distributed in the lymphatic system when delivered orally, and to investigate the short-term fate of the vaccine in lymph nodes. We also wanted to understand the risk of shedding of BCG into the environment.

The badgers were randomly assigned to 3 groups of six animals per group and five badgers in each group were orally vaccinated with BCG in week 1. The remaining badger in each group received placebo. The persistence of BCG in the badgers was assessed at three different time points, 4, 8 and 12 weeks. Over the course of the study, blood samples were taken for immunological analysis. Six badgers were euthanized at each time point and tissue samples removed for bacteriological culture and cytokine profiling. Euthanasia was required in order to target a wide range of lymph nodes where BCG is likely at each time point.

Data analysis from the completed study is continuing. The principle analysis of the distribution is descriptive. We aim to describe (a) where BCG can be detected post-vaccination? (b) what are the differences in BCG distribution between individuals? (c) how the distribution of BCG changes over time? (d) how distribution of BCG in badgers at 12 weeks post-vaccination may influence protective immunity, and (e) to investigate distribution of BCG, especially in excreta, at all time points to assess how it may contribute to the risk of excretion of BCG from the badger. With this data we can estimate the risk of shedding of vaccine into the environment. In previous studies, we reported intermittent low-level shedding of BCG in faeces in the first weeks after vaccination but as yet there is no published data relating to persistence and dissemination of BCG in badger tissues, particularly the lymphatic system. The results will be published and included in a dossier for licensing of oral BCG as a veterinary medicine.

b. Development of badger immunodiagnosics

We are working with colleagues at APHA UK to assess and validate a range of immunodiagnostic tests that have potential for use in tuberculosis surveillance in badger populations to monitor the effect of vaccination. It has already been established that the sensitivity of immunodiagnostic assays improves as the disease severity increases and that this is more pronounced with the serological based assays. In recent years a number of new serological tests have been developed but have not been subject to robust validation. Because of the availability of large bank of badger serum samples gathered during the field trial, these are invaluable for validation of tests on naturally infected badgers.

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

Aznar, I.^{1,2}, Frankena, K.³, More, S.J.^{1,4}, Whelan, C.⁵, Martin, S.W.⁶, Gormley, E.⁴, Corner, L.A.L.⁴, Murphy, D.⁷, De Jong, M.C.M.³

¹ UCD CVERA, ² DAFM, ³ Quantitative Veterinary Epidemiology Group, Wageningen Institute of Animal Sciences, Wageningen University, Wageningen, The Netherlands, ⁴ UCD School of Veterinary Medicine, ⁵ Enfer Scientific, Co. Kildare, ⁶ University of Guelph, Guelph, Ontario, Canada,

⁷ DAFM Veterinary Laboratory Service

PLoS One 9, e100139 (2014)

A long-term research programme has been underway in Ireland to evaluate the usefulness of badger vaccination as part of the national bTB (bovine tuberculosis) control strategy. This culminated in a field trial which commenced in county Kilkenny in 2009 to determine the effects of badger vaccination on *Mycobacterium bovis* transmission in badgers under field conditions. In the present study, we sought to optimise the characteristics of a multiplex chemiluminescent assay for detection of *M. bovis* infection in live badgers. Our goal was to maximise specificity, and therefore statistical power, during evaluation of the badger vaccine trial data. In addition, we also aimed to explore the effects of vaccination on test characteristics. For the test optimisation, we ran a stepwise logistic regression with analytical weights on the converted Relative Light Units (RLU) obtained from testing blood samples from 215 badgers captured as part of culling operations by the national Department of Agriculture, Food and the Marine (DAFM). The optimised test was applied to two other datasets obtained from two captive badger studies (Study 1 and Study 2), and the sensitivity and specificity of the test was attained separately for vaccinated and non-vaccinated badgers. During optimisation, test sensitivity was maximised (30.77%), while retaining specificity at 99.99%. When the optimised test was then applied to the captive badger studies data, we observed that test characteristics did not vary greatly between vaccinated and non-vaccinated badgers. However, a different time lag between infection and a positive test result was observed in vaccinated and non-vaccinated badgers. We propose that the optimized multiplex immunoassay be used to analyse the vaccine trial data. In relation to the difference in the time lag observed for vaccinated and non-vaccinated badgers, we also present a strategy to enable the test to be used during trial evaluation.

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Infection dynamics and effective control strategies for tuberculosis in badgers and cattle in the Republic of Ireland

Aznar, I. et al.

UCD CVERA & DAFM

Mathematical modelling has become an essential tool to understand the maintenance and transmission of multi-host pathogens. In this manuscript and by using compartmental models we aim to assess the impact of several control measures on the bTB-badger-cattle system. Estimations of the current R_0 for the bTB badger-cattle system in ROI as well as changes to it when a number of additional control options in one/both species are applied while allowing for inter-species transmission are presented. These outcomes will help decision makers to optimize future control options for bTB with the view of eradication in cattle. Furthermore, the developed models will also allow for further follow up of the R_0 for the system as new strategies are put in place.

BCG vaccination in badgers, results of the Kilkenny Vaccine Trial

Aznar, I. et al.

UCD CVERA & DAFM

BCG vaccination in badgers has been proposed as one of several strategies to eradicate bovine tuberculosis (bTB) in cattle in Ireland. Laboratory studies where captive badgers were challenged with *M. bovis* subsequent to BCG vaccination consistently showed a reduction in both the number of colony forming units (CFU) and severity of lesions in vaccinated compared to non-vaccinated badgers. To elucidate whether the reduction in lesion severity observed in the laboratory translates into a reduction in infectivity or susceptibility to natural infection, and thus reduction in transmission in the field, a badger vaccine field trial was designed. Here we present the results of this vaccine trial. The main goals of this research were to estimate both vaccine efficacy for susceptibility and vaccine efficacy for infectivity and more importantly, their combined effect measured as R_p or the basic reproduction ratio at different vaccination coverage.

Pulmonary *Mycobacterium bovis* BCG vaccination confers dose-dependent superior protection compared to that of subcutaneous vaccination

Aguilo, N.^{1,2}, Toledo, A.M.³, Lopez-Roman, E.M.³, Perez-Herran, E.³, Gormley, E.⁴, Rullas-Trincado, J.³, Angulo-Barturen, I.³, Martin, C.^{1,2,5}

¹ Grupo de Genética de Micobacterias, Departamento de Microbiología, Medicina Preventiva y Salud Pública, Faculty of Medicine, Universidad de Zaragoza, Zaragoza, Spain, ² CIBER Enfermedades Respiratorias, Instituto de Salud Carlos III, Madrid, Spain, ³ Diseases of the Developing World, GlaxoSmithKline, Tres Cantos, Madrid, Spain, ⁴ UCD School of Veterinary Medicine, ⁵ Servicio de Microbiología, Hospital Universitario Miguel Servet, IIS Aragón, Zaragoza, Spain

Clinical and Vaccine Immunology 21, 594-597 (2014)

Worldwide, the *Mycobacterium bovis* BCG vaccine is one of the most widely used vaccines. However, it appears to be ineffective in preventing pulmonary tuberculosis. Here, we show that pulmonary BCG vaccination of mice with a broad dose range provides superior protection against *Mycobacterium tuberculosis* challenge compared to that of subcutaneous vaccination.

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Kilkenny Oral Vaccine Field Trial

Gormley, E. et al.

UCD School of Veterinary Medicine

The badger (*Meles meles*) has been identified as a vector for the spread of bovine tuberculosis (*Mycobacterium bovis*) to Irish cattle herds, and for some time culling has been conducted on badgers living within the vicinity of a TB breakdown. This field trial examines the efficacy of oral BCG vaccination, as an alternative to culling, in reducing the incidence of TB amongst badgers. The results and experience gained from the field trial will facilitate the development of strategies for the use of vaccination in the national tuberculosis control and eradication programme.

Oral vaccination of badgers (*Meles meles*) against tuberculosis: Comparison of the protection generated by BCG vaccine strains Pasteur and Danish

Murphy, D.¹, Costello, E.², Aldwell, F.E.³, Lesellier, S.⁴, Chambers, M.A.⁴, Fitzsimons, T.¹, Corner, L.A.L.¹, Gormley, E.¹

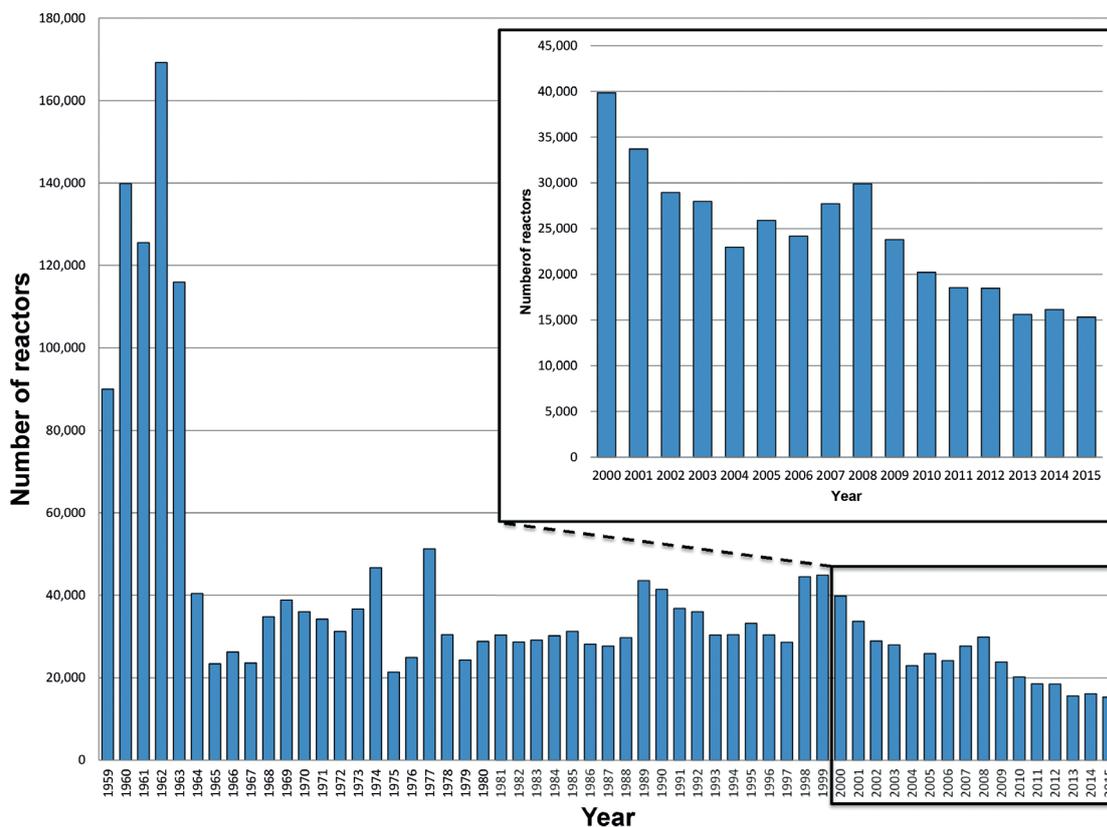
¹ UCD School of Veterinary Medicine, ² DAFM Veterinary Laboratory Service, ³ Immune Solutions Ltd, Centre for Innovation, The University of Otago, Dunedin, New Zealand, ⁴ Department of Bovine Tuberculosis, Animal Health and Veterinary Laboratories Agency, New Haw, Addlestone, Surrey, United Kingdom

The Veterinary Journal 200, 362-367 (2014)

Vaccination of badgers by the subcutaneous, mucosal and oral routes with the Pasteur strain of *Mycobacterium bovis* bacille Calmette-Guérin (BCG) has resulted in significant protection against experimental infection with virulent *M. bovis*. However, as the BCG Danish strain is the only commercially licensed BCG vaccine for use in humans in the European Union it is the vaccine of choice for delivery to badger populations. As all oral vaccination studies in badgers were previously conducted using the BCG Pasteur strain, this study compared protection in badgers following oral vaccination with the Pasteur and the Danish strains. Groups of badgers were vaccinated orally with 10^8 colony forming units (CFU) BCG Danish 1331 ($n = 7$ badgers) or 10^8 CFU BCG Pasteur 1173P2 ($n = 6$). Another group ($n = 8$) served as non-vaccinated controls. At 12 weeks post-vaccination, the animals were challenged by the endobronchial route with 6×10^3 CFU *M. bovis*, and at 15 weeks post-infection, all of the badgers were euthanased. Vaccination with either BCG strain provided protection against challenge compared with controls. The vaccinated badgers had significantly fewer sites with gross pathology and significantly lower gross pathological severity scores, fewer sites with histological lesions and fewer sites of infection, significantly lower bacterial counts in the thoracic lymph node, and lower bacterial counts in the lungs than the control group. No differences were observed between either of the vaccine groups by any of the pathology and bacteriology measures. The ELISPOT analysis, measuring production of badger interferon – gamma (IFN- γ), was also similar across the vaccinated groups.

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The national programme



The number of TB reactors detected in Ireland each year between 1959 and 2015

Estimating the probability that a cattle imported into Scotland from high risk areas is infected with bovine tuberculosis

Bessell, P.R. et al.

The Roslin Institute, The University of Edinburgh, 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.

Future risk of bovine tuberculosis recurrence among higher risk herds in Ireland

Clegg, T.A.¹, Good, M.², More, S.J.^{1,3}

¹ UCD CVERA, ² DAFM, ³ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 118, 71–79 (2015)

Within the Irish national bovine tuberculosis (bTB) eradication programme, controls are tighter on higher risk herds, known as H-herds. These H-herds are defined as herds that have previously had a bTB restriction (also known as a bTB episode), with at least 2 animals positive to the single intradermal comparative tuberculin test (SICTT) or with a bTB lesion detected at slaughter. Such herds are considered at higher risk of recurrence following the end of the bTB episode. In this study, we examined if, and when, the future bTB risk of H-herds returned to a similar level comparable to herds with no history of bTB. In addition, the proportion of bTB episodes in 2012 that could be attributed to the recent introduction of an infected animal was also estimated, providing an update of earlier work. The study population consisted of all Irish herds that were not bTB restricted at the start of 2012 and with at least one whole-herd SICTT in 2012, with the herd being the unit of interest. The outcome measure was a bTB restriction, defined as any herd where at least 1 standard SICTT reactor or an animal with a bTB lesion at slaughter in 2012 was identified. A logistic regression model was used to model the probability of a herd being restricted in 2012. Herds that were previously restricted had significantly higher odds of being restricted in 2012 compared to herds that had not. Similarly, the odds of being restricted in 2012 decreased as the time since the previous restriction increased, but increased as the severity of the previous restriction increased. Odds of being restricted also increased with an increase (although not linear) in herd size, the number of animals greater than 1 year of age purchased in 2011, the county incidence rate and the proportion of cows in the herd. The recent introduction of an infected animal accounted for 7.4% (6.7–8.2) of herd restrictions. This study confirms the key role of past bTB history in determining the future risk of Irish herds, with the odds related to both the severity of and time since the previous restriction. It also illustrates the difficulty in clearly defining H-herds, noting that risk persists for extended periods following a bTB restriction, regardless of breakdown severity. There is a need for robust controls on H-herds for an extended period post de-restriction.

Preventive Veterinary Medicine, 118, Clegg et al., Future risk of bovine tuberculosis recurrence among higher risk herds in Ireland, 71-79, Copyright © 2015, with permission from Elsevier B.V.

Investigation of the north Sligo bTB outbreak

Doyle, R. et al.

DAFM

An outbreak of bovine tuberculosis (bTB) occurred in the north Sligo region of the Republic of Ireland in 2013. Primarily due to rapid intervention and active management, the outbreak was successfully contained. There are important lessons to be learned, such as early identification of infected herds and reducing opportunity for herd to herd spread, which may help in containing future bTB outbreaks. It is the aim of this study to discuss what we consider to be the three key issues which led to containing the outbreak in north Sligo, namely, management, accelerated testing and use of gamma interferon testing.

Temporal and seasonal trends in bovine tuberculosis in Ireland during 1993 to 2012

Gallagher, M. et al.

UCD CVERA

There has been a steady improvement in the bovine tuberculosis (bTB) situation in Ireland in recent years, both in terms of surveillance and control. The herd bTB incidence rate in 2013 was lower than at any year since the start of the national programme. The objective of this study was to use time series analysis to investigate temporal and seasonal trends in bTB incidence in Ireland during 1993 to 2012.

Comparison of bovine tuberculosis recurrence in Irish herds between 1998 and 2015

Houtsma, E. et al.

UCD CVERA

During the last several decades in Ireland, there has been a steadily improving situation in the bovine tuberculosis (bTB) eradication programme. However, research has highlighted an ongoing problem of residual infection, which is contributing to prevent eradication. Therefore it is of interest to examine how well current measures to prevent recurrence are working. In light of this, the aim of this study is to compare the herd level risk of recurrence of bTB in Ireland between 1998 and 2015.

Recent spatial changes in bovine tuberculosis in the Republic of Ireland

McGrath, G.¹, Clegg, T.A.¹, More, S.J.^{1,2}

¹ UCD CVERA, ² UCD School of Veterinary Medicine

Veterinary Record 175, 45 (2014)

There has been a steady reduction in the levels of bovine tuberculosis (bTB) in Ireland for some years. This paper presents a number of methods employing geographical information systems to examine how this reduction is manifested in space and time. The focus of disease mapping has traditionally been placed on identifying areas with problems. There has been limited work done in visualising improvements. The authors describe recent spatial changes in the relative incidence of bTB in Ireland across an uniform hexagonal grid, comparing the mean of the annual animal level bTB incidence during the 10-year period from 1998 to 2007 to the years 2008 to 2012. The authors map bTB incidence trends for three successive five-year periods (1998–2002, 2003–2007 and 2008–2012). Finally, the authors investigate the change in extent and severity of interpolated bTB reactor density over time.

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Spatial structure of farms in Ireland

McGrath, G. et al.

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.

Movement analysis: Are there risks associated with purchasing of animals from high-density bovine tuberculosis breakdown areas?

McGrath, G. & Tratalos, J.

UCD CVERA

We will establish areas with recent persistent above-average relative risk rates of bovine tuberculosis bTB. We will analyse the national movement database investigating if animals originating from these areas have a higher subsequent risk of being part of a bTB breakdown.

Movement in the national herd

McGrath, G. & Tratalos, J.

UCD CVERA

This study aims 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 would be a valuable visualisation to emphasise the extent to which herds are connected through the transfer of animals. Additional movement statistics will highlight the national spatial variation of cattle movements within a calendar year.

Network analysis: Building a network contact rate indices between farms in Ireland

McGrath, G. & Tratalos, J.

UCD CVERA

A network will be constructed through the scoring of all farm to farm and mart to farm movements creating a national contact matrix.

Lessons learned during the successful eradication of bovine tuberculosis from Australia

More, S.J.^{1,2}, Radunz, B.³, Glanville, R.J.⁴

¹ UCD CVERA, ² UCD School of Veterinary Medicine, ³ Howard Springs, Northern Territory, Australia,

⁴ Biosecurity Advisory Service, Essendon, Victoria, Australia

Veterinary Record 177, 224-232 (2015)

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

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Understanding and managing bTB risk: Perspectives from Ireland

More, S.J.^{1,2}, Good, M.³

¹ UCD CVERA, ² UCD School of Veterinary Medicine, ³ DAFM

Veterinary Microbiology 176, 209-218 (2015)

There is substantial variation in herd risk for bovine tuberculosis (bTB) in Ireland, with most herds playing little to no role in the ongoing endemic. In infected areas, bTB persistence (affecting one or a group of herds) is a key feature of the infection. In this paper, we present our current understanding and management of bTB risk in Ireland, based on a detailed review of research and policy. There is close interaction between science and policy in Ireland, seeking both to understand and effectively manage bTB risk. Detailed research on bTB persistence is presented, including current understanding of the relative importance of different infection sources, which can include residual infection in cattle and/or re-infection, either from local sources or following cattle introduction. In recent years, there have been three primary drivers for policy change, including scientific advances, ongoing improvements to programme supports, and ongoing programme review. In this review, three key future programme challenges are identified. Although good progress is being made, eradication has not yet been achieved. Firstly, a key question concerns the additional effort that will be required, to move towards final eradication. Secondly, a percentage of non-infected animals are falsely positive to current testing methods. This is an ongoing challenge, given the imperfect specificity of test methods but will become more so, as the positive predictive value falls with reducing bTB prevalence. Finally, there is a need to re-engage with the farming community, so that they play a much greater role in programme ownership.

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Further evaluation of bovine tuberculosis trends in the UK and the Republic of Ireland, 1993-2014

More, S.J. et al.

UCD CVERA & UCD School of Veterinary Medicine

Bovine tuberculosis (bTB) is a major animal health challenge in a number of countries, including the UK and the Republic of Ireland. Within the field of bTB research, there is many examples of the value gained between countries from shared experiences and lessons learned. Comparison across countries can be problematic, however, as differing measures of progress are often used. Some progress has been made comparing bTB trends in the UK and the Republic of Ireland during 1995-2010, providing a valuable but superficial insight in factors affecting eradication. In this study, we are seeking to conduct further in-depth evaluation of bTB trends in the UK and the Republic of Ireland, during 1995 to 2014.

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

Sheridan, M.¹, Good, M.¹, More, S.J.^{2,3}, Gormley, E.³

¹ DAFM, ² UCD CVERA, ³ UCD School of Veterinary Medicine

In *Zoonotic tuberculosis: mycobacterium bovis and other pathogenic mycobacteria*, 323-340, 3rd edition, Thoen, C.O., Steele, J.H., Kaneene, J.B., (editors), Wiley-Blackwell, Iowa, USA (2014)

Significant improvement in bovine tuberculosis (BTB) levels has been achieved in Ireland over the past 10 years. This is attributed to a coordinated program of control and eradication in both the cattle herd and also in the wildlife reservoir, the badger, underpinned by a comprehensive research and development program. It is hoped that a new drive toward final eradication will commence in the next few years once the novel badger vaccination strategy has been proven and refined. At the end of 2011, 97.8% of cattle herds were officially BTB free. During 2011, 99.68% of animals were BTB free.

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Quality control

The relative effectiveness of testers during field surveillance for bovine tuberculosis in unrestricted low-risk herds in Ireland

Clegg, T.A.¹, Duignan, A.², More, S.J.^{1,3}

¹ UCD CVERA, ² DAFM, ³ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 119, 85–89 (2015)

In Ireland, new bovine tuberculosis (bTB) cases are detected using both field and abattoir surveillance. Field surveillance is conducted on all cattle annually using the single intradermal comparative tuberculin test (SICTT). Testing is reliant on the skills and experience of the tester and a broad range of factors may adversely affect test accuracy. There is considerable emphasis on quality control (QC) within the national programme and field inspection of testers has been conducted in Ireland for many years. Since 2008, inspection has been supplemented with quantitative performance reports, enabling testers to be evaluated and ranked using a range of performance indicators. The objectives of this study were first, to quantify the relative effectiveness of testers during field surveillance and, second, to assess whether there has been any change in the performance of testers between 2008 and 2011. Mixed logistic regression was used to assess the relative effectiveness of testers. The study population included all testers who carried out at least ten eligible tests in Ireland during 2008 or 2011. The outcome measure was a herd restriction at the eligible test. Results from the mixed model indicated that the variation by tester had significantly ($p = 0.039$) decreased from 0.589 in 2008 to 0.426 in 2011, indicating an increase in consistency of testing, after accounting for other known risk factors. This study provides objective data on the variation in tester performance over time and the relative performance of testers during field surveillance in Ireland.

Preventive Veterinary Medicine, 119, Clegg et al., The relative effectiveness of testers during field surveillance for bovine tuberculosis in unrestricted low-risk herds in Ireland, 85-89, Copyright © 2015, with permission from Elsevier B.V.

Application of the ER13A form - a critical review of progress

Duignan, A. et al.

DAFM

The principal means of detection of bovine tuberculosis in the live animal is the Single Intradermal Comparative Tuberculin Test (SICTT) which is carried out on circa 8 million animal tests by 950 Private Veterinary Practitioners (PVPs) annually. Consistent application of the test in compliance with national and international requirements is critical to the success of the eradication programme. A specialist report (known as ER13A) which details key performance indicators using the Animal Health Computer System (AHCS) was introduced in 2008 to monitor each PVP in delivery of the SICTT. This study evaluates the impact of the ER13A on PVP performance during the period 2008 to 2014.

Quality control in the Irish bTB programme

Duignan, A. et al.

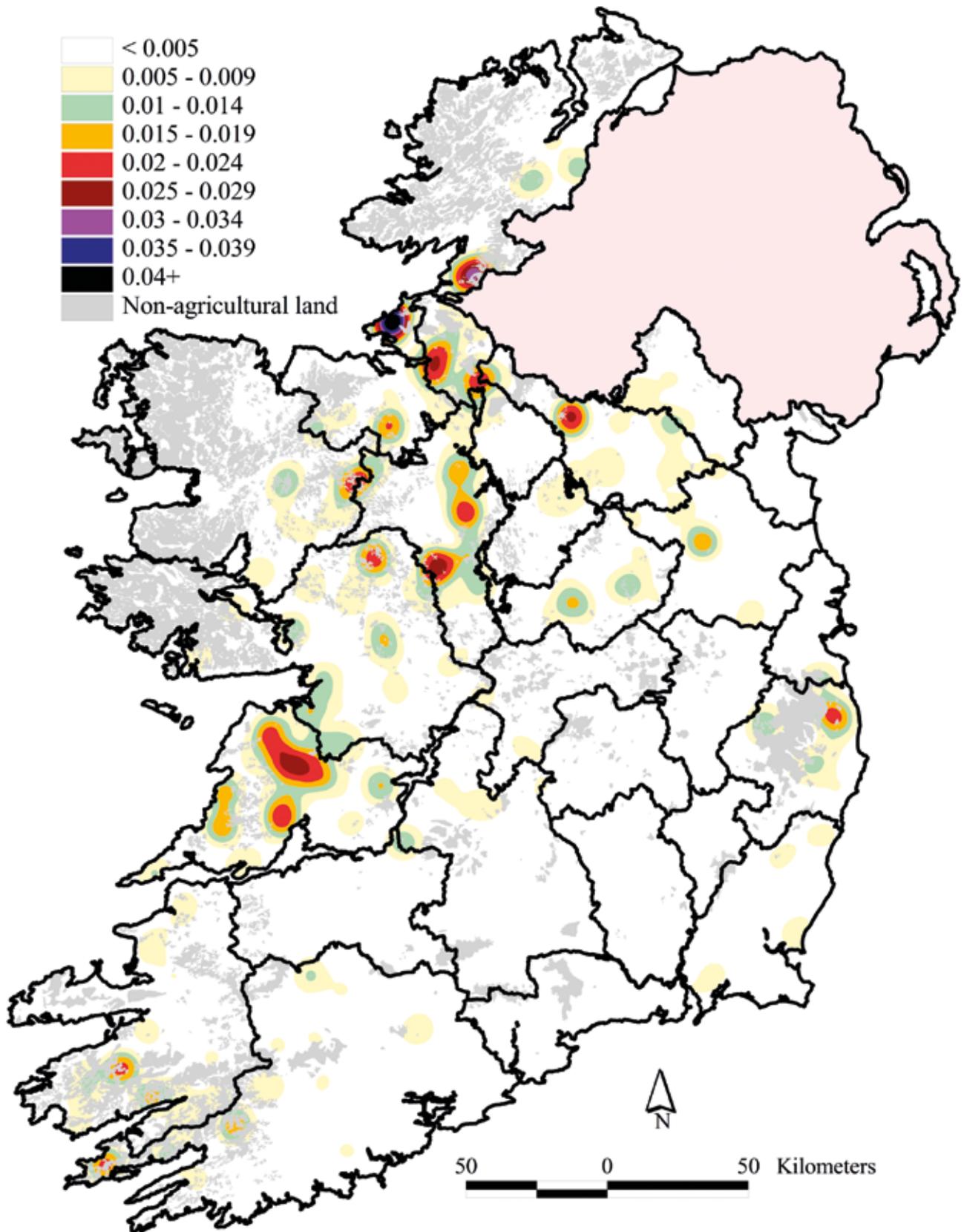
DAFM

The Irish bTB programme has made considerable progress in recent years resulting in consistent reduction in disease prevalence. Enhanced quality control measures have been introduced in recent years as an integral element of programme. This study describes the quality control measures employed and their impact on the reduction in disease prevalence.

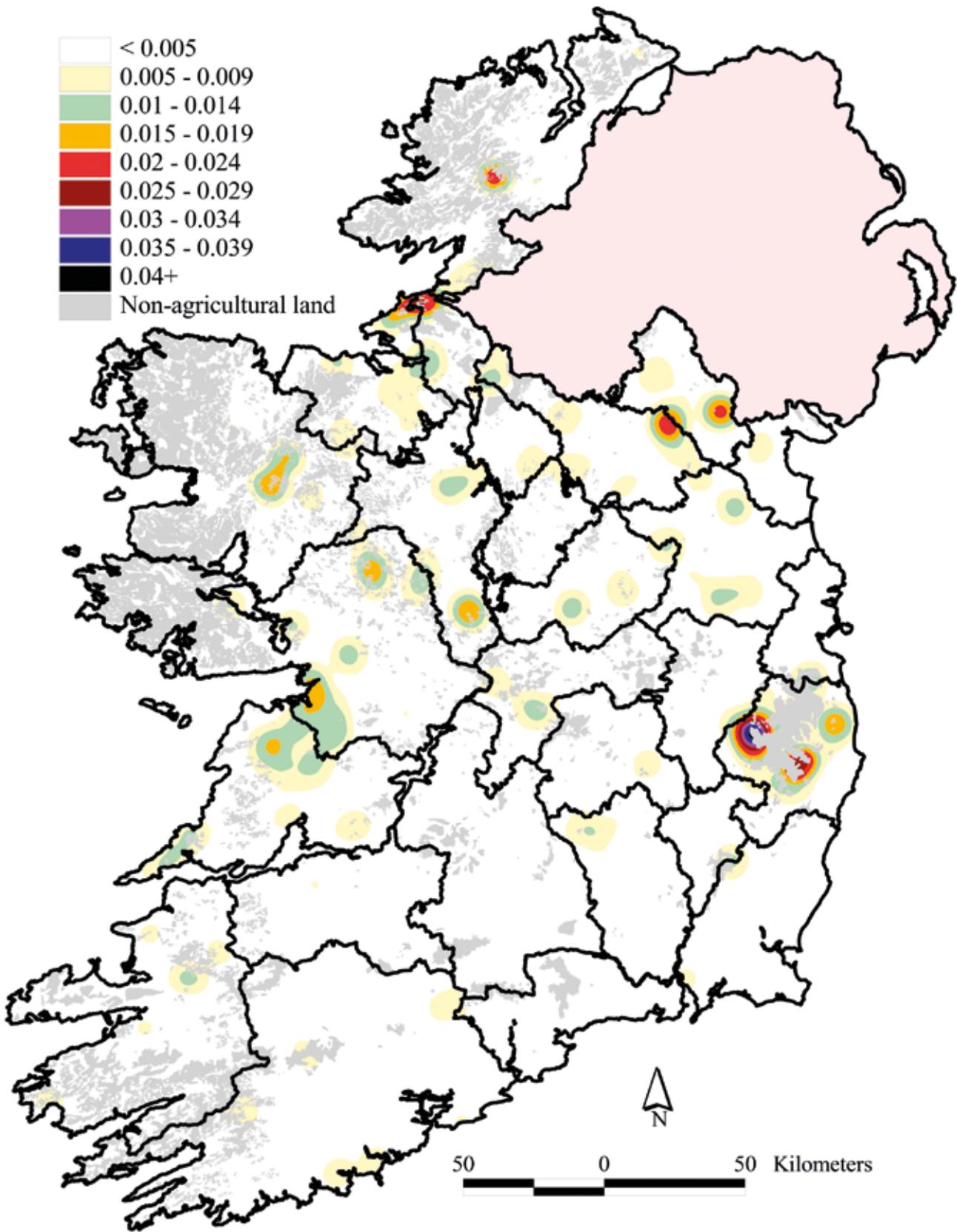


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Density of bTB incidence



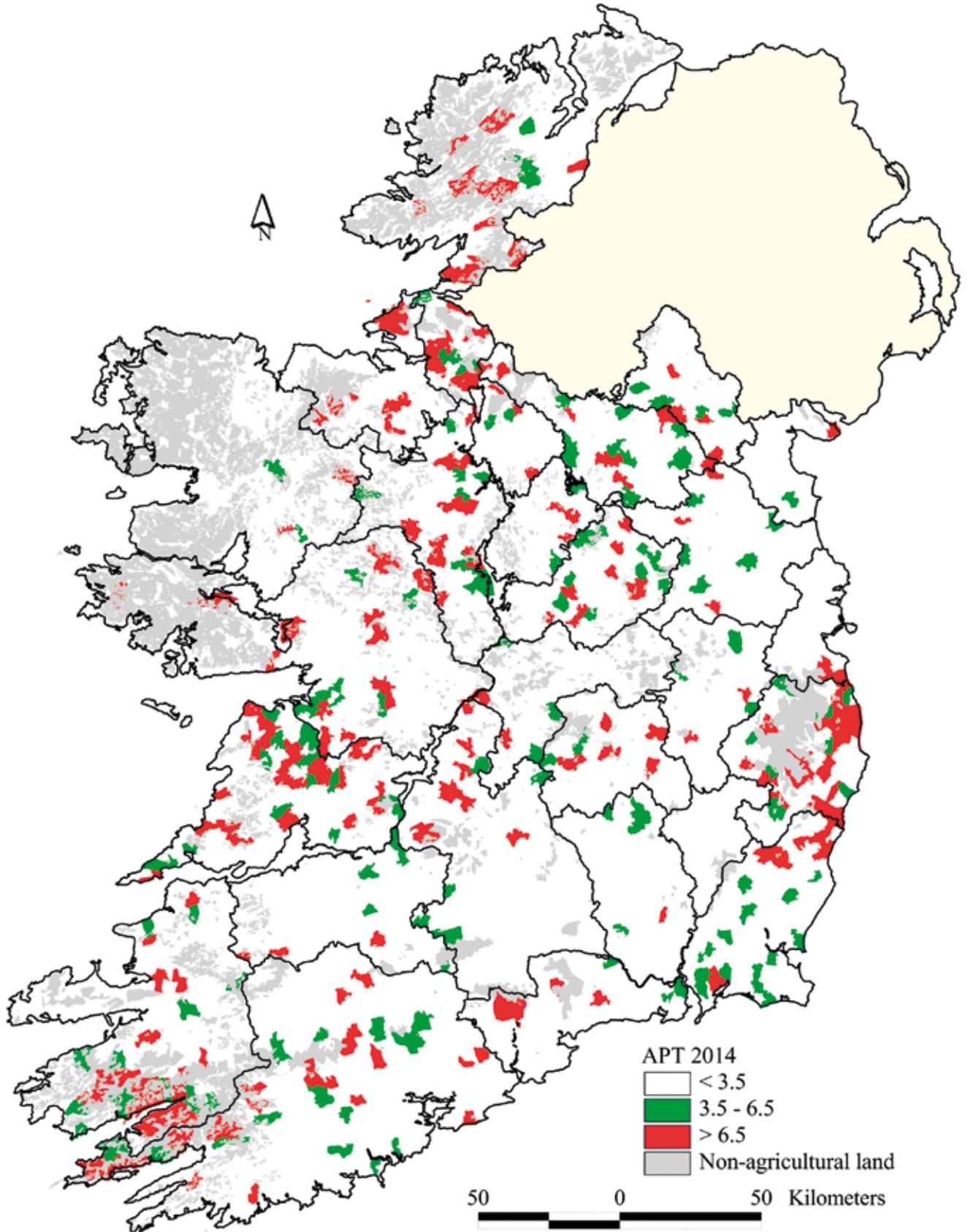
Density of bTB incidence per square km during 2014 (kernel density with search radius at 10km)



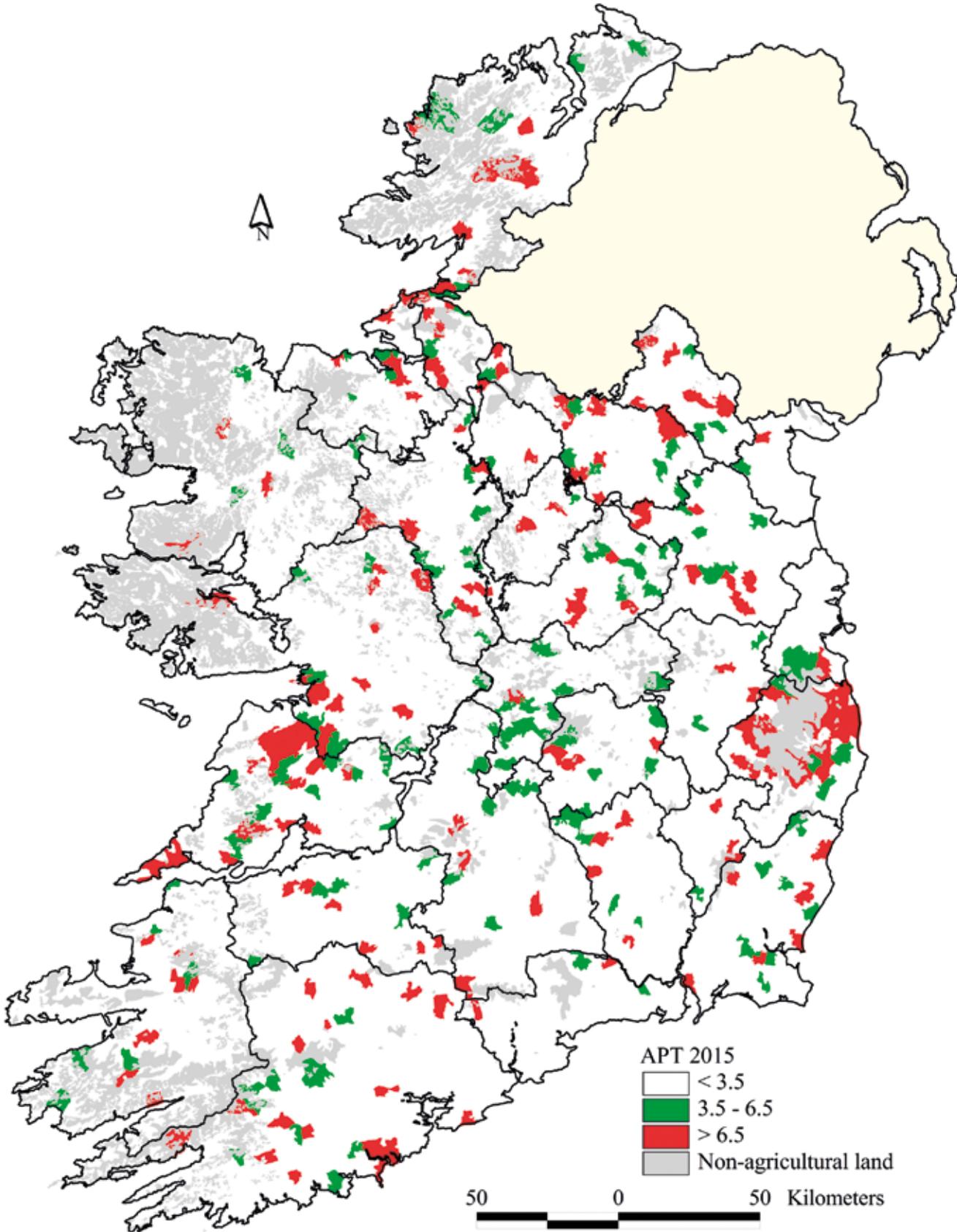
Density of bTB incidence per square km during 2015 (kernel density with search radius at 10km)

APT per DED

NATIONAL MAPS
APT per DED



APT (reactors per 1000 tests) per district electoral division, 2014



APT (reactors per 1000 tests) per district electoral division, 2015





Non-regulatory cattle health issues

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Biosecure diseases

Biosecurity

Biosecurity

Glanville, R.J.^{1,2}, Firestone, S.M.², More, S.J.^{3,4}

¹ Biosecurity Advisory Service, Melbourne, Australia, ² Asia-Pacific Centre for Animal Health, Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, VIC, Australia, ³ UCD CVERA, ⁴ UCD School of Veterinary Medicine

In *Encyclopedia of Global Bioethics*, 1-14, 1st edition, ten Have, H., (editor), Springer International Publishing, Netherlands (2014)

Biosecurity is a term widely used in a number of different fields, particularly in agriculture, human health, research, and national/international security. However, the meaning may differ slightly, depending on the context. In this discussion, it is broadly defined as “*The management of risks from invasive species to human and animal health, the natural and built environments, and agriculture.*” This occurs through prevention, surveillance, preparedness, and response activities, supported by appropriate capacity and capability. A wide range of ethical issues arise, including prioritization of activities based on resources and risk assessments; uneven investment in global biosecurity, with rich countries dictating associated policies; fears around bioterrorism and emerging infectious diseases; trade rules and inconsistency of implementation; application of the precautionary principle in decision making; the impact of biosecurity activities on individuals for the public good; animal health, welfare and rights; and the impact of humans globally on the distribution of invasive species.

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Johne’s disease

Analysis of the bovine monocyte-derived macrophage response to *Mycobacterium avium* subspecies *paratuberculosis* infection using RNA-seq

Casey, M.E.^{1,2}, Meade, K.G.², Nalpas, N.C.¹, Taraktsoglou, M.³, Browne, J.A.¹, Killick, K.E.^{1,4}, Park, S.D.E.¹, Gormley, E.⁵, Hokamp, K.⁶, Magee, D.A.¹, MacHugh, D.E.^{1,7}

¹ Animal Genomics Laboratory, UCD School of Agriculture and Food Science, ² Animal and Bioscience Research Department, Teagasc, ³ Biological Agents Unit, Health and Safety Executive, Leeds, UK, ⁴ Systems Biology Ireland, UCD Conway Institute of Biomolecular and Biomedical Research, ⁵ UCD School of Veterinary Medicine, ⁶ TCD Smurfit Institute of Genetics, ⁷ UCD Conway Institute of Biomolecular and Biomedical Research

Frontiers in Immunology 6, 23 (2015)

Johne’s disease, caused by infection with *Mycobacterium avium* subsp. *paratuberculosis*, (MAP), is a chronic intestinal disease of ruminants with serious economic consequences for cattle production in the United States and elsewhere. During infection, MAP bacilli are phagocytosed and subvert host macrophage processes, resulting in subclinical infections that can lead to immunopathology and dissemination of disease. Analysis of the host macrophage transcriptome during infection can therefore shed light on the molecular mechanisms and host-pathogen interplay associated with Johne’s disease. Here, we describe results of an in vitro study of the bovine monocyte-derived macrophage (MDM) transcriptome response during MAP infection using RNA-seq. MDM were obtained from seven age- and sex-matched Holstein-Friesian cattle and were infected with MAP across a 6-h infection time course with non-infected controls. We observed 245 and 574 differentially expressed (DE) genes in MAP-infected versus non-infected control samples (adjusted P value ≤ 0.05) at 2 and 6 h post-infection, respectively. Functional analyses of these DE genes, including biological

pathway enrichment, highlighted potential functional roles for genes that have not been previously described in the host response to infection with MAP bacilli. In addition, differential expression of pro- and anti-inflammatory cytokine genes, such as those associated with the IL-10 signaling pathway, and other immune-related genes that encode proteins involved in the bovine macrophage response to MAP infection emphasize the balance between protective host immunity and bacilli survival and proliferation. Systematic comparisons of RNA-seq gene expression results with Affymetrix® microarray data generated from the same experimental samples also demonstrated that RNA-seq represents a superior technology for studying host transcriptional responses to intracellular infection.

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

Geraghty, T.¹, Graham, D.A.², Mullowney, P.³, More, S.J.^{4,5}

¹ Scottish Centre for Production Animal Health and Food Safety, University of Glasgow Veterinary School, Glasgow, Scotland, ² Animal Health Ireland,

³ DAFM, ⁴ UCD CVERA, ⁵ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 116, 1–11 (2014)

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

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Development of a HACCP-based approach to control paratuberculosis in infected Irish dairy herds

McAloon, C.G.¹, Whyte, P.¹, More, S.J.^{1,2}, O'Grady, L.¹, Doherty, M.L.¹

¹ UCD School of Veterinary Medicine, ² UCD CVERA

Preventive Veterinary Medicine 120, 152-161 (2015)

Paratuberculosis is a challenging disease to control at farm level, in part due to the poor sensitivity of diagnostic tests and a prolonged incubation period. Simulation studies have highlighted on-farm management to be the most important factor in preventing on-farm spread. A risk assessment (RA) and management plan (MP) approach (collectively, RAMP) has been adopted around the world as the most appropriate method of controlling disease in infected farms. However, there are problems with RAMP that remain to be resolved. The RA relies heavily on farmer recollection and estimation resulting in subjectivity and substantial inter-observer variability. MPs consist of a series of qualitative, farm specific recommendations showing how management can be improved. However, MP assessment is generally conducted informally, and progress is monitored through 'end-point' diagnostic testing of adult animals and repeated risk assessments. Hazard analysis and critical control point (HACCP) has been developed as a proactive alternative to end-point testing. We hypothesise that farm-based HACCP systems may be a useful alternative to RAMP on farms where more intensive monitoring and evaluation of controls for paratuberculosis is required. Therefore, the objective of this methodological study was to develop a HACCP-based system for paratuberculosis control. Critical control points (CCPs) relating to peri-parturient area management, calving, new-born calf management and colostrum management were identified as areas where additional control could be exerted above existing methods. Novel monitoring systems were developed for each CCP, along with targets and corrective actions. This system is intended for use in high prevalence herds, or farms where more robust monitoring of key control points may be beneficial. It is currently being trialled on infected commercial dairy herds in Ireland.

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Bayesian estimation of prevalence of paratuberculosis in dairy herds enrolled in a voluntary Johne's Disease control programme in Ireland

McAloon, C. et al.

UCD School of Veterinary Medicine

A national voluntary control programme for Johne's Disease (JD; paratuberculosis) was introduced in Ireland in 2013. In 2005, the herd-level JD prevalence on dairy farms was estimated at around 20%, based on the results of a serological survey. This is considerably lower than "best guess" estimates across Europe of greater than 50%. The objective of this study was to use Bayesian methodology to estimate the prevalence of Irish herds infected with paratuberculosis among herds enrolled in the national voluntary control programme in 2013-14.

The effect of paratuberculosis on milk yield - A systematic review and meta-analysis

McAloon, C. et al.

UCD School of Veterinary Medicine

Bovine paratuberculosis is a disease characterized by chronic granulomatous enteritis causing protein-losing enteropathy. Adverse effects on animal productivity are key drivers in the attempt to control paratuberculosis at the farm level. Economic models require an accurate estimation of the production effects associated with paratuberculosis. The aim of this study was to conduct a systematic review and meta-analysis to investigate the effect of paratuberculosis on milk production.

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

More, S.J.^{1,2}, Cameron, A.R.³, Strain, S.⁴, Cashman, W.⁵, Ezanno, P.⁶, Kenny, K.⁷, Fourichon, C.⁶, Graham, D.⁸

¹ UCD CVERA, ² UCD School of Veterinary Medicine, ³ AusVet Animal Health Services Pty Ltd., Lyon, France, ⁴ Animal Health & Welfare Northern Ireland, Dungannon, Northern Ireland, ⁵ Private consultant, ⁶ INRA, Oniris, LUNAM Université, Biologie, Epidémiologie et Analyse de Risque en Santé Animale, Nantes, France, ⁷ DAFM Veterinary Laboratory Service, ⁸ Animal Health Ireland

Journal of Dairy Science 98, 5194-5210 (2015)

As part of a broader control strategy within herds known to be infected with *Mycobacterium avium* ssp. *paratuberculosis* (MAP), individual animal testing is generally conducted to identify infected animals for action, usually culling. Opportunities are now available to quantitatively compare different testing strategies (combinations of tests) in known infected herds. This study evaluates 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. A model was developed, taking account of both within-herd infection dynamics and test performance, to simulate the use of different tests at a single round of testing in a known infected herd. Model inputs included the number of animals at different stages of infection, the sensitivity and specificity of each test, and the costs of testing and culling. Testing strategies included either milk or serum ELISA alone or with fecal culture in series. Model outputs included effectiveness (detection fraction, the proportion of truly infected animals in the herd that are successfully detected by the testing strategy), cost, and cost-effectiveness (testing cost per true positive detected, total cost per true positive detected). Several assumptions were made: MAP was introduced with a single animal and no management interventions were implemented to limit within-herd transmission of MAP before this test. In medium herds, between 7 and 26% of infected animals are detected at a single round of testing, the former using the milk ELISA and fecal culture in series 5 yr after MAP introduction and the latter using fecal culture alone 15 yr after MAP introduction. The combined costs of testing and culling at a single round of testing increases with time since introduction of MAP infection, with culling costs being much greater than testing costs. The cost-effectiveness of testing varied by testing strategy. It was also greater at 5 yr, compared with 10 or 15 yr, since MAP introduction, highlighting the importance of early detection. Future work is needed to evaluate these testing strategies in subsequent rounds of testing as well as accounting for different herd dynamics and different levels of herd biocontainment.

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Bovine viral diarrhoea (BVD)

A study into the trends in retention of BVD virus positive calves and characteristics of retained BVDV positive calves

Clegg, T.A. et al.

UCD CVERA

Within the Irish eradication programme for bovine viral diarrhoea virus (BVDV), it is recommended that all persistently infected (PI) calves are culled as soon as possible after identification. During both the voluntary and the compulsory phases of the Irish programme, limited financial incentives have been available for the removal of PI calves. In the absence of full compensation, the retention of PI animals has been identified as an on-going challenge, albeit one that is not unique to the programme in Ireland. The aims of this study are to describe the trends in the retention of BVDV calves over time and identify the main characteristics of the animals retained and the herds that retain them.

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.¹, Graham, D.A.², Guelbenzu, M.³, Doherty, M.L.⁴, More, S.J.^{4,5}

¹ MSD Animal Health, ² Animal Health Ireland, ³ Agri-Food and Biosciences Institute, Belfast, Northern Ireland,

⁴ UCD School of Veterinary Medicine, ⁵ UCD CVERA

Irish Veterinary Journal 67, 18 (2014)

Infections with bovine herpesvirus 1 (BoHV-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. An indirect antibody ELISA test (SVANOVA, Biotech AB, Uppsala, Sweden) was applied to serum pools which were constructed from serum samples taken for a cross-sectional study of a convenience sample of 500 Northern Irish dairy and beef cow herds in 2010, for which vaccination status was determined by telephone survey. The herd-level seroprevalence of BoHV-1 and BVDV in Northern Ireland was estimated in non-vaccinating herds and associations between possible risk factors (herd type and herd size (quartiles)) and herd-level prevalence were determined using chi-squared analysis. The herd-level seroprevalence (of BoHV-1 and BVDV) in non-vaccinating herds was 77.3% (95% CI: 73.6–80.9%) and 98.4% (95% CI: 97.3–99.5%) respectively in the cross-sectional study. A significant difference existed in BoHV-1 herd-level seroprevalence between dairy and beef herds (74.7% vs 86.5% respectively; $p < 0.02$) though not for BVDV seroprevalence (98.5% vs 98.3% respectively; $p > 0.91$). A significant association was found between herd size (quartiles) and herd-level classification for BoHV-1 herd-level seroprevalence based on cut-off percentage positivity (COPP) ($p < 0.01$) while no such association was found for BVDV ($p = 0.22$). 15.5% and 23.8% of farmers used BoHV-1 and BVDV vaccines, respectively. BoHV-1 vaccine was used in 30% of dairy herds and in 11% of beef herds, while BVDV vaccine was used in 46% and 16% of dairy and beef herds, respectively.

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Influence of the retention of PI calves identified in 2012 during the voluntary phase of the Irish national bovine viral diarrhoea virus (BVDV) eradication programme on herd-level outcomes in 2013

Graham, D.A.¹, Clegg, T.A.², O'Sullivan, P.³, More, S.J.^{2,4}

¹ Animal Health Ireland, ² UCD CVERA, ³ Irish Cattle Breeding Federation, ⁴ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 120, 298–305 (2015)

This study was undertaken to investigate the impact of the retention of calves born in one calving season and considered to be persistently infected (PI) with bovine viral diarrhoea virus (BVDV) on herd-level outcomes in the following calving season. A secondary aim was to investigate the relationship between retention and the number of BVD+ calves detected the following season. The study population included a subset of herds enrolled in the 2012 voluntary BVD eradication programme in Ireland, specifically those with a birth registered to more than 80% of the cows between 1st January and 15th July and BVDV test results available for at least 80% of these calves, during both 2012 and 2013. Calves were considered PI based on either an initial positive result without further testing (BVDPOS) or a positive result on confirmatory testing (BVDPI), collectively considered BVD+ calves. Herd-level outcomes included the BVD status of the herd, and the number of BVD+ calves born between 1st January and 15th July 2013 (the study period). There was a significant univariable association between herd BVD status in 2013 and a number of general herd factors, including location, herd type, size and number of introduced animals (overall and those pregnant at time of introduction), as well as with each of six different factors related to the retention of virus-positive calves: the number of BVD+ calves in 2012; the maximum time (days) any one BVD+ born in 2012 was retained up to September 2013; the mean time (days) BVD+ animal(s) born in 2012 were retained up to September 2013; the date (quarter/year) the last BVD+ left the herd; the presence/number of 2012-born BVD+ retained in the herd at 1st January 2013. Separate multivariable models were constructed for each retention variable. The best model fit (based on AIC) was obtained using the retention variable “date (quarter/year) last BVD+ calf left the herd”, followed by “total time all BVD+ calves were retained in the herd”, with (log) herd size also retained in the models. Significant differences were also found in the number of positive calves detected in positive herds in 2013 for all of the calf retention risk factors. These findings confirm an increased probability of finding a BVD+ animal in a herd following the retention of positive calves born in the previous calving season, highlighting the importance of their prompt removal.

Preventive Veterinary Medicine, 120, Graham et al., Influence of the retention of PI calves identified in 2012 during the voluntary phase of the Irish national bovine viral diarrhoea virus (BVDV) eradication programme on herd-level outcomes in 2013, 298-305, Copyright © 2015, with permission from Elsevier B.V.

Survival time of calves with positive BVD virus results born during the voluntary phase of the Irish eradication programme

Graham, D.A.¹, Clegg, T.A.², O'Sullivan, P.³, More, S.J.^{2,4}

¹ Animal Health Ireland, ² UCD CVERA, ³ Irish Cattle Breeding Federation, ⁴ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 119, 123–133 (2015)

A retrospective case–control study was undertaken to investigate the temporal pattern of, and factors associated with, the survival of BVD virus-positive calves, identified between January and July 2012 during the voluntary phase of the Irish national eradication programme. Potential statuses for case and control calves consisted of: alive in birth herd; slaughtered; sold; dead (due to culling or death from natural causes and termed ‘involuntary removal’). An initial comparison of cases and controls found significant differences between the outcomes for cases and controls and also between cases

in relation to herd type (beef, dairy, dual purpose), sex, age and test status (BVDPOS – no confirmatory test; BVDPI – positive on confirmatory test). Key differences included a higher level of case animals still alive in, or slaughtered from, beef herds, a greater proportion of BVDPI animals being retained relative to those with a BVDPOS status and a significantly lower slaughter weight (89 kg) for case animals relative to controls. Separate multivariable models were constructed for dairy and beef cases. In the final dairy model breed (Jersey or non-Jersey), county and BVD status were retained, with the last two found to be time-varying covariates with significant changes in hazard ratios (HR) over time. In the beef model, herd size, county and BVD status were retained, with the HR for the last two factors again varying significantly over time. With the exception of the addition of the number of BVD positive calves in the herd to the dairy model, the same factors were identified when models were restricted to the first 90 days following the birth of case animals. A greater knowledge and understanding of all of these factors will allow refinement of programme communications and incentives to encourage prompt removal of PI calves from all sectors of the Irish breeding herd during the compulsory phase of the national eradication programme.

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Quantifying the risk of spread of bovine viral diarrhoea virus (BVDV) between contiguous herds in Ireland

Graham, D. et al.

Animal Health Ireland

The control of bovine viral diarrhoea virus (BVDV) mainly focuses on the identification and restriction of persistently infected (PI) animals. However, other transmission pathways can also result in new breakdowns, including the movement of animals pregnant with PI calves (Trojan animals) and the spread of infection between contiguous farms. Contiguous spread is likely an important problem in the BVD eradication programme in Ireland, given the spatial distribution of residual infection, and the highly fragmented nature of land holdings on many Irish farms. In this study, we seek to quantify the risk of BVD spread between contiguous herds in Ireland.

The impact of retention of persistently infected (PI) animals on 'time to eradication' in the national BVD eradication programme: a modelling study

Lange, M. et al.

Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany

Persistently infected (PI) retention has been an ongoing problem in the industry-led BVD eradication programme in Ireland. This is of concern, noting that PI animals play a central role in the epidemiology of BVD infection, both on-farm and regionally. In this work, a modelling approach is proposed, allowing us to answer to a broad series of 'what-if' questions, including the impact of PI retention on time to eradication. The objectives of this paper are to develop a model of BVD infection within the Irish cattle population, and to investigate the impact of PI retention on time to eradication in the national BVD eradication programme, based on current metrics achieved.

The impact on 'time to eradication' of alternative BVD control methods in herds once negative herd status has been attained: a modelling approach

Graham, D. et al.

Animal Health Ireland

Two primary control methods have been used in BVD eradication programmes, including the use of screening tests to determine herd BVD status and the use of direct methods to identify BVD+ animals. To date, direct methods have formed the basis of control in the national BVD eradication programme in Ireland. There have been suggestions that indirect methods may prove cost-effective in herds, once negative herd status (NHS) has been achieved. This question can be addressed, using a BVD model recently developed for Ireland. The objective of this study is to investigate the impact on 'time to eradication' of alternative BVD control methods in Ireland from 2016 on all farms where NHS had been attained: either continued tissue tagging of newborn calves or a shift to serosurveillance.

Who benefits? Who pays? Resolving PI retention in the Irish BVD eradication programme

More, S.J. et al.

UCD CVERA & UCD School of Veterinary Medicine

The benefits to Ireland of BVD eradication are well recognised. In earlier work, the annualised benefits of eradicating BVD virus were estimated to exceed the costs by a factor of 5 in the suckler beef sector and by a factor of 14 in the dairy sector. Further, the benefits of BVDV eradication from Ireland were predicted to far exceed the direct financial costs. A compulsory national programme of BVD eradication commenced in 2013, based primarily on the identification and removal of persistently infected (PI) animals. National progress towards eradication has been constrained, however, by an ongoing problem of PI retention on some farms. This study seeks to determine the additional eradication costs incurred as a result of PI retention in the national programme, and an understanding of who is bearing these costs. In addition, the study will evaluate the cost-effectiveness of the interventions required to resolve PI retention, and an understanding of the beneficiaries of such interventions and of who should pay.

Quantifying the importance of Trojan dams in the national BVD eradication programme in Ireland

Reardon, F. et al.

UCD CVERA, Animal Health Ireland

A national eradication programme for bovine viral diarrhoea virus (BVDV) began in Ireland in 2013. Trojan dams are recognised as disseminators of infection, however, there is no published work about the number of persistently infected PI calves that are born in herds due to the introduction of Trojan dams. Therefore, the objective of the current study was to quantify the importance of Trojan dams in relation both to the number of PI births directly attributable to them and the subset of herds where BVD introduction can be attributed to a Trojan dam.

Evaluating the potential infection control benefit of measures to reduce the movement of Trojan dams in the national BVD eradication programme in Ireland

Reardon, F. et al.

UCD CVERA, Animal Health Ireland

Trojan dams have a known but unquantified role in the farm-to-farm transmission of BVDV. International research indicates that secondary methods of disease transmission, such as the farm to farm movement of pregnant dams, will become proportionately more important during an eradication programme as the movement of BVD+ animals is curtailed. The current study evaluates potential measures of controlling the movement of Trojan dams to avoid spread of BVD without unnecessarily restricting trade.

Modelling of cattle movements in Ireland, with emphasis on implications for control of bovine tuberculosis and BVD

Tratalos, J. et al.

UCD CVERA

A standardised dataset of individual cattle movements within Ireland dating back to 2000 has been compiled (N = 78,479,322), alongside records of birth to 1998 (N = 36,705,853) and herd profiles to 2004 (N = 68,190,818), linked together within a SQL server relational database. These data will be modelled within a spatially-explicit network analysis framework to examine i) how interconnectedness between farms explains the spread of cattle diseases such as TB, BVD and Johne's disease ii) how surveillance measures could be better targetted to take into account these interactions and iii) the degree to which movements of calves in the months after birth might limit the efficacy of herd level testing for BVD based on testing the immunological response of a sample of calves at 6-9 months of age.

Infectious bovine rhinotracheitis (IBR)

Patterns of exposure to two bovine herpesviruses in Irish cattle

O'Neill, R. et al.

DAFM Veterinary Laboratory Service

Herpesvirus infections cause a range of clinical syndromes in cattle – respiratory, reproductive, systemic and nervous. Although Bovine Herpesvirus 1 (BHV-1) is the most prominent due to semen collection centre controls and eradication programmes in several European countries, Bovine Herpesvirus 4 (BHV-4) shares many of the latter's features in terms of life cycle and clinical signs. This study explores together (for the first time) the patterns of exposure to BHV-4 and BHV-1 in Irish cattle and examines and compares the associations with individual animal and herd level factors.

Non-biosecure diseases and conditions

Milk quality

The relative contribution of pathology in the observed increase in somatic cell count (SCC) at the start and end of lactation

Boland, F. et al.

Population Health Sciences, Royal College of Surgeons in Ireland

In Ireland, there is a marked temporal trend in the percentage of dairy herds exceeding 200,000 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 lactation, compared with other times. It is thought that this difference may be related to SCC history of the animal. Therefore, the objective of this study is to investigate the effect of pathological factors on temporal trends in herd SCC.

The impact of removal of the seasonality formula on the eligibility of Irish herds to supply raw milk for processing of dairy products

Fenlon, C. et al.

UCD School of Computer Science

Milk sold by Irish farmers for manufacture must also comply with EU regulations. Regulations 853/2004 and 854/2004 govern the eligibility to supply raw milk for processing, using a three-month rolling average bulk tank SCC as one of the determining criteria. Irish SCC data is also subject to a monthly seasonal adjustment, for four months from November to February, as allowed under Commission Decision 96/360/EC. Its purpose is to take account of the seasonality of milk production in Ireland. However, in a recent study no evidence of a dilution effect of SCC with increasing milk yield in Irish dairy cattle, thereby questioning this latter adjustment. The aim of this paper is to estimate the impact of removal of the seasonality formula on the eligibility of Irish herds to supply raw milk for processing of dairy products.

Temporal changes in bulk tank SCC and milk volume around the time of herd suspension: insights into control measures taken in Ireland during 2013

Fenlon, C. et al.

UCD School of Computer Science

Milk sold by Irish farmers for manufacture must comply with EU regulations. Under these regulations, at least one bulk tank collection per month from a supplier must be tested for SCC. All SCC results for the individual herd for that month and the previous two months are combined, to generate a three-month rolling average (two different methods were used), which must remain under 400,000 cells/mL, before becoming ineligible to supply milk. The aim of this paper is to describe temporal changes in bulk tank SCC and milk volume in Irish herds around the time of herd suspension in 2013, providing insights into control measures taken.

Mapping milk production in Ireland

McGrath, G. et al.

UCD CVERA

This project seeks to 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.

Temporal trends in intramammary antimicrobial usage on Irish dairy farms during 2003-15

More, S.J. et al.

UCD CVERA & UCD School of Veterinary Medicine

There is increasing focus on the on-farm use of antimicrobial products in farmed animal production. Data on intramammary antimicrobial usage on Irish dairy farms are available from 2003-10, based on sales data. This study seeks to extend this earlier work, evaluating temporal trends in intramammary antimicrobial usage on Irish dairy farms during 2003-15.



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Fertility

Key factors affecting reproductive success of thoroughbred mares and stallions on a commercial stud farm

Lane, E.A. et al.

UCD CVERA & DAFM

Ireland is the third largest producer of thoroughbred horses worldwide. Despite the scale of the thoroughbred industry in Ireland, there is no research demonstrating current reproductive efficiency of thoroughbred mares in a commercial setting. The aim of this study was to evaluate key parameters contributing to reproductive success and pregnancy loss on a large commercial Irish thoroughbred farm breeding for flat-racing purposes.

Key factors influencing reproductive performance in seasonal calving dairy herds

Lane, E.A. et al.

DAFM

Economic sustainability of seasonal calving dairy herds is dependent on fertility performance. In Ireland, management systems are grass-based, and dairy cows must calve within a pre-defined calving season to maximize economic output. Breed, age, milk production, energy balance, and inter-current disease have all been demonstrated to influence dairy cow fertility. The aim of this study was to evaluate the relative importance of herd and management factors on reproductive performance in seasonal calving dairy herds.



OTHER ANIMAL HEALTH AND WELFARE ISSUES



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Emergency animal health issues

Development of high resolution local scale Foot and Mouth Disease dispersion model

McGrath, G. et al.

UCD CVERA

We will investigate the possibility of creating a new dispersion model that will run in conjunction with the existing dispersion model (HYSPLIT). This dispersion model will have a high resolution and will be based on nearest weather station data. This model will offer better precision for potential local spread.

Enhancement of the current national Foot and Mouth Disease (FMD) spread model

McGrath, G. et al.

UCD CVERA

The current FMD model consists of 3 components. An inter-herd disease spread model which controls for virus emission. A wind dispersion model (HYSPLIT) and a risk of infection of model. We intend to revise the first and third component of the overall model to perform better in an Irish context.



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Animal welfare

Bovine welfare

Conducting sensitive social science research about on-farm animal welfare incidents: challenges and approaches

Devitt, C. et al.

Private consultant

The social sciences have the potential to allow for a deeper understanding of human-farm animal relations. However, such research, exploring problematic human-farm animal interactions, can be of a sensitive nature. Despite recommendations being made for more interdisciplinary collaboration between the animal welfare sciences and social sciences, as yet there is little discussion in the animal welfare sciences on how best to conduct research of this nature on animal owners. Drawing on social science research conducted in 2012 on the human element of on-farm animal welfare incidents in Ireland, we present a case study of the sensitivities and challenges involved in social science research related to farm animal welfare.

Dilemmas experienced by government veterinarians when responding professionally to farm animal welfare incidents in Ireland

Devitt, C.¹, Kelly, P.², Blake, M.², Hanlon, A.³, More, S.J.^{3,4}

¹ Private consultant, ² DAFM, ³ UCD School of Veterinary Medicine, ⁴ UCD CVERA

Veterinary Record Open 1, e000003 (2014)

This paper identifies the dilemmas experienced by government veterinarians during their investigations of farm animal welfare incidents that involve herd owner social, health, and/or psychological difficulties. The paper builds on exploratory qualitative research into the impact of these difficulties on farm animal welfare. The study used a qualitative research approach. Focus groups were conducted. In Ireland, an Early Warning System (EWS), which brings together relevant agencies, is in place to identify and prevent farm animal welfare problems before they become critical. This study is concerned with the experiences of government veterinarians who respond to farm animal welfare incidents. Specific focus is on incidents that involve herd owner social/psychological/health-related difficulties. In total, n=18 government veterinarians (representing 15 per cent of the population sample), all with a keen interest in farm animal welfare, participated. These were selected on the basis of their interest, experience, and involvement in farm animal welfare. One government veterinarian declined to participate. Four focus groups were conducted with government veterinarians. These took place in the south (S), south-west (SW), midlands (M), and north-west region of Ireland (NW). All 16 District Veterinary Offices (DVOs) were represented in the focus groups. The results reveal three professional dilemmas that exist for government veterinarians: (1) defining professional parameters; (2) determining the appropriate response; (3) involvement versus detachment. Participants reported not wanting any additional training. Instead, it was agreed that a formal bridge to social service providers who have the professional capability to respond appropriately and with confidence, was required. Clearly defined guidelines are required for government veterinarians in their encounters with farm animal welfare incidents where there is a complex human component. A coordinated multiagency approach that is flexible enough to meet the needs of individual farm animal welfare cases is required.

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An investigation into the human element of on-farm animal welfare incidents in Ireland

Devitt, C.¹, Kelly, P.², Blake, M.², Hanlon, A.³, More, S.J.^{3,4}

¹ Private consultant, ² DAFM, ³ UCD School of Veterinary Medicine, ⁴ UCD CVERA

Sociologia Ruralis 55, 400–416 (2015)

A previous study on key farm performance indicators for animal welfare incidents in Ireland provided anecdotal evidence to suggest that farm animal welfare standards are often underpinned by social and human health-related factors among farmers. The present study took an exploratory approach to identify these factors and how they influence farm animal neglect. Semi-structured interviews were conducted with farmers. Identified factors included farming difficulties associated with age and help on the farm ($n = 5$), mental health-related problems ($n = 4$), and differing perceptions of animal welfare ($n = 4$). Stress was a prevalent theme. Evidence suggests that these negative human factors impact on farmers' ability to carry out farm management activities. Poor uptake of support services was noted and barriers included resistance, self-reliance and an inability to talk openly about mental health problems. Initiatives such as the early warning system, aimed at reducing the incidence of farm animal neglect in Ireland, should be understood as often involving a human element. In particular, further research is required into how mental health problems may lead to altered or reduced regard for animal welfare.

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A study of factors contributing to reduced animal welfare in Irish marts

O'Gorman, J. et al.

DAFM

Quantitative data about welfare of animals at Irish marts is limited, noting that most of these facilities were designed and built about 50 years ago. Such information is important, as it will inform new regulatory frameworks for movement and transfer of animals in Ireland. Therefore, the objective of this study is to quantify frequencies of some welfare outputs at Irish marts, and of contributing factors.

Equine welfare

Horse impoundments under Control of Horses legislation in the Munster region of Ireland: factors affecting euthanasia

Cullinane, M.¹, O'Sullivan, E.², Collins, D.M.³, Byrne, A.W.^{3,4}, More, S.J.^{3,5}

¹ DAFM, ² The Veterinary Department of Cork County Council, ³ UCD CVERA, ⁴ Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast, Northern Ireland, ⁵ UCD School of Veterinary Medicine

Veterinary Record 176, 100 (2015)

Recently, considerable international attention has been paid to the problem of unwanted horses. In Ireland, stray horses, particularly in urban areas, are a further problem. The Control of Horses Act 1996 was enacted in response to an ongoing problem of uncontrolled horses in public places. As yet, no research work has been conducted focusing on stray horses in Ireland. This paper describes horses impounded under the Act in the Munster region of Ireland during 2005–2012 and the factors influencing decisions regarding their disposal. A logistic regression model was developed to investigate factors influencing the probability that a horse was euthanised during impoundment. In total, 3625 seizure events were recorded, most towards the end of the study period. Predictors for euthanasia during 2010–2012 included seizure location, sex, age, colour, body condition score and year. This study highlights the problem of stray horses in Ireland, particularly in urban areas. There is a need for rigorous enforcement of newly enacted horse identification legislation, allowing a fully integrated traceability system. More is required to manage the long-established societal problems of stray horses in urban settings, with a uniform approach by all Local Authorities being long overdue.

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Porcine welfare

Docking the value of pigmeat? Prevalence and financial implications of welfare lesions in Irish slaughter pigs

Harley, S.¹, Boyle, L.A.², O'Connell, N.E.³, More, S.J.^{4,5}, Teixeira, D.L.², Hanlon, A.⁵

¹ School of Veterinary Science, University of Liverpool, Neston, Cheshire, United Kingdom, ² Teagasc, ³ Institute for Global Food Security, Northern Ireland Technology Centre, Queens University Belfast, Belfast, Northern Ireland, ⁴ UCD CVERA, ⁵ UCD School of Veterinary Medicine

Animal Welfare 23, 275-285 (2014)

Expansion of the meat inspection process to incorporate animal-based welfare measurements could contribute towards significant improvements in pig (*Sus scrofa domestica*) welfare and farm profitability. This study aimed to determine the prevalence of different welfare-related lesions on the carcass and their relationship with carcass condemnations (CC) and carcass weight (CW). The financial implications of losses associated with CC and CW reductions related to the welfare lesions were also estimated. Data on tail lesions, loin bruising and bursitis, CW and condemnation/trimming outcome (and associated weights) were collected for 3,537 slaughter pigs (mean [± SEM] carcass weight: 79.2 [± 8.82] kg). Overall, 72.5% of pigs had detectable tail lesions, whilst 16.0 and 44.0% were affected by severe loin bruising and hind limb bursitis, respectively. There were 2.5% of study carcasses condemned and a further 3.3% were trimmed. The primary cause of CC was abscessation. While tail lesion severity did not increase the risk of abscessation, it was significantly associated with CC. Male pigs had a higher risk of tail lesions and of CC. The financial loss to producers associated with CC and trimmings was estimated at €1.10 per study pig. CW was reduced by up to 12 kg in cases of severe

tail lesions. However, even mild lesions were associated with a significant reduction in CW of 1.2 kg. The value of the loss in potential CW associated with tail lesions was €0.59 per study pig. Combined with losses attributable to CC and trimmings this represented a loss of 43% of the profit margin per pig, at the time of the study, attributable to tail biting. These findings illustrate the magnitude of the impact of tail biting on pig welfare and on profitability of the pig industry. They also emphasise the potential contribution that the inclusion of welfare parameters at meat inspection could make to pig producers in informing herd health and welfare management plans.

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The relationship between tail lesion scores and viscera condemnations in slaughter pigs

Teixeira, D.L. et al.

Pontificia Universidad Católica de Chile, Santiago, Chile

Tail biting is a widespread behavioural vice of pigs, resulting in poor performance and carcass condemnation. Tail biting is the most common cause of secondary bacterial spread in pigs because the damage provides routes for the spread of infection, and tail lesion severity scores have the potential to be used as a predictor for the presence of internal lesions. As yet, the relationship between tail biting and diseases or condemnations of the heart and liver are less well investigated. Therefore, the aim of this study was to investigate if tail lesion scores can be used to predict viscera condemnations for disease lesions.



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Bovine spongiform encephalopathy (BSE)

Factors which influence the quality of BSE samples from fallen cattle in Ireland

Cahill, A. et al.

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 (fallen cattle). Some of these samples are of poor quality due to autolysis and this has 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.

Investigation of the 2015 BSE case in Ireland: Creating a BSE investigation framework for similar cases

O'Connor, J. et al.

DAFM

A case of classical BSE was confirmed in Ireland on 25 June 2015, in a cow born in county Louth in January 2010. An investigation was subsequently conducted to determine possible sources of exposure. In this study, we present details of this case, the results of this investigation and a proposed investigative framework to guide similar investigations into the future.

Schmallenberg virus

Prevalence and distribution of exposure to Schmallenberg virus in Irish cattle during October 2012 to November 2013

Barrett, D.¹, More, S.J.^{2,3}, O'Neill, R.¹, Bradshaw, B.¹, Casey, M.¹, Keane, M.¹, McGrath, G.², Sammin, D.¹

¹ DAFM Veterinary Laboratory Service, ² UCD CVERA, ³ UCD School of Veterinary Medicine

BMC Veterinary Research 11, 267 (2015)

Schmallenberg virus (SBV) was first identified in November 2011. It is a novel *Orthobunyavirus* (family *Bunyaviridae*) whose main ill effect is congenital malformation of the musculoskeletal and central nervous systems. It is borne by *Culicoides* spp., and has spread extensively in western Europe. The first case of SBV in Ireland was diagnosed in October 2012. It was anticipated that once the virus emerged in Ireland that there would be wide scale or nationwide spread over the course of the 2013 vector season. The objectives of this study were to determine the seroprevalence and distribution of exposure to Schmallenberg virus in Irish cattle from November 2012 to November 2013. Samples of brain for the pathology based surveillance were collected from malformed bovine and ovine fetuses submitted for post mortem examination. These samples were tested for SBV using RT-qPCR. Three serological surveys were carried out on sera submitted for the national brucellosis eradication programme. A spatial analysis of both sets of data was carried out. Between October 2012 and 10th May 2013, SBV was confirmed by RT-qPCR in brain tissues from malformed fetuses obtained from 49 cattle herds and 30 sheep flocks in Ireland. In national serosurveys conducted between November 2012 until November 2013 the herd-level and animal-level SBV seroprevalences in cattle were 53 and 36 % respectively for the first survey, 51 and 35 % for the second survey and 53 and 33 % for the third survey. The herd level seroprevalence in counties ranged from 0 to 100 %, with the counties in the south and southeast having the highest seroprevalence (>50 %), the midlands a moderate herd level seroprevalence (10–50 %) while northern and north western counties had a low herd level seroprevalence (0–10 %). There was close spatial agreement between the results of the two different targeted surveillance strategies. At the end of the 2012 vector season, there was widespread exposure to SBV among herds in southern and south eastern Ireland. During 2013, there was little or no evidence of further outward spread, unlike the situation in several other European countries. Given the lack of evidence for circulation of the virus since 2012, it is likely that the younger age cohort in herds previously exposed to SBV and substantial proportions of animals of all ages on the margins of affected areas are immunologically naïve to SBV, and would be susceptible to infection if the virus were to re-emerge.

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Exposure to Schmallenberg virus in Irish sheep in 2013

Barrett, D.J.¹, More, S.J.^{2,3}, O'Neill, R.G.¹, Collins, D.M.², O'Keefe, C.¹, Regazzoli, V.¹, Sammin, D.¹

¹ DAFM Veterinary Laboratory Service, ² UCD CVERA, ³ UCD School of Veterinary Medicine

Veterinary Record 177, 494 (2015)

Malformed fetuses attributable to Schmallenberg virus (SBV) were found in 49 cattle herds and 30 sheep flocks exclusively in the southern and eastern parts of Ireland during November 2012 to November 2013. National bovine serological studies late in 2012 and 2013 confirmed exposure to SBV was effectively confined to the south-east. It was unclear whether the distribution of seroconversion in cattle reflected the situation in sheep. Several studies have shown that *Culicoides* species preferentially feed on cattle rather than sheep, leading to lower levels of seroconversion in sheep

flocks than in neighbouring cattle herds. It was anticipated that SBV would continue to spread across the country over the second (2013) vector season, similar to the experience in mainland Europe. The objectives of this study were to determine the geographical distribution of SBV exposure in Irish sheep before and during the 2013 vector season, and to determine if SBV was active in 2013 in flocks where SBV infection was previously confirmed.

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The impact of infection with Schmallenberg virus on weaning rate in Irish sheep flocks

Barrett, D.¹, O'Neill, R.¹, Sammin, D.¹, Clegg, T.A.², More, S.J.^{2,3}

¹ DAFM Veterinary Laboratory Service, ² UCD CVERA, ³ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 122, 332–338 (2015)

Schmallenberg virus (SBV) disease emerged in Europe in 2011, with the virus initially identified in Germany, and the first confirmed case of SBV infection in Ireland diagnosed in a dairy calf in October 2012. SBV was subsequently confirmed by RT-PCR in 49 cattle herds and 39 sheep flocks. While these studies provide a good representation of the spatial distribution of SBV in Ireland, they do not quantify the impact of SBV on productivity. The objectives of this study were to assess the impact of SBV on weaning rate in Irish sheep flocks, based on data reported by Irish sheep farmers, and to evaluate weaning rate in sheep flocks as an indicator to be used in emerging disease surveillance systems. A questionnaire on productivity and management practices in sheep flocks was developed to gather data from sheep farmers. Valid responses from 267 sheep farmers were received. Negative binomial regression indicated that flocks with a confirmed SBV diagnosis had a weaning rate 0.9 times that of flocks free of SBV. The 10% reduction in weaning rates as a result of SBV is a justifiable concern for farmers and should be considered in formulating flock breeding policy. This study shows the value of a production database as an indicator of an emerging disease and the economic impact of that disease in Irish sheep flocks.

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To determine if there was a reduction in milk yield among dairy cows in Wexford associated with the introduction of Schmallenberg virus

Barrett, D. et al.

DAFM Veterinary Laboratory Service

Milk drop syndrome first alerted authorities to the emergence of Schmallenberg virus (SBV) in Germany and the Netherlands in 2011. Although foetal malformations due to SBV have been widely documented in the south and south east of Ireland, there have been no reports of milk drop syndrome associated with SBV. Previous studies have indicated a high level of exposure to SBV in Co Wexford and the timeline of incursion has been established. The objective of this study is to establish if there was a drop in milk yield associated with the emergence of SBV in Wexford dairy herds, and if so to develop an early warning system based on milk yield data to flag the emergence of new conditions in the future.

Schmallenberg virus bulk milk sample survey

Casey, M. et al.

UCD Veterinary Laboratory Service

5,775 bulk milk samples from a number milk purchasers were tested for Schmallenberg virus (SBV). This study will compare the spatial distribution of positive tests from these bulk milk samples to the distribution of positive tests from a serological survey.

Schmallenberg virus: retrospective profiling of the 2012 SBV incursion into Ireland

O'Neill, R. et al.

DAFM Veterinary Laboratory Service

This study aims to identify the date and source location of incursion of SBV into Ireland in 2012. Wind dispersion modelling will be used in conjunction with serological survey results to build a hypothesis for profiling the incursion event.



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Cadmium exposure in cattle

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

Canty, M.J.^{1,2}, Scanlon, A.², Collins, D.M.¹, McGrath, G.¹, Clegg, T.A.¹, Lane, E.^{1,2}, Sheridan, M.K.², More, S.J.^{1,3}

¹ UCD CVERA, ² DAFM, ³ UCD School of Veterinary Medicine

Science of The Total Environment 485/486, 223–231 (2014)

In Ireland, an estimated 15% of Irish soils exceed the EU threshold limit for soil Cd of 1 mg/kg. The aim was to determine the concentrations of Cd and other heavy metals (As, Hg and Pb) in kidneys collected from cattle at slaughter. Systematic sampling of eligible animals (animals that were born and reared until slaughter in the same Irish county) at the time of slaughter was conducted, until a threshold number of animals from all 26 counties and 6 age categories was reached. A predictive surface of soil Cd was generated, by kriging the Cd values of 1310 previously reported soil samples. A linear regression weighted model was developed to model kidney Cd concentration, using the risk factors of age, sex, breed, province and estimated soil Cd concentration. Kidney Cd (n = 393) concentrations varied between 0.040 and 8.630 mg/kg wet weight; while concentrations of As, Hg and Pb were low. The estimated weighted proportion of animals with a high (≥ 1 mg/kg) kidney Cd concentration was 11.25% (95% CI: 8.63–14.53%). Key predictors for high kidney Cd concentration were soil Cd, animal age and province. At a soil Cd concentration of 1.5 mg/kg, it was predicted that an age threshold to avoid exceeding a kidney Cd concentration of 1 mg/kg in most animals would be ~ 3 y in Connacht, > 4 y in Ulster, and > 5 y in Leinster and Munster. In naturally occurring areas of high Cd levels in soils in Ireland, the Cd level in bovine kidneys can exceed the current EU ML of 1 mg/kg in older animals. Kidneys of most cattle under three years of age will conform with EU requirements.

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Cadmium exposure and consequence for the health and productivity of farmed ruminants

Lane, E.A.¹, Canty, M.J.¹, More, S.J.^{2,3}

¹ DAFM, ² UCD School of Veterinary Medicine, ³ UCD CVERA

Research in Veterinary Science 101, 132–139 (2015)

This paper reviews Cd exposure and consequences for the health and productivity of farmed ruminants. In farmed ruminants, Cd exposure may be associated with a number of different activities, including industrial processing, mining, and agricultural practices, and is also higher in soils in some geographic regions. Cd kidney concentrations increase with age and Cd exposure. Although Cd toxicity in farmed ruminants has been demonstrated experimentally, there are no published reports of naturally occurring Cd toxicity in farmed ruminants. Clinical signs of Cd intoxication are unlikely with a daily dietary Cd intake of less than 5 mg/kg feed, which is 5–10 times higher than the maximum permitted Cd concentration in ruminant feed in the European Union. In farmed ruminants, Cd levels in tissue are largely dependent on the Cd content of diet. However, many factors affect Cd availability, relating to soils, plants and the presence of other trace elements including Ca, Cu, Fe, Mn, Mo, Se and Zn. Experimental studies have highlighted the ability of Cd to alter trace element status, and the protective effect of good mineral status, however, there remain gaps in knowledge of the impact of these interactions on the health and productivity of farmed animals.

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Other farmed ruminant health issues

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

Canty, M.J.^{1,2}, Fogarty, U.³, Sheridan, M.K.², Ensley, S.M.⁴, Schrunk, D.E.⁴, More, S.J.^{1,5}

¹ UCD CVERA, ² DAFM, ³ Irish Equine Centre, ⁴ College of Veterinary Medicine, Iowa State University, Ames, Iowa, USA, ⁵ UCD School of Veterinary Medicine

Irish Veterinary Journal 67, 21 (2014)

Four primary mycotoxicosis have been reported in livestock caused by fungal infections of grasses or cereals by members of the *Clavicipitaceae* family. Ergotism (generally associated with grasses, rye, triticale and other grains) and fescue toxicosis (associated with tall fescue grass, *Festuca arundinacea*) are both caused by ergot alkaloids, and referred to as 'ergot alkaloid intoxication'. Ryegrass staggers (associated with perennial ryegrass *Lolium perenne*) is due to intoxication with an indole-diperpene, Lolitrem B, and metabolites. Fescue-associated oedema, recently described in Australia, may be associated with a pyrrolizidine alkaloid, N-acetyl norloline. Ergotism, caused by the fungus *Claviceps purpurea*, is visible and infects the outside of the plant seed. Fescue toxicosis and ryegrass staggers are caused by *Neotyphodium coenophialum* and *N. lolii*, respectively. Fescue-associated oedema has been associated with tall fescue varieties infected with a specific strain of *N. coenophialum* (AR542, Max P or Max Q). The name *Neotyphodium* refers to asexual derivatives of *Epichloë* spp., which have collectively been termed the epichloë fungi. These fungi exist symbiotically within the grass and are invisible to the naked eye. The primary toxicological effect of ergot alkaloid involves vasoconstriction and/or hypoprolactinaemia. Ingestion of ergot alkaloid by livestock can cause a range of effects, including poor weight gain, reduced fertility, hyperthermia, convulsions, gangrene of the extremities, and death. To date there are no published reports, either internationally or nationally, reporting ergot alkaloid intoxication specifically associated with perennial ryegrass endophytes. However, unpublished reports from the Irish Equine Centre have identified a potential emerging problem of ergot alkaloid intoxication with respect to equines and bovines, on primarily perennial ryegrass-based diets. Ergovaline has been isolated in varying concentrations in the herbage of a small number of equine and bovine farms where poor animal health and performance had been reported. Additionally, in some circumstances changes to the diet, where animals were fed primarily herbage, were sufficient to reverse adverse effects. Pending additional information, these results suggest that Irish farm advisors and veterinarians should be aware of the potential adverse role on animal health and performance of ergot alkaloids from perennial ryegrass infected with endophytic fungi.

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The low milk fat syndrome in grazing Irish dairy cows

Carty, C. et al.

UCD School of Veterinary Medicine

The low milk fat syndrome most commonly occurs in dairy cows fed diets with a high ratio of carbohydrate to roughage. It is characterized by markedly depressed yields of milk fat. As yet, there is limited quantitative data on the herd-level prevalence of low milk fat syndrome in Ireland. The objectives of this study are to determine the herd-level prevalence of low milk fat syndrome in Irish milk recorded herds over the last 10 years, including associated risk factors.

The prevalence and risk factors for antibodies to *Coxiella burnetii* (Q fever) in bulk tank milk samples from Irish dairy cattle herds

Ryan, E. et al.

DAFM Veterinary Laboratory Service

Coxiella burnetii is the causative agent of Q fever, a zoonotic disease of increasing public health importance which also causes abortion and fertility problems in cattle. The objective of this work was to estimate the prevalence of antibodies to *C. burnetii* in samples of bulk tank milk collected from Irish dairy farms, to determine whether positive herds clustered spatially, and to investigate the strength of association between certain putative risk factors and positive status.

Risk factors for lameness on 10 dairy farms in Ireland

Doherty, N.¹, More, S.J.^{1,2}, Somers, J.¹

¹ UCD School of Veterinary Medicine, ² UCD CVERA

Veterinary Record 174, 609 (2014)

Lameness is an important welfare issue for dairy cows and has significant economic implications. The aetiology of lameness is multifactorial and the result of interactions between the environment, farm management, nutrition and genetics. Detailed research on risk factors for lameness have been conducted in several countries, particularly New Zealand, the UK and the USA, and are known to vary with different management systems. To date, lameness is best understood in cattle-managed in-housing, with limited knowledge available for other management systems. In Ireland, the prevalence of lameness in cows at grass and indoors is 17 per cent and 42 per cent, respectively. This is similar to results from the UK, with relatively comparable management systems and climate, with 15 per cent for grazing herds and 39 per cent for zero-grazing herds. With the impending abolition of quotas within the European Union, many farmers will be seeking to increase their herd size, and it is therefore imperative that relevant risk factors are identified and corrected. The aim of this investigation was to evaluate risk factors for lameness on 10 dairy farms in Ireland.

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A retrospective epidemiological analysis of fatal cases of bovine respiratory disease diagnosed in cattle in the Irish Regional Veterinary Laboratories (RVLs) between 2005 and 2012

Murray, G. et al.

DAFM

Respiratory disease in cattle is the main cause of morbidity and mortality in both traditional husbandry systems and in feedlots. The clinical outcome of infectious respiratory disease can comprise both acute fatal respiratory disease and prolonged intractable respiratory disease cases. In Ireland, respiratory disease is consistently recorded as the most commonly diagnosed cause of bovine mortality in the Irish Regional Veterinary Laboratories (RVLs). The aim of this study is to describe, and investigate, the epidemiological features of fatal cases of respiratory disease diagnosed on post-mortem examination of cattle by the Irish RVLs over an eight-year period, from 2005 to 2012.

Pathogens, pathological patterns and epidemiological risk factors associated with respiratory disease in recently weaned cattle

Murray, G. et al.

DAFM

The term bovine respiratory disease (BRD) encompasses pneumonias in cattle caused by an array of infectious agents and environmental factors, resulting in a complex range of pulmonary lesions. Despite the huge economic impact of BRD in Ireland and beyond, there are few detailed large-scale studies assessing the relative frequency with which the various bovine respiratory pathogens occur and the morphological patterns of pneumonia that result under such climatic and husbandry conditions. The aim of this study was to determine the pathogens, pathological patterns and associated epidemiological risk factors of BRD in a cohort of affected weaned cattle presented for post-mortem examination.

Changing epidemiology of the tick-borne bovine parasite, *Babesia divergens*

Zintl, A.¹, McGrath, G.², O'Grady, L.¹, Fanning, J.³, Downing, K.⁴, Roche, D.⁵, Casey, M.³, Gray, J.S.⁶

¹ UCD School of Veterinary Medicine, ² UCD CVERA, ³ DAFM Veterinary Laboratory Service, ⁴ Irish Cattle Breeding Federation,

⁵ Growth from Knowledge, GfK-Ireland, ⁶ UCD School of Biology and Environmental Science

Parasites & Vectors 7 (Suppl 1), 08 (2014)

Bovine babesiosis is caused by the tick-borne blood parasite, *Babesia divergens*. A survey of veterinary practitioners and farmers in Ireland in the 1980's revealed an annual incidence of 1.7% associated with considerable economic losses. However, two subsequent surveys in the 1990's indicated a decline in clinical babesiosis. Recent evidence from continental Europe suggests that, probably due to climate change, the distribution of the tick vector of *B. divergens*, *Ixodes ricinus* is extending to more northerly regions and higher altitudes. In addition, milder winters are thought to increase the window of tick activity. In order to determine whether any such changes have affected the incidence of bovine babesiosis in Ireland, a questionnaire survey of farmers and veterinarians was carried out and compared against data from previous surveys. Our results indicate that while the incidence of clinical disease has continued to decline, cases occurred at any time of year. In contrast to previous surveys, affected farms were the same size as unaffected ones and there was no correlation between disease risk and the presence of deer on the land. Disease severity and mortality rates were increased because many infections were advanced by the time they were detected and treated. While the precise reasons for the decline in the incidence of redwater are unknown, a reversal of the trend could be devastating, as vigilance among farmers and veterinarians is flagging and the national herd is losing its protective immunity to disease.

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Changing incidence of bovine babesiosis in Ireland

Zintl, A.¹, McGrath, G.², O'Grady, L.¹, Fanning, J.³, Downing, K.⁴, Roche, D.⁵, Casey, M.³, Gray, J.S.⁶

¹ UCD School of Veterinary Medicine, ² UCD CVERA, ³ DAFM Veterinary Laboratory Service, ⁴ Irish Cattle Breeding Federation,

⁵ Growth from Knowledge, GfK Kynetec Ltd., Berkshire, United Kingdom, ⁶ UCD School of Biology and Environmental Science

Irish Veterinary Journal 67, 19 (2014)

In Ireland bovine babesiosis is caused by the tick-borne blood parasite, *Babesia divergens*. A survey of veterinary practitioners and farmers in the 1980's revealed an annual incidence of 1.7% associated with considerable economic losses. However, two subsequent surveys in the 1990's indicated a decline in clinical babesiosis. Recent evidence from continental Europe suggests that, probably due to climate change, the distribution of the tick vector of *B. divergens*, *Ixodes ricinus* is extending to more northerly regions and higher altitudes. In addition, milder winters are thought to widen the window of tick activity. In order to determine whether any such changes have affected the incidence of bovine babesiosis in Ireland, a questionnaire survey of farmers and veterinarians was carried out and compared with data from previous surveys. Our survey indicates that while the incidence of clinical disease has continued to decline, cases can occur at any time of year. In contrast to previous surveys, affected farms were the same size as unaffected ones. There was no correlation between disease risk and the presence of deer on the land. Disease severity and mortality rates were increased because many infections were advanced by the time they were detected and treated. While the precise reasons for the decline in the incidence of redwater are unknown, changes in agricultural practice are likely to be of importance. A reversal of the trend could be devastating, as vigilance among farmers and veterinarians is flagging and the national herd is losing its protective immunity to disease.

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Besnoitiosis: case study and wider investigation

Ryan, E. et al.

UCD School of Veterinary Medicine

This project will consist of a number of studies describing and investigating a farm with Besnoitia. A targeted and national serological survey will be undertaken to determine the national prevalence.

Spatial variation in treatment failure with commonly used anthelmintics on Irish sheep farms

Keegan, J. et al.

UCD & Teagasc

Over the last three years, as part of the Sheep Technology Adoption Program (STAP), farmers have been testing the efficacy of the anthelmintic drug they are using on their flocks. The results of the tests will be mapped to highlight spatial variation. Environmental factors will be observed to ascertain if they could represent risk factors involved in the occurrence of treatment failure.

Co-infection study within EU-funded PARAGONE (H2020) project

Mulcahy, G. et al.

UCD School of Veterinary Medicine

This project aims to investigate whether there is a correlation (at individual and herd level) between fasciolosis and other important endemic diseases, with particular emphasis on paramphistomosis and Johne's disease.

Association between rumen fluke and liver fluke prevalence in ruminants in Ireland

Naranjo Lucena, A. et al.

UCD School of Veterinary Medicine

This study will look at the spatial variation in presence/absence and co-infection of liver and rumen fluke in Ireland.

Transition environments and disease vectors: a geographical perspective on ticks in Ireland and the associated disease risk

Vanwambeke, S. et al.

Université catholique de Louvain (UCL), Belgium

Mapping the distribution of ticks and the associated disease risk is currently considered a key aspect of risk management. This project proposes to address the questions: how suitable are transition environments for ticks in Ireland?, and can expert-based mapping methods be used to map tick distribution in an accurate and user-friendly way? We aim to investigate multi-criteria analysis as a tool to develop maps that can be easily communicated and understood by managers and decision makers.

Veterinary ethics

What do European veterinary codes of conduct actually say and mean? A case study approach

Magalhães-Sant'Ana, M.^{1,2}, More, S.J.^{1,3}, Morton, D.B.⁴, Osborne, M.⁵, Hanlon, A.¹

¹ UCD School of Veterinary Medicine, ² Escola Universitária Vasco da Gama, Coimbra, Portugal, ³ UCD CVERA,

⁴ School of BioSciences, University of Birmingham, Valeilles, France, ⁵ Forenaghts Stud

Veterinary Record 176, 654 (2015)

Codes of Professional Conduct (CPCs) are pivotal instruments of self-regulation, providing the standards to which veterinarians should, and sometimes must, comply. Despite their importance to the training and guidance of veterinary professionals, research is lacking on the scope and emphasis of the requirements set out in veterinary CPCs. This paper provides the first systematic investigation of veterinary CPCs. It relies on a case study approach, combining content and thematic analyses of five purposively selected European CPCs: Federation of Veterinarians of Europe (FVE), Denmark, Ireland, Portugal and the UK. Eight overarching themes were identified, including 'definitions and framing concepts', 'duties to animals', 'duties to clients', 'duties to other professionals', 'duties to competent authorities', 'duties to society', 'professionalism' and 'practice-related issues'. Some differences were observed, which may be indicative of different approaches to the regulation of the veterinary profession in Europe (which is reflected in having a 'code of ethics' or a 'code of conduct'), cultural differences on the status of animals in society, and regulatory bodies' proactivity in adapting to professional needs and to societal changes regarding the status of animals. These findings will contribute to an improved understanding of the roles of CPCs in regulating the veterinary profession in Europe.

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Ethical issues facing veterinary professionals in Ireland - results from a Policy Delphi with vignette methodology

Magalhães-Sant'Ana, M. et al.

UCD School of Veterinary Medicine

Ethics is a key determinant of professional conduct in veterinary medicine. Despite its importance, there has been a lack of applied research on the range of ethical challenges faced by veterinarians. The overall aims of this study are to identify significant ethical issues facing veterinary professionals in Ireland, and explore the roles and responsibilities of Irish veterinary organisations in the implementation of solutions.

Veterinary ethical challenges in Ireland: 2. Prescription and dispensing of veterinary antimicrobials

Magalhães-Sant'Ana, M. et al.

UCD School of Veterinary Medicine

Antimicrobial resistance has emerged in recent years as a significant public health threat. Within a wider research project, this is the second of a series of three case studies exploring veterinary ethical challenges in Ireland. In this exploratory study we aim to provide an Irish perspective of challenges and potential opportunities for reduced on-farm usage of veterinary antimicrobials.

Marine animal health

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

Clegg, T.A.¹, Morrissey, T.², Geoghegan, F.², Martin, S.W.³, Lyons, K.², Ashe, S.⁴, More, S.J.^{1,5}

¹ UCD CVERA, ² Marine Institute, ³ Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada,

⁴ DAFM, ⁵ UCD School of Veterinary Medicine

Preventive Veterinary Medicine 113, 257–267 (2014)

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 μ 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. A prospective cohort study was conducted during 2010–2012, involving 80 study batches, located at 24 sites within 17 bays. All 17 bays had previously tested positive for OsHV-1 μ var. All study farmers were initially surveyed to gather relevant data on each study batch, which was then tracked from placement in the bay to first grading. The outcome of interest was cumulative batch-level mortality (%). Environmental data at high and low mortality sites were compared, and a risk factor analysis, using a multiple linear regression mixed effects model, was conducted. Cumulative batch mortality ranged from 2% to 100% (median = 16%, interquartile range: 10–34%). The final multivariable risk factor model indicated that batches imported from French hatcheries had significantly lower mortalities than non-French hatcheries; sites which tested negative for OsHV-1 μ var during the study had significantly lower mortalities than sites which tested positive and mortalities increased with temperature until a peak was reached. There were several differences between the seed stocks from French and non-French hatcheries, including prior OsHV-1 μ var exposure and ploidy. A range of risk factors relating to farm management were also considered, but were not found significant. The relative importance of prior OsHV-1 μ var infection and ploidy will become clearer with ongoing selection towards OsHV-1 μ var resistant oysters. Work is currently underway in Ireland to investigate these factors further, by tracking seed from various hatchery sources which were put to sea in 2012 under similar husbandry and environmental conditions.

Reprinted from Preventive Veterinary Medicine, 113, Clegg et al., Risk factors associated with increased mortality of farmed Pacific oysters in Ireland during 2011, 257-267, Copyright © 2014, with permission from Elsevier B.V.

A study on risk factors influencing mortality in *Crassostrea gigas* oysters in Ireland during 2012

Morrissey, T. et al.

Marine Institute

Mass mortality outbreaks of Pacific Oysters, *Crassostrea gigas*, have been reported since the 1950s, particularly where the species is farmed. Losses in hatchery produced larvae and spat have been reported, most often associated with a herpes virus infection, Ostreid Herpesvirus 1 (OsHV-1). In 2008, a variant of OsHV-1, now termed Ostreid Herpesvirus-1 microvariant (OsHV-1 μ Var) was detected for the first time in France in association with massive mortality events in *C. gigas* oysters. *C. gigas* stocks in Ireland are principally sourced from France, and this reliance directly resulted in OsHV-1 μ Var being introduced to Ireland in 2008. It was found that mortality due to OsHV-1 μ Var was influenced by a combination of host and environmental factors. In this study, based on data collected during 2012, the objectives are to,

evaluate the mortality of *C. gigas* oysters in Ireland by comparing oyster stocks under similar management and environmental conditions, and to assess OsHV-1 μ Var prevalence in these oyster stocks over the course of the study.

Characterization of the live salmonid movement network in Ireland: Implications for disease prevention and control

Yatabe, T.¹, More, S.J.^{2,3}, Geoghegan, F.⁴, McManus, C.⁵, Hill, A.E.⁶, Martínez-López, B.¹

¹ Center for Animal Disease Modeling and Surveillance (CADMS), Dept. Medicine & Epidemiology, School Veterinary Medicine, University of California, Davis, USA, ² UCD CVERA, ³ UCD School of Veterinary Medicine, ⁴ Marine institute, ⁵ Marine Harvest Ireland, ⁶ California Animal Health and Food Safety Laboratories (CAHFS), Dept. Medicine & Epidemiology, School Veterinary Medicine, University of California, Davis, USA

Preventive Veterinary Medicine 122, 195-204 (2015)

Live fish movement is considered as having an important role in the transmission of infectious diseases. For that reason, interventions for cost-effective disease prevention and control rely on a sound understanding of the patterns of live fish movements in a region or country. Here, we characterize the network of live fish movements in the Irish salmonid farming industry during 2013, using social network analysis and spatial epidemiology methods, and identify interventions to limit the risk of disease introduction and spread. In the network there were 62 sites sending and/or receiving fish, with a total of 130 shipments (84 arcs) comprising approx. 17.2 million fish during the year. Atlantic salmon shipments covered longer distances than trout shipments, with some traversing the entire country. The average shipment of Atlantic salmon was 146,186 (SD 194,344) fish, compared to 77,928 (127,009) for trout, however, variability was high. There were 3 periods where shipments peaked (February–April, June–September, and November), which were related to specific stages of fish. The network was disconnected and had two major weak components, the first one with 39 nodes (mostly Atlantic salmon sites), and the second one with 10 nodes (exclusively trout sites). Correlation between in and out-degree at each site and assortativity coefficient were slightly low and non-significant: -0.08 (95% CI: $-0.22, 0.06$) and -0.13 (95% CI: $-0.36, 0.08$), respectively, indicating random mixing with regard to node degree. Although competing models also produced a good fit to degree distribution, it is likely that the network possesses both small-world and scale-free topology. This would facilitate the spread and persistence of infection in the salmon production system, but would also facilitate the design of risk-based surveillance strategies by targeting hubs, bridges or cut-points. Using Infomap community detection algorithms, 2 major communities were identified within the giant weak component, which were linked by only 4 nodes. Communities found had no correspondence with geographical zones within the country, which could potentially hinder the implementation of zoning strategies for disease control and eradication. Three significant spatial clusters of node centrality measures were detected, two in county Donegal (betweenness and outcloseness) and one in county Galway (incloseness), highlighting the importance of these locations as hot spots of highly central sites with a higher potential for both introduction and spread of infection. These results will assist in the design and implementation of measures to reduce the sanitary risks emerging from live fish trade within Ireland.

Reprinted from Preventive Veterinary Medicine, 122, Yatabe et al., Characterization of the live salmonid movement network in Ireland: Implications for disease prevention and control, 195-204, Copyright © 2015, with permission from Elsevier B.V.

Evaluation of the biosecurity practices in salmonid farms in Ireland

Yatabe, T. et al.

Center for Animal Disease Modeling and Surveillance (CADMS), Dept. Medicine & Epidemiology, School Veterinary Medicine, University of California, Davis, USA

Effective biosecurity strategies provide protection to both farmed and wild aquatic animal populations. In spite of the importance of good biosecurity practices, little is known about their current application in salmonid farms in Ireland. The objective of this study is to characterize the biosecurity levels of Irish salmonid farms in space and time, using data collected by the Department of Agriculture, Food and the Marine in Ireland during official veterinary inspections, and a biosecurity survey applied in person to farm managers during 2015.

Assessment of the risk of introduction and spread into Ireland of infectious salmon anemia through consignments of Atlantic salmon fertilized eggs and milt

Yatabe, T. et al.

Center for Animal Disease Modeling and Surveillance (CADMS), Dept. Medicine & Epidemiology, School Veterinary Medicine, University of California, Davis, USA

Ireland is free of many economically important diseases of farmed Atlantic salmon, nevertheless, the country's salmon farming industry requires the import of a significant amount of fertilized eggs and milt on a yearly basis. These are sourced from countries with a different sanitary status, where diseases that are absent in Ireland are endemic. This is the case of Norway, where official reports to the OIE show several detections and outbreaks of infectious salmon anemia per year. In spite of being free of this disease, Ireland's main supplier of Atlantic salmon fertilized eggs and milt is Norway. The objective of this study is to evaluate the risk of introduction and spread of infectious salmon anemia into Ireland through imports of consignments of fertilized eggs and milt from Norway.

Risk ranking of salmonid farms in Ireland

Yatabe, T. et al.

Center for Animal Disease Modeling and Surveillance (CADMS), Dept. Medicine & Epidemiology, School Veterinary Medicine, University of California, Davis, USA

Movements of fish is one of the most important vehicles for disease spread, while good biosecurity minimizes both the risk of introducing pathogens and their consequences or further spread. Although important, fish movement and biosecurity practices of salmonid farms are rarely combined (or used) for decision making. The objective of this study is to classify salmonid farms in terms of their risk for disease introduction and spread (e.g. low, medium, and high risk) based on their history of fish movements and biosecurity levels. This ranking could form the basis for a risk-based surveillance system.

Food safety & quality

Outbreak of *Salmonella enteritidis* in chickens in Ireland

Aznar, I. et al.

UCD CVERA & DAFM

An outbreak of *Salmonella enteritidis* occurred in the poultry industry in Ireland in early 2015. In this manuscript, we document this Salmonella outbreak focusing not only on the epidemiological aspects but also on lessons learned. The research was carried out in close collaboration with DAFM, laboratories, poultry industry and private field veterinarians.

Private animal health and welfare standards in quality assurance programmes: application and critical review

More, S.J. et al.

UCD CVERA & UCD School of Veterinary Medicine

In many countries, there has been a long tradition of 'public standards' in animal health. These are mandatory rules, underpinned by legislation and applied by governments, to achieve desired animal health outcomes. In recent years, there has been an emergence of 'private standards' in a range of areas, including animal health and welfare. Private standards have the potential to substantial competitive advantage, but without the level of scrutiny required of public standards. A framework is needed to allow robust and critical review of private animal health and welfare standards. As yet, however, little work has been done in this area. This paper presents an overview of private animal health and welfare standards in quality assurance programmes, and proposes a framework to facilitate critical evaluation.

Efficacy of washing and disinfection in cattle markets in Ireland

O'Connor, J. et al.

DAFM

In Ireland, approximately 60% of annual cattle movements are through livestock markets. Apart from the obvious risk of direct spread of infectious agents due to commingling, another risk is faecal contamination of cattle hides from dirty market infrastructure e.g. floors/pens. The primary objective of this study was to assess the efficacy of standard washing and disinfection techniques at markets in reducing bacterial load in the pen environment. Secondary objectives included assessing the effect of direct supervision of market staff engaging in washing and disinfection, and assessing the efficacy of three commonly available disinfecting agents, on bacterial load in the pen environment.

Companion animal epidemiology

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

Downes, M.J. et al.

Centre for Applied Health Economics, Griffith Health Institute, Gold Coast, Queensland, Australia

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.

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.^{1,2}, Devitt, C.³, Downes, M.T.⁴, More, S.J.^{2,5}

¹ Centre for Applied Health Economics, Menzies Health Institute Queensland, Griffith University, Queensland, Australia, ² UCD CVERA,

³ Private consultant, ⁴ Greencross Vets, Brisbane, Queensland, Australia, ⁵ UCD School of Veterinary Medicine

PeerJ 3, e1196 (2015)

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. There are also differences between male and female pet owners. There is no research pertaining to Irish pet owner attitudes towards neutering their pets. This paper identified the perceptions of a sample of Irish cat and dog owners that influenced their decisions on pet neutering. This study was conducted using social science (qualitative) methods, including an interview-administered survey questionnaire and focus group discussions. Data was coded and managed using Nvivo 8 qualitative data analysis software. Focus groups were conducted with 43 pet (cats and dogs) owners. Two major categories relating to the decision to neuter were identified: (1) enabling perceptions in the decision to neuter (subcategories were: controlling unwanted pet behaviour; positive perceptions regarding pet health and welfare outcomes; perceived owner responsibility; pet function; and the influence of veterinary advice), and (2) disabling perceptions in the decision to neuter (subcategories were: perceived financial cost of neutering; perceived adequacy of existing controls; and negative perceptions regarding pet health and welfare outcomes). Pet owner sense of responsibility and control are two central issues to the decision to neuter their pets. 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.

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Geographic distribution of *Angiostrongylus vasorum* in foxes (*Vulpes vulpes*) in the Republic of Ireland

McCarthy, G. et al.

UCD School of Veterinary Medicine

This is a national survey to establish the prevalence of *Angiostrongylus vasorum* in the Republic of Ireland.

Miscellaneous

Farm mineral maps

McGrath, G. et al.

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 an indicator of mineral deficiencies or excesses.

Significant milestone for the Irish Veterinary Journal

Doherty, M.¹, More, S.J.^{1,2}, Mee, J.F.³

¹ UCD School of Veterinary Medicine, ² UCD CVERA, ³ Teagasc

Irish Veterinary Journal 67, 23 (2014)

The Irish Veterinary Journal finds itself on an upward trajectory and we are delighted to announce that major progress has been made since the re-launch of the Irish Veterinary Journal as an open access journal within BioMed Central in March 2011. The new Impact Factor for the journal, its first based solely on open access content, is 1.71, up from last year's 0.44. This new Impact Factor sees the Irish Veterinary Journal, founded in 1946 and published in partnership with Veterinary Ireland, move up from the third quartile to the first quartile in the Veterinary Sciences category of this year's Journal Citation Report.

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SCIENTIFIC SUPPORT



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Scientific support

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<i>Statistical support</i>	87
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Scientific support

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* or 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 2014 and 2015.

Annual Meeting of the Society for Veterinary Epidemiology and Preventive Medicine - SVEPM 2014

Advancing thinking in veterinary epidemiology and preventive medicine

Veterinary Record 174, 496 (2014)

MORE than 225 scientists and policymakers gathered in Dublin recently for the annual conference of the Society for Veterinary Epidemiology and Preventive Medicine (SVEPM). Held at Dublin Castle from March 26 to 28, under the presidency of Kristien Verheyen of the Royal Veterinary College, the meeting attracted delegates from 25 countries, primarily from Europe but also from North and South America, the Middle East, Asia and Australasia. The local organisers were Simon More and Daniel Collins from the Centre for Veterinary Epidemiology and Risk Analysis at University College Dublin.



Delegates attending Society for Veterinary Epidemiology and Preventive Medicine's annual meeting at Dublin Castle.

The SVEPM was founded in 1982 and brings together scientists and policymakers, particularly within Europe, with the common aim to advance thinking in veterinary epidemiology and preventive medicine.

The scientific programme at this year's meeting included an opening and closing plenary lecture, plus a further 21 presentations in a range of themed sessions, including bovine mastitis, drug resistance, emerging infections, cattle health management, novel approaches, animal contact structures, bovine TB and bee health management. The opening plenary talk, entitled 'Confessions of a wannabe Bayesian', was given by Nils Toft from the Technical University of Denmark and focused on the use of Bayesian models in diagnostic test evaluation, in particular in the absence of a gold standard. The closing plenary, the Gareth Davies Lecture, was delivered by Ian Gardner from the University of Prince Edward Island, Canada. In his talk, entitled 'Bridging the gap in infectious disease epidemiology between aquatic and terrestrial food animals: challenges and future opportunities', Professor Gardner spoke of the opportunities for epidemiological research in aquatic animal systems, including outbreak investigation, studies on pathogen transfer between wild and farmed stocks, and issues relating to population decline.

In addition to the main scientific sessions, there were a number of workshops, on subjects including 'getting the most out of the conference', spatial analysis, aquatic animal epidemiology, qualitative methods, multilevel modelling, exotic disease incursion and animal health, and greenhouse gas emission intensity. Over 90 posters were displayed during the conference, and poster tours were arranged allowing authors to present a brief outline of their projects in groups. This was an important aspect of the conference as it allowed many students to present their studies to epidemiologists outside of their research group for the first time.

A number of social events were organised for delegates, introducing them to some of the most popular tourist attractions in Dublin. A preconference student dinner was held in Temple Bar; delegates visited the Book of Kells and the Old Library at Trinity College Dublin; and the gala dinner and céilí took place in the Guinness Storehouse. In addition, some delegates visited Glendalough and undertook a hillwalk in the surrounding mountains.

For more information about the Society, please visit:

<http://www.svepm.org.uk>

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Kristien Verheyen, president of the SVEPM during the conference (second from right), with Simon More, Nils Toft and Ian Gardner.

Epidemiological support

Simon More & Inma Aznar

Department of Agriculture, Food and the Marine

- Member, Scientific Advisory Committee on Animal Health and Welfare
- Member, 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 Johne'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) and Dairy Herd Health (VETS40180)

Postgraduate supervision/support

- Finalised during 2014/15: Tracy Clegg (PhD University of Bolton) [bTB], Lucy Metcalfe (DipECEIM) [equine medicine], Eoin Ryan (DipECBHM) [leptospirosis]
- Ongoing: Inma Aznar (PhD Wageningen) [bTB], Damien Barrett (PhD) [Schmallenberg epidemiology], Martin Gallagher (MSc) [bTB epidemiology], Ger Murray (PhD) [bovine respiratory disease], Fiona Reardon (MVSc) [BVD epidemiology], Tadaishi Yatabe (PhD UC Davis) [fish epidemiology], Paul White (PhD Wageningen) [bTB epidemiology]

Other

- Animal Health Ireland
 - Chair of the Technical Working Groups on Johne's disease and mastitis
- European Food Safety Authority
 - Chair of the Animal Health and Welfare (AHAW) Panel
 - Membership of the Scientific Committee (SC)
 - Chair of the SC's MUST-B working group
- 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 & Erik Houtsma

Department of Agriculture, Food and the Marine

- Statistical support on a range of issues including:
 - National bTB eradication programme
 - Estimation of the potency of tuberculin supplied to Ireland
 - Non-regulatory animal health issues (including bovine viral diarrhoea and Johnes disease)
 - Assistance with the study design for a national disease surveillance programme for Aujesky's disease in pigs
 - Efficacy of washing and disinfection in cattle markets in Ireland. O'Connor et al.
 - Pathogens, pathological patterns and epidemiological risk factors associated with respiratory disease in recently weaned cattle. Murray et al.
 - A retrospective epidemiological analysis of fatal bovine respiratory disease cases diagnosed in the Irish Regional Veterinary Laboratories (RVLs) between 2005 and 2012. Murray et al.
 - Q fever prevalence and risk factors based on bulk milk testing. Ryan et al.
 - Advances in monitoring of tuberculin testing in the Irish bTB eradication programme, 2008 - 2014. Duignan et al.
 - Hogan, I., Doherty, M., Fagan, J., Kennedy, E., Conneely, M., Brady, P., Ryan, C., Lorenz, I., 2015. Comparison of rapid laboratory tests for failure of passive transfer in the bovine. *Irish Veterinary Journal* 68, 18.

University College Dublin

- Statistical support for a range of studies, including:
 - Assistance with the study design looking at the use of slaughter data as an indicator of on-farm welfare problems
 - Statistical advice on a study looking at the optimisation of the zinc sulphate turbidity test for the determination of immune status. Hogan et al.
 - Harley, S., Boyle, L.A., O'Connell, N.E., More, S.J., Teixeira, D.L., Hanlon, A., 2014. Docking the value of pigmeat? Prevalence and financial implications of welfare lesions in Irish slaughter pigs. *Animal Welfare* 23, 275-285.
 - Murphy, D., Costello, E., Aldwell, F.E., Lesellier, S., Chambers, M.A., Fitzsimons, T., Corner, L.A.L., Gormley, E., 2014. Oral vaccination of badgers (*Meles meles*) against tuberculosis: Comparison of the protection generated by BCG vaccine strains Pasteur and Danish. *The Veterinary Journal* 200, 362-367.

Other

- Statistical support for a range of studies, including:
 - Quantifying the importance of Trojan dams in the national BVD eradication programme in Ireland. Reardon et al.
 - Independent referee (ongoing), numerous international peer reviewed journals
 - Cowley, D.J.B., Graham, D.A., Guelbenzu, M., Doherty, M.L., More, S.J., 2014. Aspects of bovine herpesvirus 1 and bovine viral diarrhoea virus herd-level seroprevalence and vaccination in dairy and beef herds in Northern Ireland. *Irish Veterinary Journal* 67, 18.
 - Bermingham, M.L., Handel, I.G., Glass, E.J., Woolliams, J.A., Bronsvort, B.M.C., McBride, S.H., Skuce, R.A., Allen, A.R., McDowell, S.W.J., Bishop, S.C., 2015. Hui and Walter's latent-class model extended to estimate diagnostic test properties from surveillance data: a latent model for latent data. *Scientific Reports* 5, 11861.

Geographic Information Systems (GIS) support

Guy McGrath, Daniel M. Collins & Jamie Tratalos

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
 - Resources for vaccine study areas
 - Identification of setts suitable for bait marking studies
 - Liaising with Coillte for data sharing on setts locations
 - Provision of data to the National Biodiversity Data Centre
- GIS assistance for Central Veterinary Laboratories studies:
 - *Coxiella burnetii*
 - Wicklow deer tuberculosis
 - *Echinococcus*
 - *Trichinella*
 - Calf mortality
- General mapping support:
 - Animal population density maps for contingency planning
 - Control post location mapping for live export planning
 - Local mapping to support epidemiological investigations in cases of severe tuberculosis outbreaks
 - Mapping to assist in the 2015 BSE case investigation
 - Available GIS assistance in the event of a Class A disease outbreak
 - Dispersion modelling and assessment of risk of spread in the event of an outbreak of Foot and Mouth Disease
 - Johnson, A., Bradshaw, B., Boland, C., Ross, P., 2014. A bulk milk tank study to detect evidence of spread of Schmallenberg virus infection in the south-west of Ireland in 2013. *Irish Veterinary Journal* 67, 11.

University College Dublin

- GIS support for a range of studies, including:
 - Clegg, T.A., Morrissey, T., Geoghegan, F., Martin, S.W., Lyons, K., Ashe, S., More, S.J., 2014. Risk factors associated with increased mortality of farmed Pacific oysters in Ireland during 2011. *Preventive Veterinary Medicine* 113, 257-267.
 - More, S.J., Radunz, B., Glanville, R.J., 2015. Lessons learned during the successful eradication of bovine tuberculosis from Australia. *Veterinary Record* 177, 224-232.

Animal Health Ireland

- GIS support for the National BVD Eradication Programme
- Additional *ad hoc* support for AHI driven projects and education programmes
- Graham, D.A., Clegg, T.A., O'Sullivan, P., More, S.J., 2015. Survival time of calves with positive BVD virus results born during the voluntary phase of the Irish eradication programme. *Preventive Veterinary Medicine* 119, 123-133.

Other

- Member of Irish HYSPLIT dispersion model working group
- GIS support for a range of studies, including:
 - Modelling tick distribution in Ireland and Europe. M.Sc. by Raphaël Rousseau, Université Catholique de Louvain (UCL), Belgium
 - Distribution of antibiotic resistant bacteria in livestock in Ireland. PhD. Aideen Dowling, University of Limerick
 - Historic importance of rabbits as a source of food and for local economies in Ireland. Michael Conry
 - Bloemhoff, Y., Danaher, M., Forbes, A., Morgan, E., Mulcahy, G., Power, C., Sayers, R., 2014. Parasite control practices on pasture-based dairy farms in the Republic of Ireland. *Veterinary Parasitology* 204, 352-363.
 - Bloemhoff, Y., Forbes, A., Danaher, M., Good, B., Morgan, E., Mulcahy, G., Sekiya, M., Sayers, R., 2015. Determining the prevalence and seasonality of *Fasciola hepatica* in pasture-based dairy herds in Ireland using a bulk tank milk ELISA. *Irish Veterinary Journal* 68, 16.
 - Sayers, R.G., Byrne, N., O'Doherty, E., Arkins, S., 2015. Prevalence of exposure to bovine viral diarrhoea virus (BVDV) and bovine herpesvirus-1 (BoHV-1) in Irish dairy herds. *Research in Veterinary Science* 100, 21-30.

Database support

Jamie Tratalos

Department of Agriculture, Food and the Marine

- AIM Bovine Statistics Report 2014
- Advice and data processing for study of patterns of exposure to two bovine herpesviruses in Irish cattle

Other

- Database support for a range of studies, including:
 - Development of SQL data bases to ensure that CVERA is in compliance with national Data Protection legislation and that data is readily available in standardised formats for analysis by CVERA staff



PUBLICATIONS

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Publications

<i>During 2014 - 2015</i>	92
<i>Between 2006 - 2013</i>	98

During 2014 - 2015

Peer reviewed papers & book chapters

Aguilo, N., Toledo, A.M., Lopez-Roman, E.M., Perez-Herran, E., Gormley, E., Rullas-Trincado, J., Angulo-Barturen, I., Martin, C., 2014. Pulmonary *Mycobacterium bovis* BCG vaccination confers dose-dependent superior protection compared to that of subcutaneous vaccination. *Clinical and Vaccine Immunology* 21, 594-597.

Aznar, I., Frankena, K., More, S.J., Whelan, C., Martin, W., Gormley, E., Corner, L.A.L., Murphy, D., De Jong, M.C.M., 2014. Optimising and evaluating the characteristics of a multiple antigen ELISA for detection of *Mycobacterium bovis* infection in a badger vaccine field trial. *PLoS One* 9, e100139.

Barrett, D., More, S.J., O'Neill, R., Bradshaw, B., Casey, M., Keane, M., McGrath, G., Sammin, D., 2015. Prevalence and distribution of exposure to Schmallenberg virus in Irish cattle during October 2012 to November 2013. *BMC Veterinary Research* 11, 267.

Barrett, D., O'Neill, R., Sammin, D., Clegg, T.A., More, S.J., 2015. The impact of infection with Schmallenberg virus on weaning rate in Irish sheep flocks. *Preventive Veterinary Medicine* 122, 332-338.

Barrett, D.J., More, S.J., O'Neill, R.G., Collins, D.M., O'Keefe, C., Regazzoli, V., Sammin, D., 2015. Exposure to Schmallenberg virus in Irish sheep in 2013. *Veterinary Record* 177, 494.

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Byrne, A.W., Kenny, K., Fogarty, U., O'Keefe, J.J., More, S.J., McGrath, G., Teeling, M., Martin, S.W., Dohoo, I.R., 2015. Spatial and temporal analysis of metrics of tuberculosis infection in badgers (*Meles meles*) from the Republic of Ireland: trends in apparent prevalence. *Preventive Veterinary Medicine* 122, 345-354.

Byrne, A.W., O'Keefe, J., Fogarty, U., Rooney, P., Martin, S.W., 2015. Monitoring trap-related injury status during large-scale wildlife management programmes: an adaptive management approach. *European Journal of Wildlife Research* 61, 445-455.

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Canty, M.J., Fogarty, U., Sheridan, M.K., Ensley, S., Schrunck, D.E., More, S.J., 2014. Ergot alkaloid intoxication in perennial ryegrass (*Lolium perenne*): an emerging animal health concern in Ireland? *Irish Veterinary Journal* 67, 21.

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- Chambers, M.A., Gormley, E., Corner, L.A.L., Smith, G.C., Delahay, R.J., 2015. Tuberculosis in badgers (*Meles meles*). In *Tuberculosis, leprosy and mycobacterial diseases of man and animals: the many hosts of mycobacteria*, 296-312, 1st edition, Mukundan, H., Chambers, M., Waters, R., Larsen, M.H. (editors), CABI International, Oxfordshire, United Kingdom.
- Clegg, T.A., Duignan, A., More, S.J., 2015. The relative effectiveness of testers during field surveillance for bovine tuberculosis in unrestricted low-risk herds in Ireland. *Preventive Veterinary Medicine* 119, 85-89.
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- Corner, L.A., Stuart, L.J., Kelly, D.J., Marples N.M., 2015. Reproductive biology including evidence for superfetation in the European badger *Meles meles* (Carnivora: Mustelidae). *PLoS One* 10, e0138093.
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- Graham, D.A., Clegg, T.A., O'Sullivan, P., More, S.J., 2015. Survival time of calves with positive BVD virus results born during the voluntary phase of the Irish eradication programme. *Preventive Veterinary Medicine* 119, 123-133.
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Scientific opinions

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

EFSA Panel on Animal Health and Welfare (AHAW), 2014. Scientific opinion on the main welfare risks related to the farming of sheep for wool, meat and milk production. *EFSA Journal* 12 (12), 3933.

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Scientific Committee, 2015. Potential for transmission of antimicrobial resistance in the food chain. Food Safety Authority of Ireland, Dublin. [https://www.fsai.ie/news_centre/press_releases/AMR_report_03122015.html]

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Bermingham, M.L., Brotherstone, S., Berry, D.P., More, S.J., Good, M., Cromie, A.R., White, I.M.S., Higgins, I.M., Coffey, M., Downs, S.H., Glass, E.J., Bishop, S.C., Mitchell, A.P., Clifton-Hadley, R.S., Woolliams, J.A., 2011.

Evidence for genetic variance in resistance to tuberculosis in Great Britain and Irish Holstein-Friesian populations.

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