EPIC Centre of Expertise

Annual Report 2018 – 2019

Contents

Glossary

AI	Avian Influenza
AHDB	Agriculture and Horticulture Development Board
AHWD	Animal Health & Welfare Division
AHS	African Horse Sickness
AMLS	Animal Movement Licensing System
AMR	Antimicrobial Resistance
APHA	Animal & Plant Health Agency
ASF	African Swine Fever
BioSS	Biomathematics and Statistics Scotland
bTB	Bovine Tuberculosis
BTv	Blue Tongue virus
BVDv	Bovine Viral Diarrhoea virus
BZ	Benzimidazole
CSF	Classical Swine Fever
COE	Centres of Expertise
CTS	Cattle Tracing System
Defra	Department for Environment, Food and Rural Affairs
DSCs	Disease Surveillance Centres
ECVPH	European College of Veterinary Public Health
EPIC	Epidemiology, Population Health & Infectious disease Control
EU	European Union
FMD	Foot & Mouth Disease
FSA	Food Standards Agency
FSS	Food Standards Scotland
FTE	Full time equivalent
GA	Global Academy
GB	Great Britain
GDPR	General Data Protection Regulations
HPAI	Highly Pathogenic Avian Influenza
HPS	Health Protection Scotland
ISBA	International Society for Bayesian Analysis
ISESSAH	International Society for Economics and Social Sciences of Animal Health
ISVEE	International Society for Veterinary Epidemiology and Economics
JHI	James Hutton Institute
KE	Knowledge Exchange
KEAC	Knowledge Exchange Advisory Committee
LA	Local Authority
MRI	Moredun Research Institute
NEEG	National Emergency Epidemiology Group
NFUS	National Farmers Union Scotland
PEDv	Porcine Epidemic Diarrhoea virus
PHE	Public Health England
PHWC	Pig Health & Welfare Council
PI	Persistently Infected
PRRSV	Porcine Reproductive and Respiratory Syndrome virus

QMS	Quality Meat Scotland
RESAS	Rural and Environment Science and Analytical Services
RHS	Royal Highland Show
RI	Roslin Institute
RNA	Ribonucleic Acid
ROI	Republic of Ireland
SAC	Scottish Agricultural College
SAOS	Scottish Agricultural Organisation Society
ScotEID	Scottish Electronic Identification
SEFARI	Scottish Environment, Food and Agriculture Research Institutes
SEPA	Scottish Environment Protection Agency
SERVAL	Surveillance Evaluation Framework
SG	Scottish Government
SG AHWD	Scottish Government Animal Health & Welfare Division
SICCT	Single Intra-dermal Comparative Cervical Tuberculin
SMBVS	Strategic Management Board for Veterinary Surveillance
SRP	Strategic Research Programme
SRUC	Scotland's Rural College
SVEPM	Society for Veterinary Epidemiology and Preventive Medicine
SVZG	Scottish Veterinary Zoonoses Group
TSEs	Transmissible Spongiform Encephalopathies
UK	United Kingdom
UoE	University of Edinburgh
UoG	University of Glasgow
USA	United States of America
USDA	United States Department of Agriculture
VRA	Veterinary Risk Assessment

EXECUTIVE SUMMARY/FOREWORD

In 2018-19, EPIC (Epidemiology, Population health and Infection Control) again focussed on delivering its core outputs in support of Scottish Government (SG) Animal Health and Welfare Division (AHWD) policy for animal disease outbreak preparedness and response.

The external context during the reporting period can be briefly summarised as follows:
1) the main exotic animal disease threats of concern to Scotland were again incursion of Highly Pathogenic Avian Influenza (HPAI) through migrating wild birds in the winter months, though this did not occur; Bluetongue virus (BTv) incursion, either through import of undisclosed infected livestock (which did occur in England) or through wind-blown spread of infected midge vectors from other affected parts of Europe, African Swine Fever (ASF) incursion through various possible pathways, the most likely of which is movement of contaminated pork products or fomites with travellers or on vehicles from Europe or China, where the disease has been spreading in the last year. There was a marked increase in West Nile Fever cases in mainland Europe during summer 2018; however we do not consider this to be a major threat to equine and human populations of Scotland in summer 2019 due to the unsuitability of Scotland's climate and mosquito vectors. Horizon scanning activities in Topic 5, in close reciprocal collaboration with Department for Environment, Food and Rural Affairs (Defra's) international disease monitoring team, continue to monitor these and other evolving threats closely.
2) the current political climate, characterised by ongoing uncertainty: and is associated with the wide ranging likely impacts of the UK decision to leave the European Union (EU), and, more generally, with short-termism and diminishing resources. The effect of these factors is to limit EPIC's ability to plan longer term pieces of work and the deliverables that would come from these. There was an opportunity to highlight this latter issue, and other aspects of partnership and governance of all of the Centres of Expertise (CoE), through the mid-programme review conducted by Rural and Environment Science and Analytical Services (RESAS) between August and October 2018. EPIC was pleased to have the opportunity to submit a report, summarising issues that impact on the sustainability of the EPIC model. Interactions with the panel, and the contents of their feedback report, were almost entirely positive, which was very welcome, but a small number of issues, particularly those impacting on longer-term planning, remain a challenge.

As a consortium, we have continued to meet monthly by teleconference, with a face-to-face meeting every third month. The face-to-face meetings are also used to present, share and discuss scientific ideas internally as well as to develop and enhance collaborative relationships. EPIC has devoted a proportion of this valuable time together to explore strategic issues, seeking approaches which will sustain the long term vibrant partnership which underpins EPIC, an initiative which we anticipate will be beneficial to both EPIC members and its customers and stakeholders in the long term.

During the reporting year, EPIC has seen a greater than usual number of personnel changes. These have arisen for a variety of reasons and in relevant instances, as previously and where possible, these have been managed with RESAS to allow staff

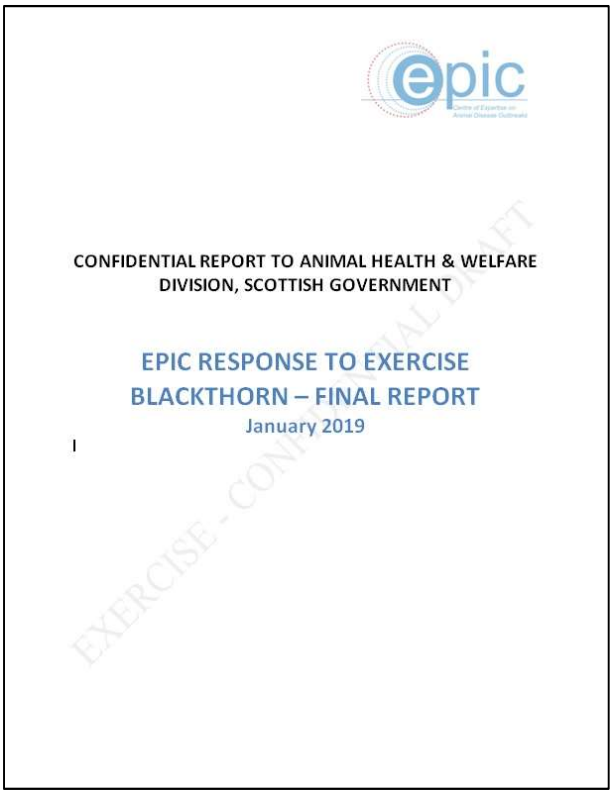
moving between partner institutions to retain their involvement in EPIC. In instances in which vacancies have arisen, whilst there may have been minor impacts on work continuity, posts have generally been quickly filled with able and enthusiastic people eager to contribute to and enhance EPIC. Alistair Stott, a long term participant in EPIC and a lead for Topic 5 (T5) retired from Scotland's Rural College (SRUC). His role in Animal Health Economics will now be provided by Andrew Barnes of SRUC. Also at SRUC, Ian Hutchinson's time in EPIC has reduced to allow him to focus on other opportunities, but we are very pleased to retain his input into our website. An appointment to replace Ian's role as communications officer will shortly be made at SRUC. Lucy Gilbert transferred her tick work in Topic 2 (T2) from James Hutton Institute (JHI) to University of Glasgow (UoG), a move completed with negligible impact on milestones and deliverables. Adam Calo joined JHI to complement and enhance the social science work in T2 led by Orla Shortall (now the recipient of a Fellowship award). Natascha Meunier and Margo Chase-Topping, who were jointly filling a 1 full-time equivalent (FTE) post doctoral post at University of Edinburgh Roslin Institute (UoE/RI) on a shared basis, both moved on to other opportunities. Interviews have recently been held to fill this post. Anne-Sophie Ruget has joined the team at UoE/RI as a PhD student affiliated to EPIC supervised by Rowland Kao. Jiayi Liu, who has worked in Topics 3 and 5 (T3 andT5) has recently left her post at Biomathematics and Statistics Scotland (BioSS) and options for filling her post, while best contributing to EPIC objectives, are currently under consideration by the institutional leads there. May Fujiwara joined EPIC at the University of Edinburgh Global Academy of Agriculture and Food Security (UoE/GA) as part of Topic 1 (T1), working closely with Lisa Boden. Kim Jones recently joined the team at UoG, replacing Julie Norden as administrative support for the EPIC project.

In terms of EPIC work, real-time involvement in Exercise Blackthorn dominated the early part of the year, which then generated further work, reviewing EPIC's involvement and producing a comprehensive report of lessons learned. Work on diseases of pigs has been a high priority, given increasing concerns about ASF. It has been important for scientists in EPIC to be part of international networks making efforts to respond to these threats. This has allowed us to provide key policy briefs responding to these risks in a Scottish context. We have continued to contribute complementary, interdisciplinary effort to Strategic Research Programme (SRP) work on endemic diseases, principally as a means of understanding more about mechanisms of disease spread and drivers for these, so as to be best placed to advise on disease control strategies, but also to add value to that work. Effective Knowledge Exchange (KE) around our work remains at the core of our success. We pride ourselves on the positive and effective relations we maintain with our stakeholders, particularly with our policy colleagues, despite personnel changes on both sides, by supporting and recognising the importance of 'knowledge brokering' as a specialist role between science and policy in animal health.

HIGHLIGHTS

Exercise Blackthorn

The early part of the year was dominated by the 'live play' of Exercise Blackthorn, a UK-wide disease preparedness exercise to test responses and resilience to a (simulated) outbreak of Foot and Mouth Disease (FMD). A member of EPIC's T1 was invited to be a part of the team that planned and ran the exercise. Two members of the EPIC team worked closely with SG AHWD staff to 'surprise' EPIC with a request that we respond to the simulated outbreak from day 1, whereas the official 'live play' for all other players was for days 7 & 8 only. Thus, by the time the official 'live play' exercise began, EPIC had already been operating in 'emergency mode' and responding to SG AHWD requests for a week. This provided an excellent opportunity for us to test and affirm our capability to respond to an emergency complementary to/in partnership with other 'players' and to provide useful outputs in response to policy requests in a timely fashion. The requests received and outputs provided can be summarised as: Veterinary Risk Assessments (VRAs) to support policy decisions such as licensing of animal movements and access to the countryside; analyses of movements and movement chains of susceptible livestock species from confirmed or suspected infected premises and areas surrounding these into Scotland; modelling of disease spread scenarios; combined use of these approaches to assess the risks of decisions to lift movement bans on a regional basis in Scotland to allow some aspects of business to resume. Members of the EPIC team were present at all 'table top' components of the exercise, both prior to, and after the 'live play' element, and we have contributed to 'wash up' sessions and feedback questionnaires. A detailed lessons learned report on our experiences of the exercise has been shared with our SG AHWD colleagues and will be the subject of a future joint meeting.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CONFIDENTIAL REPORT TO ANIMAL HEALTH & WELFARE DIVISION, SCOTTISH GOVERNMENT

EPIC RESPONSE TO EXERCISE BLACKTHORN – FINAL REPORT

January 2019

EPIC's lessons learned report on Exercise Blackthorn

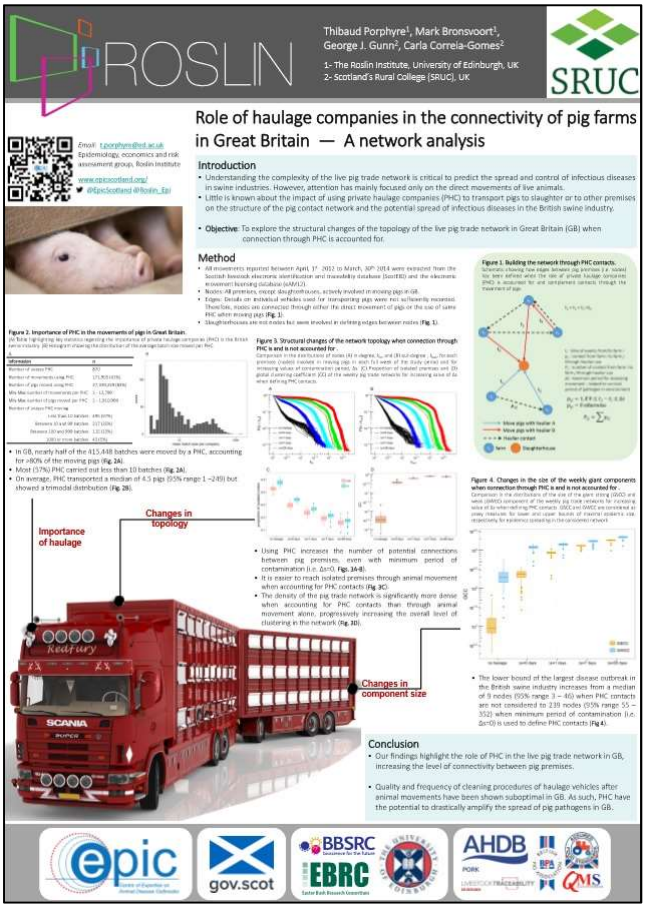
Veterinary Risk Assessments

Exercise Blackthorn highlighted the relevance of EPIC's work on VRAs and the importance of curating an up-to-date VRA library so that the VRAs are fit for purpose in the event of an emergency. The exercise illustrated that reviewing and refreshing any number of these under emergency conditions would be extremely resource intensive. To assist with quick responses in an emergency, EPIC has begun work on a catalogue of literature for priority exotic diseases so that the most up-to-date information is gathered together in one place ready to be used for rapid risk assessment or modelling purposes. During the reporting year we have added to our portfolio of VRAs: one concerning animal movement and BTv risk and two concerning movements to and from game bird hatcheries in the event of confirmed HPAI infection in the UK (under review). In order to support the latter, EPIC scientists and members of SG AHWD jointly were given a tour of SRUC Elmwood's game bird hatchery facilities and a local release site.

EPIC has continued to work with and coordinate a '5 Nations VRA forum' with involvement of leaders from all relevant agencies and governments (Chief Veterinary Officers and staff) from England, the other UK devolved administrations (DAs) and Republic of Ireland (ROI). Through this forum, members of EPIC have contributed, as appropriate and usually over short time scales, to reviewing UK wide VRAs produced by Defra/APHA, most notably on ASF.

Modelling and Animal Movements

Concern about the extent and nature of spread of ASF in Europe, and in China, have justifiably increased the focus on this pathogen within EPIC. Disease modelling and pig industry interface work in Topic 4 (T4) has been a strong feature of this round of EPIC funding, and this work has generated a vital platform for responding to growing concerns about threats from pig diseases. Policy briefs have been provided to SG AHWD covering spread of ASF and Classical Swine Fever (CSF), as well as drawing attention to the risks from inanimate vehicles of transmission between farms, specifically, haulage trucks. This work is highly relevant and has been the subject of a specific collaborative workshop with key staff from APHA in October 2018. EPIC scientists are well connected internationally, allowing them to share knowledge, expertise and tools (such as computer code) to address these evolving and potentially serious threats. EPIC scientists are likely to seek to prioritise more highly our focus on these threats over the coming year(s).



EPIC poster featuring work on haulage as a potential means of spread of pig diseases

In response to a request from SG AHWD, a framework to represent and study deer populations at the Great Britain (GB) level was developed, based on deer density estimates and data from tracking actual movements of some groups of animals of one deer species. Outputs from the model are informative for potential surveillance and control of cervid infectious diseases, including Transmissible Spongiform Encephalopathies (TSEs). This work has been the subject of presentations and discussions in a number of UK fora, including Defra, SG, the Scottish Veterinary Zoonoses Group (SVZG) and the Advisory Committee on Dangerous Pathogens (ACDP).

Changes to movement standstill regulations could change farmers' decision-making on when and where to sell their livestock, and thus would influence the risks of FMD associated with livestock movements. Responding to another request from SG AHWD, using a combination of network analysis and simulation, EPIC scientists investigated the possible consequences of changing durations of movement standstills (either 6-days or 13-days) and exemptions (allowing exemptions or not) on the potential for FMD spread through Scotland via a combination of the livestock movement network and spatial spread. The main findings were: (1) prohibiting standstill exemptions changes the network and results in a lower probability of large outbreaks, with these outbreaks also reduced in spatial extent; (2) if no exemptions are allowed, a shorter movement standstill (6-days) is only marginally less effective than a longer standstill period (13-days).

Modelling work in T3, employed Machine Learning methods to take into account herd attributes and has performed significantly better in predicting herd-level bovine tuberculosis (bTB) breakdowns in GB than relying on current test results alone.

Data for modelling and analyses

In the past year, a major focus of the EPIC data team has been on improving and better reporting the security of the EPIC Data Repository. This repository contains information from a variety of sources, much of which is subject to the General Data Protection Regulations (GDPR). APHA, a major supplier of data to EPIC, has asked that we institute periodic reporting of use of data by members of the EPIC consortium, as well as that of other researchers who access data in the repository. APHA also conducted an audit of EPIC's data security procedures. In an otherwise highly satisfactory report, this audit raised two minor recommendations and a number of smaller suggestions for improvement. Both recommendations have been implemented, and plans are in place to address the remaining suggestions. EPIC has undertaken its first annual security survey, with the joint aims of reporting on practices currently used by individual researchers and of raising awareness about the need for data security to protect our access to detailed, sensitive data, without which EPIC could not continue to function.

Once again, EPIC was well represented, by invitation, at the annual APHA modelling symposium held in Weybridge in February 2019, and once again we were pleased to organise a second day at this meeting specifically focussing on livestock data and demographics and how EPIC and APHA modellers can work in a mutually supportive and complementary way. This has been the subject of recent blogs on the EPIC website (https://www.epicscotland.org/epic-blog/).

Knowledge Exchange

As ever, Knowledge Exchange (KE) activity has been a constant high priority throughout the reporting period, with a key focus being the use of our website (www.epicscotland.org) to feature news and updates on the developments and outputs of our work.

This year saw the launch of a new blog page (see above). A KE highlight for the year was EPIC's presence at the Royal Highland Show (RHS). EPIC contributed a presence at the Scottish Agricultural Organisation Society (SAOS) stand in partnership with ScotEID. The focus was on Bovine Viral Diarrhoea virus (BVDv) control with emphasis on EPIC's work on economics and attitudes to biosecurity. It also featured specifically designed interactive App that allows farmers to view a map of historic BVD cases in Scotland, chart the progress of the BVD eradication programme and view results by year, quarter or month.

EPIC Stand in the SAOS building at RHS

In addition, EPIC hosted a panel discussion at the Royal Highland Pavilion in partnership with ScotEID, SG and the National Farmers Union Scotland (NFUS). The focus was again on BVDv control, with a message which emphasised the research work on this topic funded by RESAS, and the way in which this is being harnessed in partnership with industry and policy to progress disease control.

Quarterly meetings with other Centres of Expertise (CoE) and with Scottish Environment, Food and Agricultural Research Institutes (SEFARI) Gateway have continued throughout the year, so that we keep abreast of one another's progress and share our experiences. We were very pleased to work collaboratively to promote the work of the centres using the 'Pufferfish' display equipment in the JHI tent during the RHS.

2018/19 was a good year for conference presentations from EPIC's work, with strong representation at the European College of Veterinary Public Health (ECVPH), Society for Veterinary Epidemiology and Preventive Medicine (SVEPM), the International Society for Veterinary Epidemiology and Economics (ISVEE) and the International Society for Bayesian Analysis (ISBA).

Improving Veterinary Surveillance Strategy

EPIC has continued to evaluate a number of different data sources for their strengths and weaknesses in their potential to detect exotic notifiable and novel emerging diseases. Substantial progress has been made in the development of collaboration with Health Protection Scotland (HPS) and SRUC Veterinary Services. Using Cryptosporidiosis as an exemplar, following productive discussions and iterative analyses, all parties now have an improved understanding of the potential and limitations for use of animal health data alongside human disease data in the surveillance of zoonoses. A collaboration with Food Standards Scotland (FSS) is also being developed to explore the value of FSS data for animal health surveillance. Elements of this work have been presented to the Strategic Management Board for

Veterinary Surveillance (SMBVS), to which the EPIC surveillance topic leads are now invited to advise on research developments and opportunities.

Collectively, these studies have formed the basis of ongoing recommendations to maintain, refine or strengthen animal infection surveillance in the future, as policy evolves in response to the changing strategic priorities and obligations of the UK in the wider world.

ANNEX A
Summary of all sub-topics

Topic 1
The provision of rapid access to emergency advice and analyses in the event of disease outbreaks, and knowledge exchange

Sub-topic 1.1 Contingency Planning
T1 has continued to provide VRAs to SG when requested, as well as liaising with APHA to identify VRAs for proactive development. Risk assessments have been developed regarding movements to and from game bird hatcheries during avian influenza outbreaks, in response to a specific request from SG. In 2018/2019, EPIC continued to coordinate meetings of the 5 Nations Veterinary Risk Assessment working group (with representation across of devolved administrations, England and ROI) to develop collaborative approaches to producing VRAs and develop best practices. T1 conducted a workshop on science-policy-industry engagement to explore best practices at the annual ECVPH at the Annual Congress in Perugia in 2018. This built on the previous year's work at the ECVPH Annual Congress in Liege in 2017.

Sub-topic 1.2 Outbreak Response
T1 has maintained presence at Defra, APHA and National Emergency Epidemiology Group (NEEG) meetings. In 2019, EPIC members presented at the APHA modelling symposium and T1 arranged a separate meeting between APHA and EPIC personnel to compare and streamline approaches to livestock data analysis. T1 played a collaborative role with SG and the NEEG in the planning, development and 'live play' of the national disease outbreak exercise (Exercise Blackthorn) as well as a Scottish disease exercise (Exercise Juniper), exploring avian influenza incursion. Exercise Blackthorn was a two day national exercise involving devolved governments, Defra, APHA, Public Health England (PHE), HPS, Local Authorities (LAs), Scottish Environment Protection Agency (SEPA),Food Standards Agency (FSA)/FSS and other partners. This exercise tested the reaction of the governments and veterinary services to an outbreak of FMD (an exemplar of an exotic disease which results in the loss of international markets – recall FMD outbreak 2001). EPIC received multiple requests for analyses and input from SG. T1 coordinated EPIC's response, providing analyses and channelling outputs to both SG and the NEEG. As part of this exercise, the EPIC VRAs which are used by SG, and by Defra/APHA, were tested in realistic 'game-play'. Outputs include a lessons learned report which documented and evaluated EPIC's response to emergency requests and participation in Exercise Blackthorn.

Sub-topic 1.3 Knowledge Exchange
EPIC continues to utilise a 'SG hot-desk' in SG AHWD that offers proximity to policymakers and facilitates science-policy communication and knowledge exchange both in 'peace-time' and in disease emergencies. T1 has a routine presence at the SG Livestock and Equine stakeholder group meetings to facilitate knowledge exchange with industry leads. The relationship between EPIC and the other CoE has strengthened over the last year and is enhanced through regular meetings, also involving SEFARI Gateway, coordinated by EPIC. T1 has a presence at relevant SEFARI Gateway meetings to identify and coordinate opportunities for joint

engagement. Through engagement with the EPIC KE Advisory Committee (KEAC), EPIC's network of expertise in knowledge exchange has broadened. Stakeholder and public engagement has increased. This included an enhanced presence at the RHS in partnership with the SAOS and T1 hosted an interactive event with farmers, policy-makers and scientists at the RHS Pavilion to improve dialogue around BVDv eradication (see also Sub-topic 4.3). A member of T1 participated in a 'Pint of Science' – highlighting EPIC's Contingency Planning Work to the public. EPIC work was also showcased in a variety of international conferences including ECVPH, SVEPM, ISVEE, the International Biometric Conference and the ISBA. T1 staff are lead editors on a Special Research Topic in *Frontiers in Veterinary Science*, focusing on Risk Based Evidence for Animal Health Policy, which will be published later this year.

Topic 2
Greater Understanding of Disease Risks Due to Animal Movements and Other Factors

Sub-topic 2.1 Animal Movement Networks
A number of approaches have been tried to differentiate between farms based on animal purchase and sales behaviour, but none provided useful insights into these differences. T2 are now developing tools to visualise the complexity of animal movement data and allow users to interact directly with the data to explore patterns.

Our analyses show that the risk of a large FMD outbreak isn't affected by some reduction in the duration of movement standstills, especially if existing standstills exemptions cease to be permitted and possible violations are prevented.

The "SimInf" modelling framework (software allowing simulation of infection spread based on animal movement data) was adapted for EPIC and used to identify premises likely to be involved in highly transmissible livestock disease outbreaks. Analysis of the combined cattle-sheep system in Scotland shows that some premises are likely to be more important in disease spread than would be indicated by considering individual species separately (work presented at SVEPM 2019).

Proposed work on the consequences of uncertainty in movement history had to be postponed due to ongoing delays with data sharing agreements, despite the best efforts of our data team.. T2 have started to develop tools to examine the effect of missing information on the ability to define in-contact farms in a disease outbreak investigation. For example, this might be relevant to a situation in which movements of batches (discrete groups) of animals, rather than individuals, are known.

Sub-topic 2.2 Better Inference for Better Models
In response to a request from SG AHWD, a framework to represent deer populations at GB level was developed, based on deer density estimates and data from tracking actual movements of some groups of animals of one deer species. Outcomes from the model are informative for potential surveillance and control of cervid infectious diseases, including Transmissible Spongiform Encephalopathies (TSEs). This work has been presented to Defra, SG the Scottish Veterinary Zoonoses Group (SVZG), and at the 2018 International Biometric Conference.

Methods enabling estimation of between-farm transmission rates and time to detect disease, from outbreak data, were extended to also estimate potential multiple introductions of disease from outwith the modelled population. Bayesian parameter inference and model selection tools based on Latent Residuals were extended to account for this process. These tools proved crucial in understanding an exemplar avian influenza outbreak in the United States of America (USA) (see also Sub-topic 4.2).

Louping ill virus kills sheep and red grouse. A paper identifying environmental risk factors for Louping ill in sheep is in preparation for the Special Research Topic of *Frontiers in Veterinary Science* (see also Sub-topic 1.3). T2 have produced preliminary risk maps predicting Louping ill virus risk over Scotland depending on climate, hosts and habitat. Results were presented in a poster at the SRUC Land Use conference at Our Dynamic Earth, Edinburgh, January 2019, and at 3 seminars at the University of Glasgow (between October 2018-January 2019).

Sub-topic 2.3 Epidemiology with Genetic Data

Almost 5,300 samples from cattle have been tested since 2012 with a success rate of 85%. Sample numbers reduced in 2018/19 (<500 compared to >900 in 2016/2017) and the proportions of different virus strains found have changed (85% BVDV1a, 14% BVDV1b in 2013/14; 70% BVDV1a/ 27% BVDV1b in 2017/18). However, no clear difference is seen between samples from Scotland and the rest of the UK suggesting the change is not linked to eradication. Having explored additional genetic analysis of eartag samples, T2 have confirmed that this won't be a routine analysis method due to its high failure rate (50%). However, extraction of Ribonucleic Acid (RNA) from eartag samples can allow reliable analysis of selected samples. This was used in collaborative work involving colleagues in Boehringer Ingelheim Animal Health (BIAH) and SRUC Veterinary Services, demonstrating value to industry.

Sub-topic 2.4 Understanding and Influencing On-farm Biosecurity Practices

A paper from farmer interviews about the BVDv eradication scheme was accepted to Environment and Planning E: Nature and Space. This work was presented at an interdisciplinary workshop at the Swedish University of Agricultural Sciences.

Twenty-three interviews about AI with poultry producers and key stakeholders, will contribute to a report and policy brief due March 2020 (with updates in the 6-monthly SG_AHWD Interface Meetings with). Interviews are ongoing with key stakeholders involved in BVD eradication schemes in the UK and Ireland, with a report and policy brief in June 2019. An abstract was accepted for the Special Research Topic of *Frontiers in Veterinary Science* (see also Sub-topic 1.3).

Models to identify risk factors associated with benzimidazole (BZ)-resistance in *Nematodirus battus* showed that adoption of a quarantine strategy, using faecal egg count monitoring, and co-grazing of sheep and cattle were associated with lower risk of BZ-resistance. Reseeding pastures and permanent/set stocking increased the likelihood of BZ-resistance. Further testing is required to quantify on-farm impacts.

Cryptosporidium, a ubiquitous gastrointestinal protozoan parasite, is a significant cause of enteritis in neonatal animals and immune-compromised humans. With the Cryptosporidium Reference Unit in Wales, T2 have validated new assays for genotyping *Cryptosporidium* spp. for improved outbreak investigation and source attribution. These will be used to screen *Cryptosporidium* from livestock and wildlife on the same farm to investigate parasite transmission.

Topic 3
Improving Veterinary Surveillance Strategy

Sub-topic 3.1 Adding Value to Existing Data Collection - Scoping the properties of Scottish animal health surveillance data

Data sources relevant to poultry health in Scotland were identified and assessed using SuRveillance EVALuation framework (SERVAL), a framework for systematic assessment of animal health surveillance systems. Data sources were evaluated for their strengths and weaknesses in detecting exotic notifiable and novel emerging diseases. Based on the assessments, recommendations were made to maintain or strengthen surveillance in the future. Input was sought from the organisations holding relevant data, including SRUC Veterinary Services and Food Standards Scotland (FSS). A report was provided to SG, and the findings presented to the Strategic Management Board for Veterinary Surveillance (SMBVS).

Subtopic 3.2 Adding value to existing data collection - Adding value to current surveillance datasets

Substantial progress was made in the collaboration with HPS and SRUC Veterinary Services. Using Cryptosporidiosis as an example, following productive discussions and iterative analyses, all parties now have an improved understanding of the potential and limitations for use of animal health data alongside human disease data in the surveillance of zoonoses. A new collaboration with FSS has resulted in discussions about the type of data available, development of an analytical plan and data sharing agreements which, though delayed by Brexit-related issues, are being finalised. Both these studies contribute to the commitment made in the recent report[1] on the UK approach to animal health surveillance to have effective communication and relationships based on trust, respect and understanding of mutual benefits, while seeking to exploit all sources of information. Discussions were held to clarify the properties of information available on farmer/veterinarian drivers for sample submission to SRUC Disease Surveillance Centres (DSCs), in the light of work delivered in the previous Strategic Research Programme (SRP). A re-analysis of SRUC Veterinary Services data for a new time period, to compare with a former analysis and production of disease risk maps from EPIC outputs, has been identified as a likely starting point for this objective.

Subtopic 3.3 <Not active during 2018/19>

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/771423/uksf-animal-surveillance-approach.pdf

Subtopic 3.4 <Not active during 2018/19>

Subtopic 3.5 Developing Statistical Approaches to Analyse and Integrate Available Data - Refining statistical methods to strengthen diagnostic information

A data-driven model was used to predict herd-level bovine tuberculosis (bTB) breakdowns in GB with the aim of improving test sensitivity. The results of single intra-dermal comparative cervical tuberculin (SICCT) tests were correlated with farm attribute data related to infection risk, e.g., holding size and contacts with other farms through animal movements. Four machine learning methods (Neural Network, Random Forest, Gradient Boosted Trees and Support Vector Classifier) were independently trained and optimised with data from 2012–2014, including 4,605–4,818 positive herd-level SICCT test results annually. The performance of the best predictive model was compared to the observed sensitivity and specificity of the herd-level SICCT test calculated on the 2015 testing data. This model performed significantly better in predicting breakdowns, increasing mean herd-level sensitivity from 61.3% to 67.6% (95% confidence interval: 66.4–68.8%) and mean herd-level specificity from 90.5% to 92.3% (95% confidence interval: 91.6–93.1%). T3 continue to investigate the scope of incorporating herd and animal level data with test results to increase the sensitivity of the test in the field, and thus to help drive better use of control measures. This work was presented at the 2019 SVEPM Conference in Utrecht.

Subtopic 3.6 Refining statistical methods to better support active surveillance

All diagnostic tests are imperfect. That is, they give false positive and false negative results. Unless accounted for in an analysis, this will lead to biased estimates if, for example, there is a wish to quantify how much disease is present in a population, or how much risk should be ascribed to factors such as breed, management or age. Using computationally intensive methods, T3 have developed new statistical algorithms to analyse different types of data, assuming no prior knowledge of the sensitivity and specificity of the tests. These can be used when observations from two different diagnostic tests are available. Specifically, during this reporting year, T3 have extended the methodology to deal with observations collected repeatedly over a period of time, and to data mapped spatially. The results allow estimation both of key epidemiological parameters and also the properties sensitivity and specificity of the two tests. Some field data have now been identified that can be used to trial use of these methods, in collaboration with EPIC colleagues at the UoE/RI.

Subtopic 3.7 <Not active during 2018/19>

Subtopic 3.8 Seeking Early Warning of Changes in Population Characteristics - New methods of syndromic surveillance

A report assessing the statistical and practical issues in seeking to use different data sources for syndromic surveillance in Scotland, previously circulated in draft and presented to the SMBVS last year, was completed and circulated to SG stakeholders. When compared to the previous version of the report, the main change was the addition of a stronger veterinary epidemiology focus to the text. The main conclusions of the report were unchanged, namely that the use of abattoir-derived data offered a good balance of realistic opportunities; that developing methods to integrate different data sources would be worthwhile; while, by contrast,

production-data based methods offered great opportunities but would be much more challenging to deliver within EPIC.

Subtopic 3.9 Farm-oriented Risk Assessment
Work on the farm-orientated disease risk scorecard was stalled in this reporting year, due to dependence on the completion of ongoing research in Sub-Topic 2.1(see also Sub-topic 2.1).

Subtopic 3.10 Developing Risk-based Approaches to Surveillance - phylodynamics analysis to identify high-risk paths of disease incursion
Pathogen genome sequences can be used to trace the source, including location and host species, of outbreaks and to monitor changes in transmission patterns in endemic situations using phylodynamic modelling. In addition to the EPIC BVDv sequences (see also Sub-topic2.3), T3 have a collection of publically available virus sequences including isolation date, location and host species for CSF, ASF, Porcine Epidemic Diarrhoea virus (PEDv), and BTv. Existing Avian and Swine Influenza datasets have been updated to give representation of all Influenza A strains (avian, swine, human, equine, canine). The collections of FMDv and Porcine Reproductive and Respiratory Syndrome virus (PRRSv) sequences suitable for phylodynamic analysis have grown over the reporting year. These sequences aid our ongoing work to help understand exotic disease incursion risk into the UK and Scotland from Europe, Africa, Asia and North America. During Exercise Blackthorn, FMDv sequences were used in a realistic fashion to explore the implementation speed of phylodynamic models and hence the turn-around-time for answers to policy-derived questions under outbreak conditions.

Subtopic 3.11 <Not active during 2018/19>

Subtopic 3.12 <Not active during 2018/19>

Subtopic 3.13 APHA Risk matrix request
This work, aimed at optimising the process by which Local Authorities (LAs) decide which premises would most benefit from advisory visits, is progressing through two strands. In collaboration with T2, work has been undertaken on the identification of high risk premises due to animal movements. Secondly, T3 have looked at the distribution of premises types across LA areas, and how these would be categorised into different risk levels on the basis of the information available. T3 have obtained data from Argyll and Bute LA as an exemplar to assess how data driven decisions on risk category compare with decisions taken at the LA level. A summary report is currently being developed.

Topic 4
Analyses of Potential Disease Control Options

Sub-topic 4.1 Industry Interface Meetings
Swine fever model outputs and an appraisal of available data sources for detection of exotic and emerging livestock/zoonotic disease for pigs were presented to representatives from the Scottish pig industry (Quality Meat Scotland (QMS), Scottish pig producers and a pig vet) via a webinar (February 2019). Feedback was positive, although the industry voiced concerns about ASF and asked to have more regular updates from EPIC activities. Three policy briefs on ASF (see below) promoted interest from APHA and resulted in a joint EPIC-APHA workshop on the use of pig movement data for modelling and demographics (October 2018), with good attendance from policy makers and industry stakeholders.

Use of vaccines, the role of BVDv phylogenetics in the Scottish BVD Eradication scheme and the use of sheep movement data in the design of slaughterhouse based surveillance were presented at a joint T3/T4 and SRP Research-Industry Beef and Sheep sector interface meeting with representatives present from QMS, National Sheep Association Scotland, Livestock Health Scotland, practicing vets, farmers, SRUC Veterinary Services and SAC Consulting. There was positive feedback on relevance, interest and willingness to attend similar future events. Positive meetings have also been held with the poultry sector and have established a basis for increased, regular future interaction with EPIC.

Sub-topic 4.2 Simulation Models
Activities have focused on preparing the pig industry for an outbreak of ASF – using epidemiological models to assess the risk of ASF spread in GB and to evaluate the role of different routes of transmission. Three research briefs have resulted which show 1) how ASF spreads between pigs within a farm and for how long ASF could remain undetected despite active surveillance, 2) where the risk of onward transmission of CSF is highest and 3) the risk of spread of ASF posed by sharing of haulage vehicles.

In parallel, a novel statistical framework has been developed that quantifies landscape-scale disease transmission in situations in which the population at risk is unknown. This has been validated using simulated scenarios and is now being tested using ASF data. Similar earlier approaches were applied to AI in an international collaboration with United States Department of Agriculture (USDA).

Adding value to work on endemic disease control, sheep-scab models have been calibrated using data on infestation levels and immune responses from experimental trials at Moredun Research Institute (MRI). The between-host transmission model has also been extended to capture vaccination. The efficacy of vaccination will be determined using data from upcoming trials at MRI scheduled for Spring 2019.

Subtopic 4.3 Economic and behavioural analysis
Work to estimate the indirect, dynamic market impacts of a hypothetical FMD outbreak is complete and has been submitted to *Frontiers in Veterinary Science* for publication as part of the Proceedings of the 2nd International Society for Economics and Social Sciences of Animal Health (ISESSAH) conference, at which preliminary

results were presented in May 2018. A policy brief has been submitted to SG AHWD on the economic and production impacts of animals persistently infected (PI) with BVDv for a typical Scottish dairy and beef farm. This work informs both the SG BVD eradication scheme and plans to remove all PIs from Scottish dairy and beef herds. This work was an essential element of EPIC's exhibit at the RHS in June 2018 (see also Sub-topic 1.3). In collaboration with RESAS SRP RD3.1.4/EPIC Subtopic 5.1, stakeholder experimental (Group Model Building) workshops were held on incentives to control antimicrobial resistance (AMR) and food waste along the dairy supply chain (see also Sub-topic 5.1). The workshops had good attendance from industry stakeholders along the range of the supply chain. A similar workshop is being organised to identify interventions in the dairy supply chain effective in reducing BVD and Johne's disease.

Subtopic 4.4 Data Curation and Management

The data team work effectively with an increasing pool of data providers to obtain timely, accurate data. Data provided by ScotEID, which now encompass sheep movements (both batch movements and individual animal data), pig movements, BVD testing information and ScotMoves data containing details of within-business movements of cattle in Scotland, are received normally on a monthly basis. Recent data updates from APHA include Animal Movement Licensing System (AMLS) (sheep and pig movements data from England and Wales), the Sheep and Goat Inventory (for England and Wales (2010 – 2019), Scotland (2010 – 2015)) which have been added to the EPIC repository and updated Cattle Tracing System (CTS) data are currently being processed. A request is currently being made to RESAS for the updated Scottish Sheep and Goat Inventory and a data sharing agreement is being finalised to obtain eAML2 (pig movements data) from Agriculture and Horticulture Development Board (AHDB). During exercise Blackthorn a number of requests were made from the EPIC data team to data providers (ScotEID, APHA) for new data or data updates outwith the usual request periods. Data were delivered promptly, so could be uploaded and available to EPIC users quickly.

A successful audit of EPIC's data security and protocols was carried out by APHA in June.

Topic 5
Development of Advice on the Implications, Risks and Opportunities Presented by Local, National and International Economic, Agricultural and Legislative Developments

Subtopic 5.1 Economic Analysis of the Implications, Risks, and Opportunities to the Scottish Livestock Industry Resulting from a Changing Local and International Policy Environment

Two papers have been submitted detailing work on the uptake of animal health and welfare technologies by livestock farmers, with a focus on the identification of different behavioural patterns occurring in subpopulations of farmers and the assessment of the effects that socio-economic and attitudinal factors have on these patterns. Work has continued on a study to assess how to validate Latent Class models when these are used to analyse the results of survey questionnaires in behavioural studies such as those used to explore the motivations of livestock

farmers. A briefing on technological uptake behaviours has been published. In collaboration with RESAS SRP RD3.1.4/EPIC T4, stakeholders experimental (Group Model Building) workshops have been held on incentives to control AMR and food waste along the dairy supply chain (see also Sub-topic 4.3).

Subtopic 5.2 Future-proofing Scottish Animal Health Resilience

Salient disease threats continue to be monitored, in particular BTv, ASF and HPAI. Bluetongue models that describe the overall risks across Europe and the specific times of year that Scotland and England are at risk were presented at the ISVEE conference. The scope of this model has been expanded to evaluate African horse sickness (AHS) and epizootic haemorrhagic disease. This is being followed up by two further pieces of work (scoping documents submitted) that will provide SG with maps showing the times of year at which there is risk of BTv transmission. This will speed assessment of whether an import of infected animals poses a risk to other livestock. The second scoping document proposes work to look at the risks of introduction of BTv via movements of animals from England; work motivated by potential legislative changes in the BTv restriction zones.

In 2018, members of T5 held a multidisciplinary workshop on the ’Future of Food Security‘ for the Scottish Futures Group and presented the work of EPIC’s foresighting activities on animal health post-Brexit. An EPIC Innovation Summit was held to explore the role of organisational culture with respect to knowledge seeking and sharing behaviour and to codify a suitable framework to ensure sustainable, resilient and efficient science-policy communication. A preliminary report has been produced summarising this work.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