EPIC Centre of Expertise

Annual Report 2017 – 2018

Contents

Glossary

AI	Avian Influenza
AMR	Antimicrobial Resistance
APHA	Animal & Plant Health Agency
ASF	African Swine Fever
BioSS	Biomathematics and Statistics Scotland
BTv	Blue Tongue virus
BVDV	Bovine Viral Diarrhoea virus
CEH	Centre for Ecology & Hydrology
CREW	Scotland's Centre of Expertise for Waters
CSF	Classical Swine Fever
CsOE	Centres of Expertise
CVO	Chief Veterinary Officer
CWD	Chronic Wasting Disease
CXC	Scotland's Centre of Expertise on Climate Change
ECCLR	Environment, Climate Change & Land Reform
EPIC	Epidemiology, Population Health & Infectious disease Control
ESFA	European Food Safety Authority
EU	European Union
FMD	Foot & Mouth Disease
GB	Great Britain
HPAI	Highly Pathogenic Avian Influenza
HPS	Health Protection Scotland
JHI	James Hutton Institute
KE	Knowledge Exchange
KEAC	Knowledge Exchange Advisory Committee
MRI	Moredun Research Institute
NEEG	National Emergency Epidemiology Group
NFUS	National Farmers Union Scotland
PCR	Polymerase Chain Reaction
PEDv	Porcine Epidemic Diarrhoea virus
PHWC	Pig Health & Welfare Council
PM	Project Manager
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
SACCVS	Scottish Agricultural College Consulting Veterinary Services
SCM	Structural Choice Model
ScotEID	Scottish Electronic Identification
SEFARI	Scottish Environment, Food and Agriculture Research Institutes
SEM	Structural Equilibrium Model
SERVAL	Surveillance Evaluation Framework
SG	Scottish Government

SGAHWD	Scottish Government Animal Health & Welfare Division
SIRS	Susceptible Infected Recovered Susceptible
SMB	Strategic Management Board for Veterinary Surveillance
SRP	Strategic Research Programme
SRUC	Scotland's Rural College
UK	United Kingdom
UoE	University of Edinburgh
UoG	University of Glasgow
USDA	United States Department of Agriculture
UTR	Untranslated Region
VRA	Veterinary Risk Assessment

EXECUTIVE SUMMARY

In 2017-18, EPIC continued to focus on delivering its core outputs in support of Scottish Government Animal Health and Welfare Division (SGAHWD) policy around 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 incursion of Highly Pathogenic Avian Influenza (HPAI) through migrating wild birds in the winter months, and Bluetongue virus incursion, either through import of undisclosed infected livestock or through wind-blown spread of infected midge vectors from other affected parts of Europe. Although there was evidence for pathways for both these diseases to pose a genuine threat to livestock health in Scotland, fortunately, outbreaks of disease spreading quickly between livestock premises did not occur. Horizon scanning activities continue to closely monitor these and other evolving threats. 2) the political climate, characterised by uncertainty associated with the wide ranging likely impacts of the UK decision to leave the EU, and more generally of 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 may be a knock-on effect on staff recruitment and retention, especially for scientists who are EU (but not UK) nationals, for whom job prospects and job security are critically important.

Throughout the reporting year, EPIC has seen a number of personnel changes. A post-doctoral fellow left the Roslin Institute (RI) at the end of summer 2017; temporary replacements have been identified to contribute to work in Topic 3 (T3). Rowland Kao (a Topic Lead on T2) and Lisa Boden (a Topic Lead on T1 and T5) both moved from University of Glasgow (UoG) to University of Edinburgh (UoE). By mutual arrangement, and with close involvement from RESAS, the parties involved agreed a transfer of budget from UoG and UoE to secure the continued involvement of these scientists within EPIC for the remainder of the current 5-year programme. Although just in post at the beginning of the reporting period, this has been the first year that EPIC has enjoyed the support of a full-time project manager (PM) and the impact of that post has been profoundly positive. In addition to ensuring the smooth running of the month to month activities of the EPIC project, the PM has been instrumental in facilitating closer links with other groups, in particular the other Centres of Expertise (CsoE), and in contributing to our KE activities, especially helping T1 to coordinate EPIC's presence at the Royal Highland Show (RHS) and running the EPIC Conference. EPIC's Steering Group met twice during the reporting period, providing much appreciated strategic support and advice to the Director and assurance of quality to SG and RESAS. A new member of the Steering Group, Dr Sandra Telfer (University of Aberdeen), was appointed in the summer of 2017 and attended the EPIC Conference and her first Steering Group meeting immediately after that. EPIC's Knowledge Exchange Advisory Committee (KEAC) has also met twice during the reporting period, offering advice and feedback on EPIC activities in general as well as specifically on the conference and planned RHS activities.

In autumn 2017, vigilance by one of the EPIC partners identified possible evidence of a data breach. Swift response by the EPIC data manager and associated team identified that a technical data breach had occurred; this was contained immediately.

The relevant data providers were notified and all parties involved worked with great industry and speed to investigate the problem. The investigation revealed that although some data had been inadvertently placed on a publicly accessible website, it is most unlikely that they were accessed by anyone outside EPIC. Nevertheless, EPIC has treated this as a very grave 'near miss' and has used it to develop 'lessons learned' as well as enhanced procedures of managing and monitoring access to all the datasets that we hold and curate. Happily, the data providers have been content with EPIC's response to this situation and full access to all of the data held by EPIC, that is so crucial to it being able to fulfil the needs of SG, has been maintained.

Prompted by a request from a SG Scientific Advisor, EPIC came together with CREW and CXC to produce a short document summarising how the CsoE collectively add value to SG ('The Scottish Government's Centres of Expertise: Amplifying Value and Accelerating Impact'). As a result of this work, the CsoE now have quarterly face-to-face meetings between Directors/PMs to share experiences and discuss issues and priorities going forward. The last two meetings of the reporting period also involved SEFARI Gateway and the last meeting also included Director and PM of the CoE on Plant Health. These meetings are very useful for coordinating work and sharing opportunities, especially for KE.

In terms of EPIC's work, providing evidence to support SGAHWD in the final stages of their response to the HPAI H5N8 incursion into the UK in wild birds over the winter of 2016-17, including lifting the prevention zone, was particularly important. A number of actions and work streams followed on from this, through which EPIC developed new key relationships and materials with the poultry industry in Scotland, and with animal disease risk assessment groups in other UK administrations and the Republic of Ireland. This alliance of animal disease risk assessment groups across the British Isles will be an ongoing feature of EPIC's integration into animal disease control policy advice at the highest level. Epidemiological, economic and behavioural analyses of likely animal disease transmission scenarios, and of candidate mitigation measures against these, continued to be the core of EPIC's activities. Often, these activities make use of well-studied and well-characterised endemic animal diseases as exemplars, often in partnership with, and complementary to, RESAS funded research in the Strategic Research Programme (SRP). Such work serves the double purpose of adding important value to knowledge about endemic diseases whilst also providing a 'training ground' for development and application of tools to support exotic animal disease management.

Knowledge Exchange (KE) activity has been a constant high priority throughout the reporting period, the most important vehicle being the use of our website (www.epicscotland.org), featuring news and updates on developments and outputs from our work. A particular highlight was our EPIC Conference, held in Edinburgh in September 2017, which focussed on interdisciplinary working as its core theme. We were delighted that the Scottish Parliament hosted a reception for our conference guests and attendees, and feedback from the meeting has been universally positive. As part of our KE activity for the year, we filmed all the conference presentations, and these are available on our website. In addition, we made a short film about EPIC based on interviews with our members and stakeholders during the conference, which is also available at http://www.epicscotland.org/about-epic/epic-conference-2017/.

HIGHLIGHTS

EPIC's core purpose is to deliver the highest quality scientific evidence to support SG in the prevention of, preparation for and eradication of important animal disease outbreaks. In the current reporting year, EPIC has fulfilled this purpose through a diverse programme of work that has at its heart collaboration between scientists from its partner institutions, SG, the Animal and Plant Health Agency (APHA), the animal keeping industries and scientists from outside the consortium. The following has been structured to focus on critical aspects of EPIC's work. KE and collaboration within EPIC, with science in the SRP and beyond, and with SG and other stakeholders are common themes that run richly through each of the sections below.

Supporting the policy response to animal health emergencies
Incursion of HPAI viruses H5N8 (2016-17) and H5N6 (2017-18) into the UK through wild bird migration was anticipated by EPIC's Horizon Scanning activities under T5. This helped us to be ready to quickly support immediate policy needs through provision of Veterinary Risk Assessments (VRAs) to support decisions concerning the lifting of the prevention zone at the end of the 2016-17 season and considerations with respect to implementing another in 2017-18. This work was led by EPIC's T1 who worked closely with SG policy and veterinary advisors to agree specific requirements to ensure that policy timelines were met.

A number of strands of work have followed on from this:

1. The formation of a Scottish Poultry Group as a joint initiative between Scottish Government Animal Health and Welfare (SGAHWD) and EPIC to foster closer relationships between the poultry industry, policy and the science supporting policy in Scotland. The group met several times over the summer and autumn of 2017 and was instrumental in developing the concept and content for Scotland's Poultry Hub (T1, T2 & T4). These interactive web pages went 'live' at the end of October 2017 as part of the Scotland's Healthy Animals website (http://www.scotlandshealthyanimals.scot/farmers-livestock-owners/biosecurity-disease-avoidance/additional-guidance-for-specific-species-of-animals/poultry/poultry-hub/) offering simple advice and guidance to poultry keepers, especially smallholders, on steps that can be taken to avoid infectious diseases in their birds. Much of the insight for this work arose from social science work conducted in T2 during the first year of the current EPIC programme. There was a ministerial launch of the Scotland's Healthy Animals website in November 2017. Further work with the Scottish Poultry Group is planned for future years.
2. At the request of the UK Chief Veterinary Officer (CVO), the Scottish CVO and EPIC jointly convened and hosted in Edinburgh a meeting of the animal disease risk assessment teams from England, Wales, Northern Ireland, Republic of Ireland and Scotland, along with APHA colleagues, to review and discuss experiences and common approaches to completing, sharing and curating rapid risk assessments in support of exotic disease outbreak management. The meeting achieved a strong and cordial mutual understanding, and it was agreed that such meetings will become a regular fixture in helping us to ensure that we work together coherently in the future.
3. Revision and, where appropriate, update of EPIC's growing library of VRAs, specifically those on Foot & Mouth Disease (FMD) in anticipation of a UK-

wide FMD exercise (Exercise Blackthorn) in the spring of 2018. Such VRAs are always required, especially at the start of an outbreak, and having a library of these, up-to-date and 'on the shelf', greatly enhances the speed of response.

4. A member of the EPIC team has been closely involved in scenario development and planning of Exercise Blackthorn. EPIC have had representatives present at both table top exercises, in February and March 2018, as forerunners to the 'live play' exercise in April.
5. Internal EPIC exercises and training to improve familiarity and experience among a greater number and depth of the EPIC team with:
    a. Data resources, procedures and security
    b. Models and modelling
6. More general revision and reinforcement, through face-to-face meetings, of EPIC's communication pathways and protocols, both internally and with SG and others, to ensure our resiliency and preparedness.

Identification, in Scotland, of imported cattle from France that tested positive for Bluetongue virus (BTv) by polymerase chain reaction (PCR) prompted EPIC (T5) to offer analyses of local temperature profiles and the probability of these being compatible with local midges being capable of transmitting infection during the risk period (Figure 1). These outputs helped to reassure SGAHWD that risk was very low and that their chosen course of action was likely to be effective in preventing spread.

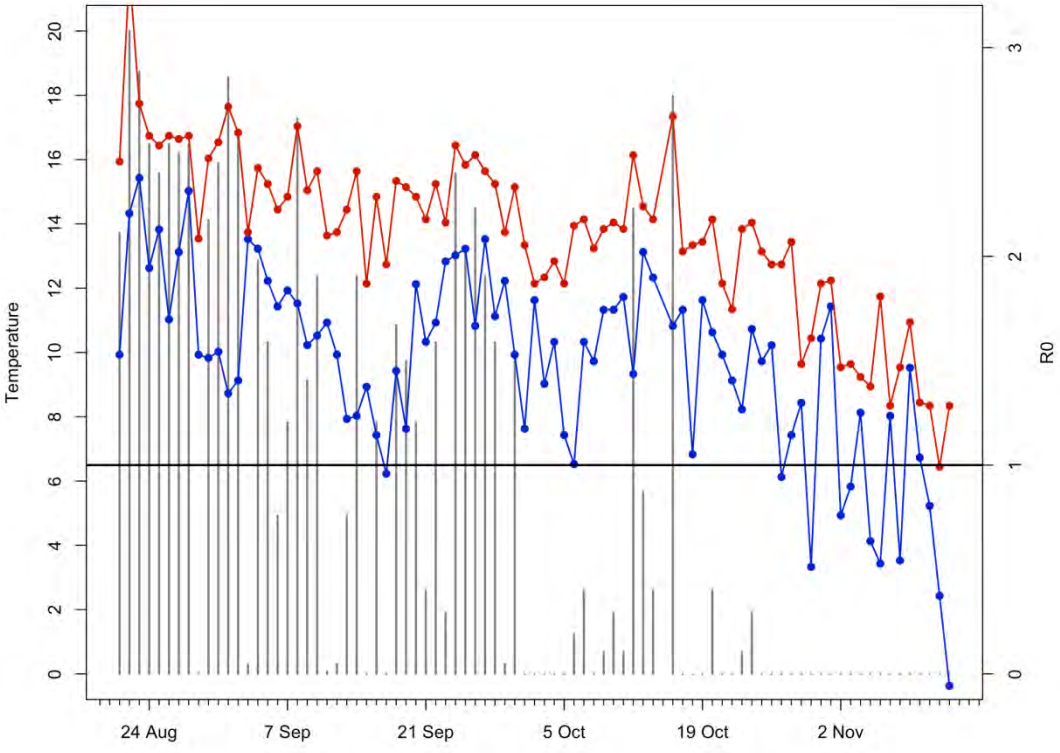

Figure 1: Daily maximum (red lines) and minimum (blue lines) temperatures from a station in Kirkcudbright. The grey bars represent estimates of the R_0. Note that multiple days of R_0 above 1 would be necessary to achieve transmission; the estimated number of such days was assessed as insufficient for transmission.

Risk management: Developing, refining and applying tools to support animal disease outbreak management and control

EPIC has continued to develop, expand and refine its repertoire of modelling tools and capabilities to inform risk management in avoiding, and/or responding to, animal disease outbreaks. In addition to internal KE to ensure that existing tools are up-to-date (curation) and familiar to a range of users (resilience), new approaches are being developed to new diseases in response to evolving policy needs (All Topics).

Of particular interest in this regard are efforts to identify clusters of animal-keeping premises, based on a number of data driven attributes, such as trading patterns or local population density of different animal species, that are likely to be associated with a greater risk of disease occurrence and/or wider dissemination of infectious disease. Economic and social science aspects of such work allow consideration of behavioural choices that may modify risk as well as measures of impact (i.e. financial) that go beyond basic estimates of the size of an outbreak in terms of numbers of premises and/or animals affected (T2 & T4).

The discovery of a number of cases of the spongiform encephalopathy, Chronic Wasting Disease (CWD), in reindeer and European Elk in Norway, where the disease had not been previously recorded, prompted calls for surveillance of wild deer species in the UK from some government advisory groups. EPIC has worked closely with colleagues in the James Hutton Institute (JHI) and Defra to use existing knowledge of deer population distribution by species in the UK to model CWD transmission potential to inform a surveillance strategy, should one be needed (T2). Existing models for BTv transmission in Scotland were refined and updated by T2, T4 and T5 based on data newly available to EPIC on midge density. This work has provided novel insights into the spatio-temporal variation in BTv transmission potential, and thus the populations of susceptible animals at risk. This work has direct policy relevance in informing plans for outbreak response.

Endemic animal disease exemplars of exotic animal disease spread and control

Although EPIC's principal focus is on preparedness for, and response to, exotic animal disease outbreaks, studying endemic diseases of Scottish livestock offers many instructive exemplars of how infectious pathogens and various animal species interact. Understanding the drivers for, and the outcomes of, these interactions greatly enhances EPIC's capability to respond quickly and effectively in the event of an emergency. In addition, the insights generated by EPIC's work on these pathogens serve to complement work supported principally through the SRP, and enhances the body of knowledge and expertise available in Scotland.

Inter-institutional and interdisciplinary synthesis of evidence from previously disparate sources has been conducted to update knowledge on endemic disease risks (e.g. liver fluke, louping ill). Patterns of such diseases are likely to be altered as an effect of climate change, hence they are also instructive as models of the ways in which exotic diseases with complex life cycles involving multiple hosts might behave. Work in T4 exploits opportunities that arise from experimental work on vaccine efficacy (against sheep scab) in the SRP to combine with modelling expertise in EPIC to evaluate the potential of such a control option (i.e. vaccination) against an ectoparasite at population level.

The ongoing Scottish BVD Eradication Scheme has provided EPIC with the opportunity to contribute through sequencing of virus isolates working closely with the SRP. Work in T2, using higher resolution sequencing to discriminate among isolates previously considered to be effectively identical, has illustrated the power of combining advanced molecular microbiology with epidemiological evidence to appreciate linkages and transmission pathways hitherto unrecognised. These general principles are transferrable to other pathogens, so experience gained working on genetic epidemiology of Scottish BVDV equips the EPIC team to apply the same thinking and methods to any infectious agent that may arrive. This has already been exploited in analyses of gene sequences and transmission pathways of HPAI viruses that have threatened Scotland in recent years and is a critical capability for EPIC going forward. A further component of T2 uses social science to focus on farmer experiences and attitudes to BVDV control as important drivers in the eventual success of the eradication scheme. Once again, awareness of, and familiarity with, the diversity of perspectives on this greatly increases the potential to design interventions in future, against any disease, that will be more acceptable to more animal keepers. Economic capability is a key component of EPIC's offering to SGAHWD policy colleagues. EPIC has finite capacity in this area, so work is carefully prioritised in close discussion with SGAHWD. In the reporting period, endemic diseases, and especially BVDV, have been an important focus for EPIC's economists, responding to policy questions about different options for the next phase of the eradication scheme. Following close on the heels of this work are new questions concerning the economic consequences of imposition of a prevention zone for HPAI control.

Evolving key relationships

As stated above, Knowledge Exchange (KE) and collaboration within EPIC, with science in the Strategic Research Programme (SRP) and beyond, and with SG and other stakeholders are central to all of EPIC's activities. Nevertheless, a number of evolving key relationships are worthy of specific mention. As noted in the Executive Summary, closer working relationships have been established with the other CsoE, beginning with our shared 'value proposition statement'. Requests to provide evidence to the Environment, Climate Change and Land Reform (ECCLR) Committee in late 2017 allowed us the opportunity to highlight important unique aspects of each CoE, as well as our collective value. For EPIC, this is chiefly about our emergency response preparedness capability. We were also given the opportunity to contribute to a review of SEFARI Gateway at the beginning of 2018, and were pleased to comment positively on a growing, complementary relationship based on shared trust and understanding.

Led by T5 and T3, the recently published scenario planning work on the future of animal health surveillance in Scotland has been presented to Scotland's Strategic Management Board for Veterinary Surveillance (SMB). At a recent workshop of the SMB, the scenario planning report was used as a reference point for considering strategic priorities for veterinary surveillance in Scotland for the years to come. Also in T3, work on exploring the utility of combined analyses of surveillance data from animals and humans for zoonotic infections has led to closer working relationships between members of EPIC and Health Protection Scotland (HPS). This offers many advantages both through the work itself and through the opportunity to share

knowledge and experience of infectious disease epidemiology and outbreak response. This evolving relationship has also been important in facilitating development of the Poultry Hub (mentioned above) and the interface with the poultry industry, much of which is catalysed by the risks posed by HPAI, for which there are, of course, concerns about zoonotic risk.

The 2017 EPIC Conference

Our first conference in the current programme was entitled 'Coordinated interdisciplinary (scientific) support of livestock outbreak response' and brought together a carefully constructed group of topics, presented by a blend of EPIC and invited participants, under an overarching theme of interdisciplinarity. The meeting was very well attended and received by our delegates and guests, and provided a great opportunity for EPIC to evaluate our own continuing evolution as a collaborative group of scientists working in support of animal health policy. This was achieved through showcasing some of our own science for critical review by our peers and stakeholders, as well as inviting them to offer us presentations and perspectives of their own. Films of the conference proceedings can be found at: http://www.epicscotland.org/about-epic/epic-conference-2017/

We were very pleased to be hosted by Graeme Dey MSP in the Scottish Parliament for a reception during the conference (Figure 2).

Figure 2: Graeme Dey MSP with Harriet Auty and Dominic Mellor at the Scottish Parliament reception during the EPIC Conference, September 12th & 13th 2017.

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
In 2017/2018, EPIC responded to SG requests for rapid risk assessments (n=4) during the avian influenza outbreaks. Two of these VRAs were used to underpin policy decisions on whether to impose prevention orders, requiring housing of birds, and were published online on the SG website. The 25+ VRAs that EPIC developed to underpin movement licenses and access to the countryside, during an FMD outbreak, were reviewed in preparation for the national disease outbreak exercise (Exercise Blackthorn) and a VRA commissioned by government to support industry to inform the risk of transmission of HPAI to a hatchery via an Egg Distribution Centre was completed.

A veterinary risk assessment working group (with representation across all devolved administrations, England and ROI) was coordinated to discuss different but equivalent methods of producing VRAs and develop best practices. T1 also had a presence at the 2018 European Food Safety Authority (EFSA) Risk Assessment Research Assembly.

Sub-topic 1.2 Outbreak Response
T1 has continued presence at Defra, APHA and National Emergency Epidemiology Group (NEEG) meetings. In 2018, EPIC members presented at the APHA modelling symposium. T1 has played a collaborative role with SG and the NEEG in the planning and development of the UK-wide FMD exercise (Exercise Blackthorn) as well as a Scottish disease exercise exploring Avian Influenza incursion in wild birds. Work was also undertaken to explore the resiliency of models used by EPIC scientists (in the face of an outbreak) through a participatory workshop. An ethical framework was developed to ensure that models used as ‘evidence for policy’ are also fit-for-purpose (Boden and McKendrick 2017 Frontiers in Public Health Policy).

Sub-topic 1.3 Knowledge Exchange
EPIC continues to utilise a ‘SG hot-desk’ that offers proximity to policymakers and facilitates science-policy communication and KE in ‘peace-time’ and in disease emergencies. T1 has a routine presence at the SG Livestock and Equine stakeholder group meetings to facilitate KE with industry leads. The relationship between EPIC and the other CsoE has developed over the last year because of quarterly meetings with and without SEFARI Gateway presence. T1 has a presence at relevant SEFARI Gateway meetings to identify and coordinate opportunities for joint engagement. Through engagement with EPIC’s KEAC, a network of expertise in KE has broadened. Stakeholder and public engagement has increased via a presence at the RHS and via the EPIC website using case studies and short films. The latter were co-produced by members of EPIC in the University of Glasgow, Scotland’s Rural College (SRUC) and the JHI and used to promote EPIC to different audiences using the content generated at the annual EPIC conference, on the importance of interdisciplinary working for animal disease contingency planning.

Outputs:
Boden, LA and McKendrick, IJ (2017) Model-Based Policymaking: A Framework to Promote Ethical 'Good Practice' in Mathematical Modelling for Public Health Policymaking. Front. Public Health 5:68. doi: 10.3389/fpubh.2017.00068

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

Sub-topic 2.1 Animal Movement Networks
UoG (with JHI and APHA) have implemented a flexible methodology for creating a network of herds/flocks at the national scale based on an arbitrary resolution population density map to improve estimates of populations (poultry and deer). This method allows us to use prior knowledge about population clustering to evaluate disease risk in terms of network measures, via putative distance kernels (i.e. variation of potential contact with distance).

Deer density estimates (six species) were obtained from the JHI and APHA for continued work on CWD. Networks were generated as described above, to evaluate the potential geographical impact of CWD should it be discovered, allowing for better recommendations on possible disease surveillance strategies and provision of insight into the implications for control of multiple infections being found (e.g. if two deer are found infected in Scotland, how likely is it that they represent the same entry into the country, or more than one?).

Sub-topic 2.2 Better Inference for Better Models
Biomathematics and Statistics Scotland (BioSS), JHI and SRUC identified environmental risk factors for liver fluke in cattle by combining data on liver condemnation at slaughter, cattle movements and spatially-structured environmental factors. Higher risk was seen after time spent in warmer, wetter areas and among older cattle. Half the risk was due to local unmeasured factors such as on-farm management. A paper was published (Innocent *et al*. 2017. Frontiers in Veterinary Science 4, 65), an article submitted to National Farmers Union Scotland (NFUS) magazine Scottish Farming Leader, and a policy brief submitted to SG.

Models of louping-ill virus in sheep found more risk in warmer areas, and in those with more deer and heather moorland.

Outputs:
Innocent GT, Gilbert L, Jones EO, McLeod JE, Gunn G, McKendrick IJ and Albon SD (2017) Combining Slaughterhouse Surveillance Data with Cattle Tracing Scheme and Environmental Data to Quantify Environmental Risk Factors for Liver Fluke in Cattle. Front. Vet. Sci. 4:65. doi: 10.3389/fvets.2017.00065

Sub-topic 2.3 Epidemiology with Genetic Data
Whilst the number of Bovine Viral Diarrhoea Virus (BVDV) non-negative premises is reducing, sample submissions for BVDV typing remain high: 854 samples from 2017, compared with 918 in 2016 and 1335 in 2015. Over 3000 5'UTR sequences were submitted to the public sequence database, following the BVDV biobank and database publication.

BVDV typing usually involves sequencing the 5'UTR from serum, but Npro sequencing of samples identical at the 5'UTR, which should provide additional resolution for tracing, showed multiple virus strains with geographical clustering of similar types. We also investigated sequencing from eartag samples, and found a 60% success rate from a batch of 96. Purification of RNA improved the success of 5'UTR typing from eartags and Npro typing from serum, although this is not yet economical for routine use.

A combined Susceptible-Infected-Recovered-Susceptible (SIRS)+phylogenetic model, developed to estimate the expected effects of eradication on virus strain diversity, suggested a reduction in both virus sequence cluster size and number over time. This is reflected in the data, with cluster numbers showing a clear decrease from over 100 in 2014 to fewer than 20 in 2017. This approach may provide a useful way to track the progress of eradication.

Sub-topic 2.4 Understanding and Influencing On-farm Biosecurity Practices
Research on medium/large scale poultry production involved 13 interviews with commercial poultry producers and 12 key stakeholders to explore attitudes to biosecurity and the management of AI. Interviews are to be completed by the end of March 2018.

A report from interviews with backyard poultry producers entitled 'Understanding Backyard Poultry Keepers and their Attitudes to Biosecurity: Final Report' was published on the EPIC website in February 2018. Dissemination activities also took place at conferences and poultry shows.

Research on farmers' attitudes to the BVDV eradication scheme involved 26 interviews with dairy and beef producers, four stakeholders, and seven video ethnographies. Results were disseminated through response to a public consultation, conferences and a report and research brief for SG.

Data collected on benzimidazole resistance in *Nematodirus battus* have been analysed with management practice questionnaires to determine risk factors. A peer-reviewed publication has been prepared and the results are due to be disseminated at farmers' meetings early in year 3 of the EPIC programme.

Topic 3
Improving Veterinary Surveillance Strategy

Sub-topic 3.1 Adding Value to the Existing Data Collection - Scoping the Properties of Scottish Animal Health Surveillance Data

A meeting of T3 EPIC scientists was held in May 2017. Good progress in populating a wiki with information about cattle and pig datasets was reported and priorities were identified for the future, both identifying other classes of dataset (sheep and poultry), the evaluation methodology to be employed, and the development of a procedure for updating the wiki. It was agreed that mechanisms should be identified to make SG colleagues aware of the wiki and to explore the scope for them to access this resource directly. This work has been delayed (with agreement from RESAS), pending the appointment of a replacement EPIC fellow at RI.

Data sources relevant to pig health in Scotland were identified and assessed using SERVAL, a framework for systematic assessment of animal health surveillance systems, evaluating their ability to detect exotic notifiable and novel emerging diseases. The assessments identified strengths and weaknesses of each data source, considered how the data sources might work to complement each other, and developed recommendations for EPIC, SG and other stakeholders to improve or maintain surveillance in the future. The final report was presented to the SMB. An equivalent analysis is now being undertaken for poultry health.

Sub-topic 3.2 Adding Value to the Existing Data Collection - Adding Value to Current Surveillance Datasets

Work was undertaken to conduct preliminary assessment of uncertainties and biases in the use of data from Scotland's Disease Surveillance Centres for inference of incidence, prevalence and trends in endemic diseases, using the zoonosis, cryptosporidiosis, and the endemic disease fasciolosis (liver fluke) as exemplars. This has involved the development of a new collaboration with HPS to assess the potential for the use of animal health data alongside human disease data in surveillance of zoonoses, and a strengthening of the existing relationship with Scottish Agricultural College Consulting Veterinary Services (SACCVS). A working interface has been developed, data shared, and initial analyses conducted.

Sub-topic 3.5 Developing Statistical Approaches to Analyse and Integrate Available Data - Refining Statistical Models to Strengthen Diagnostic Information

Statistical methods to incorporate information on diagnostic test kinetics from two or more tests for FMD and so estimate dates of disease introduction into a herd were explored. Datasets were available from Cameroon where multiple tests had been applied to individual animals and these were combined with published test kinetics. Work exploring the use of this approach in an endemic setting, as opposed to an epidemic context, was presented at the Modelling in Animal Health conference held in Nantes in June 2017. The development of better, objective methods to estimate times of disease introduction into a herd would have immediate operational relevance during an outbreak, where they would help to narrow the tracing window, and could also support better interpretation of farm-level surveillance data when seeking to eradicate endemic infections.

Sub-topic 3.6 Developing Statistical Approaches to Analyse and Integrate Available Data - Refining Statistical Methods to Better Support Active Surveillance

Methods have been developed to analyse epidemiological data depending on the observed disease status from individual animals in the absence of a perfect test, but where results from two imperfect tests of disease status have been recorded. This allows us to infer the effect of covariates on true disease status, and infer the sensitivity and specificity of both tests. This approach has been applied to both discrete and continuous covariates and gives results that appear to be unbiased. It is anticipated that this work will allow more accurate baselining of levels of disease in surveillance programmes, better estimation and identification of key drivers of population-level disease prevalences, and a better understanding of the use of disease diagnostics in the field when used for epidemiological purposes.

Work is continuing on developing these approaches and has already prompted interest at the recent EPIDEMICS 6 Conference, and been presented both internally within EPIC and to SGAHWD. Following the internal presentation, and the positive outcomes from initial simulation-based work, collaboration has begun between BioSS and the RI to identify data sets to which to apply these techniques.

Sub-topic 3.7 Seeking Early Warning of Changes in Population Characteristics - Using Syndromic Surveillance to Indicate Disease Trend

Initial work on this sub-topic was completed in the previous reporting year (Milestone 3.7.1.1). Ongoing work has awaited the appointment of a replacement EPIC post-doctoral fellow at RI (with agreement from RESAS).

Sub-topic 3.8 Seeking Early Warning of Changes in Population Characteristics - New Methods of Syndromic Surveillance

A draft report reviewing available datasets and plausible methodological approaches was produced. Results were presented to the SMB in December 2017; these indicated use of abattoir data and development of statistical methods to integrate diverse classes of data. These insights are being used to develop deliverables for Years 3-4.

The basis of an early-warning system methodology was developed early in this project, an initial paper being submitted in 2016. The approach applies the CUSUM statistical process control framework (a well-established approach to flagging deviations from trend) to the outputs of a robust analysis of a surveillance time series. To date it has proved difficult to validate the work via peer-reviewed publication. The initial submission was rejected with major revisions requested. Work during the 2017/18 reporting year was focussed on developing the methods further, rewriting the paper and resubmitting the paper (July 2017). However, the journal has rejected the paper, requesting, amongst other things, that it be applied to a different dataset. The material is now being prepared for submission to a different, more methodologically oriented journal, which it is hoped will be a better platform for the external validation that is being sought.

Sub-topic 3.9 Developing Risk-based Approaches to Surveillance - Farm-Oriented Risk Assessment

Initial work on this sub-topic was completed in the previous reporting year (Milestone 3.9.1.1). A continuation of the work was planned for Jan-Mar 2018, but other work on CWD and Key Premises for Disease Spread (both in T2) were assigned a higher priority; they also turned out to take longer than expected. Consequently, there has been no progress with the Sub-topic 3.9 work in this reporting year (with agreement from RESAS). It is anticipated that work will restart in the 2018/19 period and milestones have been amended to reflect this.

Sub- topic 3.10 Developing Risk-based Approaches to Surveillance - Phylodynamics Analysis to Identify High-Risk Paths of Disease Incursion

Sequencing pathogens during outbreaks, and when seeking to control endemic diseases, provides the evidence to deduce transmission routes, including cross host-type transmission, virulence and drug resistance properties when sequences are compared to previously known strains. We have produced and updated a curated collection of publicly available virus sequences, with isolation date, location and host species (where known). This comprises Avian and Swine Influenza (a stratified sample of around 6000 hemagglutinin sequences), Classical Swine Fever (CSF) (109 full genomes, 289 E2 sequences), African Swine Fever (ASF) (306 partial P72 and 178 P54 sequences), Porcine Epidemic Diarrhoea virus (PEDv) (~1000 sequences), and Bluetongue (BTv) (~300 sequences per segment). These sequences aid ongoing work to help understand the risk of exotic disease incursion into the UK and Scotland, and will be an invaluable resource in the event of a disease incursion.

Topic 4
Analyses of Potential Disease Control Options

Sub-Topic 4.1 Livestock Industry Interface

There have been several significant developments with EPIC interactions with the Livestock Sector over the last year. Probably most important were a series of meetings facilitated by SGAHWD with Scottish Government's poultry industry stakeholders. The highest priority for industry and SG is a detailed characterisation of the structure of the Scottish poultry industry. This will now be developed jointly by T4 and industry. At the invitation of APHA, EPIC also participated in evaluations of biosecurity arrangements and disease control plans for one of the largest table egg producers in Scotland. Working with the dairy sector, NFUS's 'Milk Committee Meeting' was identified as the key Scottish dairy stakeholder group attended by NFUS's milk policy staff and farmer regional representatives, so EPIC will be represented at future meetings.

EPIC continues to engage with all sectors through participation and attendance at a variety of events and meetings for example: Quality Meat Scotland's (QMS) Pig Health Group; the Pig Health and Welfare Council's (PHWC) Surveillance sub-group; SRUC Cross-divisional Beef, Sheep & Dairy Knowledge Exchange Group; Sheep Health and Welfare Group. Participation continues in focus groups with Scottish producers to ensure that the outputs of new research efforts are tailored to the sector's needs.

Sub-topic 4.2 Simulation Models
The CSF modelling framework is currently being extended to assess the potential spread of ASF in GB. This is in collaboration with the Royal Veterinary College and Pirbright Institute and integrates the recently published (Guinat *et al*. 2017) quantitative description of the within-herd spread of ASF from infected farms in Russia.

A statistical framework to infer the shape of the distance-based transmission function was published (Gamado *et al*. 2017) and is being extended to analyse the 2015 Iowa AI outbreak in an international collaboration with United States Department of Agriculture (USDA). Work to evaluate the benefit of this framework when responding to emergencies is ongoing.

Work on assessing the impact of haulage companies on the trade network between pig farms in GB has been recently presented at the Epidemics conference. This work benefits from new collaboration with animal welfare researchers from SRUC and the SRP.

Work on sheep scab is ongoing, with transmission models being developed and applied to analyse sheep scab field data and penned transmission experiments conducted by Moredun Research Institute (MRI) under the SRP. The ultimate goal is to use these models to assess the efficacy of vaccines developed under the SRP in the field.

Efforts to develop a modelling framework for AI in Scotland have been paused pending better understanding of the Scottish poultry industry (with agreement from RESAS).

Outputs:
Guinat C, Porphyre T, Gogin A, Dixon L, Pfeiffer DU, Gubbins S. Inferring within-herd transmission parameters for African swine fever virus using mortality data from outbreaks in the Russian Federation. Transbound Emerg Dis. 2018;65:e264–e271. doi:10.1111/tbed.12748.).

Gamado K, Marion G and Porphyre T (2017) Data-Driven Risk Assessment from Small Scale Epidemics: Estimation and Model Choice for Spatio-Temporal Data with Application to a Classical Swine Fever Outbreak. Front. Vet. Sci. 4:16. doi: 10.3389/fvets.2017.00016

Sub-topic 4.3 Economic and Behavioural Analysis
Economic analysis of the impact of Johne's disease is now complete with a policy brief submitted to SG and a paper submitted to a peer-reviewed journal.

Work on FMD addressing the impact of vaccine availability has been published (Porphyre *et al*. 2018). This paper details concepts and assumptions of EPIC's modelling framework to estimate direct cost of FMD outbreaks in Scotland. A policy brief is currently being prepared.

Thanks to regular interactions with SG, requested analysis on the economic impact of persistently-infected BVD animals on the cattle industry is complete. This work

estimates the average economic cost of an animal in a typical dairy and beef suckler herd, together with farmer-friendly metrics (i.e. milk yield, abortion). KE activities are ongoing.

Design and preparation work for planned incentive experiments are ongoing. This workshop will link with SRP work on food waste mitigation and explore how causes of waste such as animal disease on dairy farms can be mitigated through incentives to farmers and collaboration with others along the dairy supply chains. It will identify 'leverage points' and incentives in the system through which to intervene e.g.to reduce the use of antibiotics at the farm level and thus reduce AMR and waste.

Outputs:
Porphyre T, Rich KM and Auty HK (2018) Assessing the Economic Impact of Vaccine Availability When Controlling Foot and Mouth Disease Outbreaks. Front. Vet. Sci. 5:47. doi: 10.3389/fvets.2018.00047

Sub-topic 4.4 Data Curation
The EPIC Data Repository, a resource developed during the previous EPIC programme, continues to be heavily used by researchers across the consortium. Resources distributed via the Data Repository continue to expand: this year, we made major advances in documenting and distributing movement data for Scottish sheep, and are now able to provide information from ScotEID's ScotMoves database of within-business movements of cattle in Scotland to EPIC collaborators. We have expanded our links with the SRP via the EPIC Data Repository, which is now used by SRP-funded researchers from several SEFARI institutions, including JHI, SRUC, and MRI, many of whom participated in an EPIC-sponsored workshop to promote the sharing of tools, skills, and knowledge pertaining to the use of the EPIC Data Repository.

The EPIC data team has also organised work to improve cross-training in the use of disease models across EPIC. Backup personnel have been identified and have undergone training in BTv spread models and tools for genomic data analysis to provide enhanced resilience in times of emergency. Reinforcement of other capabilities will be developed with the cooperation of EPIC personnel primarily responsible for disease modelling.

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

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

Development of the theoretical behavioural models (structural equilibrium models/structural choice models (SEM/SCM) and hybrid mixture/ random-coefficient) has been completed and elements have been built into a questionnaire. The questionnaire for the survey has been completed and is currently being reviewed by RESAS (March 2018). The survey focuses on animal health technology uptake as a follow-up of the technology survey in 2015-6. In parallel, a survey focusing on Brexit, identified as the other key driver, besides technology, to influence the livestock industry, is in progress as part of the SRP, and ST5.1 analysis will also use data from that survey.

Papers 'A longitudinal analysis of farmers' uptake of animal health and welfare technologies' (Toma *et al*.) and 'Latent class analysis theory driven or data driven: farmers' uptake of animal health and welfare technological innovations' (Liu *et al*.) are close to completion and will be submitted by June 2018.

Outputs April 2017-March 2018

Jack, C., Hotchkiss, E., Sargison, N., Toma, L., Milne, C., Bartley, D. 2017. A quantitative analysis of attitudes and behaviours concerning sustainable parasite control practices from Scottish sheep farmers. Preventive Veterinary Medicine 139, Part B, 1 April 2017, 134-145

Toma, L., Barnes, A., Sutherland, L-A., Thomson, S., Mathews, K., Stott, A.W. 2017. A longitudinal analysis of farmers' uptake of animal health and welfare technologies. Contributed paper presented at the 91st Annual Conference of the Agricultural Economics Society, Dublin, 2017

Toma, L., Barnes, A., Sutherland, L-A., Thomson, S., Mathews, K., Stott, A.W. 2017. Uptake of Animal Health and Welfare Technologies by Scottish Farmers. Analysis of Longitudinal Survey Data. Contributed poster at the 15th EAAE Congress 'Towards Sustainable Agri-Food Systems: Balancing between Markets and Society', Parma, 2017

Liu, J., Toma, L., Ahmadi, B., Low, J.C., Matthews, L., Stott, A. 2018. A Typology of Escherichia Coli O157 On-Farm Control Behaviours. Foodborne Pathogens and Diseases (under review)

Sub-topic 5.2 Future-proofing Scottish Animal Health Resilience

Horizon scanning continued using the horizon scanning framework established in EPIC II; of particular concern were the continuing spread of BTv-8 and new incursion of BTv-4 in France. Following an introduction of BTv-8 into South West Scotland,

weather data were used to identify negligible risk of onward transmission. The model of Bluetongue spread for Scotland was updated to include livestock movements but these make little difference to the size of the epidemic. Further work is evaluating high-risk areas caused by the coincidence of high midge densities (from the Centre for Ecology and Hydrology (CEH)) and particular weather conditions.

In 2016, a multidisciplinary, multi-partner EPIC team facilitated a participatory two-day workshop for 40 experts in policy-making, agriculture and technology industries, and academia to consider the long-term future resilience of animal health surveillance. In 2017, the outputs of this work were published (Boden *et al*. 2017) and shared with the British Veterinary Association Surveillance Working Group; key findings were presented to the SMB, the Scottish Futures Group and the British-Irish Parliamentary Assembly Committee inquiry into the implications of Brexit for the agri-food sector.

Outputs:
Boden L.A. 2018. The Future of Food Security in Scotland. Paper presented at Scottish Futures Group meeting.

Boden, L.A., Auty, H., Reeves, A., Rydevik, G., Bessell, P., McKendrick, I.J., 2017. Animal Health Surveillance in Scotland in 2030: Using Scenario Planning to Develop Strategies in the Context of “Brexit.” Front. Vet. Sci. 4, 201. https://doi.org/10.3389/fvets.2017.00201

Boden, L.A., Auty, H., Reeves, A., Rydevik, G., Bessell, P., McKendrick, I.J., 2016. An EPIC Scenario Planning Workshop. Year 2030: What is the future of animal surveillance in Scotland? Stakeholder report. Available at http://www.epicscotland.org/resources/reports-by-epic-members/year-2030-what-is-the-future-of-animal-surveillance-in-scotland/

Duckett, D., McKee, A.J., Sutherland, L-A., Kyle, C., Boden, L.A., Auty, H., Bessel, P.R., McKendrick, I.J. (2017) Scenario planning as communicative action: lessons from participatory exercises conducted for the Scottish livestock industry. Technological Forecasting and Social Change, 114, 138-151.

Roy, H.E., Hesketh, H., Purse, B. V., Eilenberg, J., Santini, A., Scalera, R., Stentiford, G.D., Adriaens, T., Bacela-Spychalska, K., Bass, D., Beckmann, K.M., Bessell, P., Bojko, J., Booy, O., Cardoso, A.C., Essl, F., Groom, Q., Harrower, C., Kleespies, R., Martinou, A.F., van Oers, M.M., Peeler, E.J., Pergl, J., Rabitsch, W., Roques, A., Schaffner, F., Schindler, S., Schmidt, B.R., Schönrogge, K., Smith, J., Solarz, W., Stewart, A., Stroo, A., Tricarico, E., Turvey, K.M.A., Vannini, A., Vilà, M., Woodward, S., Wynns, A.A., Dunn, A.M., 2017. Alien Pathogens on the Horizon: Opportunities for Predicting their Threat to Wildlife. Conserv. Lett. https://doi.org/10.1111/conl.12297


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