



Animal &
Plant Health
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1. INTRODUCTION

This document sets out a wide range of science highlights achieved throughout the year in support of [APHA's Science Strategy 2015-20](#). It shows the range of animal and plant health expertise within the Agency and demonstrates the importance and value of linking surveillance and research activities to rapidly investigate and respond to new threats; including those with potential public health impact. It also shows our important role in the protection of animal and plant health and welfare.

The science highlights are grouped around our science portfolios as well as the main scientific disciplines working across the APHA. Important achievements are also published regularly on our [APHA science blog](#), which was launched in April 2016 on GOV.UK. The aim of the blog is to improve the communication of our science to a wider audience. It covers a wide range of scientific highlights from special interest stories on our scientists through to more detailed reports on the excellent science we do.

Dr Kath Webster
APHA Director of Scientific Services

2. SCIENCE PORTFOLIOS

2.1 PORTFOLIO: Animal and Zoonotic Viral Diseases Portfolio

The portfolio provides surveillance and policy-relevant research on viral diseases of significance, in terms of their impact on animal welfare, the economy, the food chain and human health. We ensure that the value of our national resources is maximised, by working closely with academia and public sector research establishments. We widen the impact of our work by engagement with other public and private sector stakeholders, at national and international level and work closely with funders to ensure sustainability at national level.

Our strategy is targeted to enable effective detection and control of exotic viral disease threats to livestock, companion animals and wildlife, also to protect public health through the control of zoonotic viral diseases. Our research portfolio is highly collaborative and of a size that aligns with the minimum core capability for emergency laboratory response.

Highlights

- A Chinese strain of avian influenza H7N9 that showed high mortality in humans, was shown to have novel and unexpected severe clinical effects and efficient transmission in turkeys, compared to chickens. We have also established a novel ferret model as an analogue for transmission to and from humans and other species.
- In partnership with industry, we contributed to a cost-sharing initiative to make porcine epidemic diarrhea a notifiable disease and contributed to an important review on the disease, which informed EU policy.
- We confirmed the re-emergence of Schmallenberg virus in England and we are working with industry in mitigating the risks posed by semen and advising stakeholders how to assess and minimize the impact of the disease.
- In collaboration with PHE, we have performed some preliminary studies to characterize strains of hepatitis E circulating in GB and continental Europe. This work will be expanded in a new EU project.
- We have discovered a new lyssavirus, which was detected in the brains of bats from Sri Lanka. The virus is named after the village of Gannoruwa, near where the bats were found.

- We have carried out the first ever trial of oral rabies vaccination of Ethiopian wolves, as part of an international effort to save Africa's most threatened carnivore from extinction.
- As part of an investigation into three human cases of renal failure, we detected hantavirus in rat colonies kept by the patients.
- Following a report of a cluster of cases of babesiosis in dogs in Essex, we detected *Babesia canis*, in a *Dermacentor reticulatus* tick removed from one of the dogs. This species of tick is considered new to UK, though recently reported from a number of locations in England and Wales in recent times.

Avian and Mammalian Influenza

An APHA-driven project, involving four other European partners, under the "Co-Vet Lab" initiative was recently completed for the development and validation of molecular tools for sub-typing swine influenza A viruses (swIAVs). From this project, PCR protocols have now been established for detection and differentiation of different human and avian lineages of H1 and H3 strains of influenza virus, also simultaneous detection of N1 and N2 (avian H1N1, pandemic (pdm) H1N1, H1N2 H3N2). The protocols have now been used to test clinical material from the field in addition to amplified virus. Promising results have been achieved following the identification and classification of UK influenza viruses in previously virus isolation-negative, un-typed influenza A-PCR positive (matrix gene) swabs and tissues (n=68). Further validation and accreditation of these assays for clinical material will follow, including application for new a new test code (Q1, 2017). Preliminary data has been presented to our validation group and sequencing confirmation is currently underway.

A vaccine pilot study was completed for the Swine Influenza Dynamics BBSRC sLoLa project. A commercial trivalent swine influenza vaccine was trialled, as well as two laboratory-formulated vaccines that were homologous with or heterologous to the challenge strain. The data clearly showed that, in order for vaccines to prevent virus replication and shedding, the vaccine and challenge strains must be closely matched. Antibodies elicited by the different vaccines also displayed distinct strain reactivity. The results indicate that available commercial vaccines may not provide ideal protection against currently circulating swine influenza virus strains. Further analysis is ongoing to dissect the specificity of the immune responses to the different vaccines.

In addition to the above, the *in vivo* phase for two pig studies with swine pdm09 H1N1 influenza A virus has been completed for the BBSRC sLoLa Influenza Dynamics project; a transmission chain experiment and a study with virus containing a genetic barcode.

Within a Defra-funded project to study risks and pathways for the introduction of Chinese-origin H7N9 avian influenza virus (AIV) infection into UK and European poultry (EXSE2206) we focused on a Chinese origin low pathogenic avian influenza virus (LPAIV) H7N9 that is capable of infecting and killing humans (circa 33%). We carried out a series of host susceptibility and cross-species transmission experiments, which revealed unexpected novel substantial pathogenic findings with turkey infection / transmission. In contrast, the results in chickens revealed more limited pathogenicity and little transmission, which is more in accord with published data from other institutions and that seen in live bird markets.

Full-genome sequencing of chicken and turkey progeny viruses from these experiments indicated that the virus, which was originally isolated from a human case, had reverted to its avian form, with genetic changes seen in the haemagglutinin gene, following passage in both turkeys and chickens. The significance of these changes is being investigated.

In a parallel *in vivo* study focussing on the hazard posed by flu transmission among avian and mammalian and human hosts, we demonstrated successful infection of ferrets (as a model of human disease) with the China-origin H7N9 LPAI viruses. A novel poultry-ferret transmission model was then developed, to test the hypothesis that humans infected with H7N9 “bird flu” might be a risk to UK poultry. Results from the cohousing of poultry (chickens and turkeys) with ferret donors (aerosol transmission, no direct contact) have so far not shown any evidence for transmission of infection from the infected ferrets to the naïve birds. Data analyses are ongoing to determine if exposure occurred (sero-conversion) without productive infection (virus detection).

The pandemic H1N109 virus lineage “swine flu” infects both humans and swine equally, since 2010 it has been endemic in both populations and frequently transmits in both directions. In 2010 we also detected a swine H1N2 - pdmH1N109 re-assortant virus, with H1N2 external proteins and an internal gene cassette derived from pdmH1N1. This led to the question, ‘is the novel re-assortant capable of transmitting from pigs to humans and causing infection?’ No clinical evidence is currently available. The first two phases of the work examined the ability of this re-assortant (H1N2r) virus to infect and transmit within species, pigs and ferrets (latter model of human disease). Both arms of this work were successful and mild-moderate virulence was demonstrated in both species.

The Mammalian Influenza team are completing the *in vivo* phase of Part 3 of a three part study for an influenza A virus interspecies transmission) project. The latter study involved co-housing pigs and ferrets and investigating inter-species transmission of re-assortant H1N2r. Preliminary data indicated that infected pigs rapidly transmit virus to co-housed ferrets (airborne), whereas with infected ferret transmission to co-housed pigs, there with a lag phase of eight days post-contact. Further sample processing and investigation of the infection dynamics are underway.

Collaborative work

The Molecular Resource Management team collaborated with a PhD student from the Department of Zoology at Oxford University, on a project investigating the epidemiology and ecology of viruses in natural populations. More than 800 clinical samples comprising cloacal swabs and faecal material were screened by a real-time RT-PCR assay for generic detection of avian influenza A viruses, targeting the matrix gene. The samples had been collected from wild mute swans at Abbotsbury in Dorset over the course of around eight months. Positive samples will undergo sequencing analysis at Oxford.

A PhD student from the University of Nottingham undertook a three month placement in the Mammalian Influenza team, assessing the welfare benefits of reward training for animals on scientific protocols, while also evaluating the use of nasal wipes (a non-regulated procedure) for monitoring influenza A virus shedding.

A placement student from University of the West of England, Bristol submitted their report on the development and evaluation of influenza C/D virus detection in cattle and pigs. We now have a set of tools to further investigate this novel virus (Flu D) that has been detected in the USA, Italy and France. Preliminary surveillance in the UK did not detect virus or antibodies against the infection; work is ongoing. These project outcomes were shared with both the Cattle and Pig Expert Groups.

The Mammalian Influenza team has undertaken a contract to conduct a study to investigate influenza resistance in transgenic pigs. The collaboration is with the Roslin Institute, University of Cambridge and Genus plc. Together with Animal Sciences and Pathology teams, the work was completed, data analysed and collated and the interim/final reports written. The team received plaudits from collaborators and the work is currently being written up. We are also planning further studies for future collaborations with this consortium.

International Reference Laboratory Activities

The EU/OIE/FAO International Reference Laboratory (IRL) for avian influenza provided updated reports to the European Commission and Defra on epidemiology and surveillance relevant to H5 HPAI outbreaks reported in France on 18 and 23 December 2015, this was followed by an updated report on 22 January 2016.

The IRL for avian influenza received an H5N1 HPAI European lineage virus, that has been isolated from one of the many (>70) outbreaks of avian influenza in France. We carried out an *in vivo* study in collaboration with our French colleagues, to investigate tissue tropism and transmission dynamics of this virus in Pekin (*Anas platyrhynchos*) and Mule ducks (*Anas platyrhynchos* x *Cairina moschata*). This data will address key questions of relevance for surveillance design, intra-community disease risk and trade. This urgent study was supported by the EU commission.

The IRL informed EU veterinary health officials on developments and interpretations on the ongoing H5 HPAI epidemic in France together with recommendations on necessary protective steps for the wider EU upon plans for early lifting of the restriction zone.

The IRL for AI has been liaising with the FAO to receive samples from Iraq. We provided confirmatory diagnoses of H5N1 HPAI in Iraq (apparently numerous foci of infection). The results came to the personal attention of the Iraqi Prime Minister. Results were obtained despite difficulties in shipping and quality of material received.

During November/December, the AI IRL has been very busy with the avian influenza H5N8 outbreaks in continental Europe (mainly in wild bird species, but also in poultry). Also assisting Defra with contingency planning for UK and contributions to [the Defra International Disease Monitoring Report](#) where summary details of the situation can be found. UK preparedness has been underway with respect to the high risk of this virus entering the country.

A cross-laboratory calamity exercise was undertaken with the Netherlands – mock AI samples were exchanged to test sample transfer and registration protocols. This is to be followed by further exchange, to assess testing and reporting protocols.

The role played by the Avian Virus Investigation Unit in confirming the freedom-from-infection from avian influenza and Newcastle disease in 12 Javan Green Magpies (*Cissa thalassina*) and seven Sumatran Laughing Thrushes (*Garrulax bicolor*) imported into the United Kingdom from Indonesia was acknowledged in October (2015) by Chester Zoo. They thanked all those involved in the conservation movement of these threatened birds in what was clearly a challenging importation, and stressed the importance and significance of this type of integrated field and captive conservation intervention in maintaining the survival of threatened species like these. The plaudit serves to highlight the important part played by the unit in international trade testing of avian species and the need for the APHA to continue and strengthen this service in the future.

UK notifiable disease detections

As part of the notifiable disease outbreak in Fife, Scotland, a positive Influenza A “testing to exclude” (TTE) case in chickens was escalated to a report case submission. A strain of H5N1 low-pathogenic avian influenza virus was isolated and characterized via routine sample sets and environmental samples from the premises.

Surveillance in wild birds provided early warning of the spread of H5N8 HPAI to the UK with the first detections in December primarily in waterfowl species in Wales, England and Scotland. Whilst

technically not notifiable in wild birds (other than to OIE as a new and emerging infection) these observations preceded the first cases of notifiable disease in domestic poultry with these viruses. By year end there had been two cases; turkeys in Lincolnshire, backyard poultry in Wales.

Two non-negative poultry flocks were detected in serological surveys - the first in 2.5 years. One was in chickens from Fife, the other in geese in Norfolk. Both were H5 suspects, and, though antibodies were detected, there was only limited evidence of current infection and restrictions on the farms were therefore lifted.

Specimens have been tested by RealTime PCR in the IAEA-funded Wild Bird Migration project, which included 147 and 34 faecal specimens from Bulgaria and Tajikistan. All were negative for avian influenza A virus, but one from each country was positive for avian paramyxovirus type 1 (APMV-1), collected from a coot (*Fulica spp*, Bulgaria) and a ruddy shelduck (*Tadorna ferruginea*, Tajikistan). These samples were submitted to the IRL for Avian Influenza.

An updated risk assessment for the H5N1 high pathogenic avian influenza incursion to poultry in GB via wild birds was published as a short communication in the *Veterinary Record* (<http://veterinaryrecord.bmj.com/content/early/2016/09/15/vr.103700.extract>).

As part of the FluWatch Study consortium, we demonstrated an increased risk of pig workers to influenza pdmH1N1 infection. The report also recommended flu vaccination of pig workers. (Fragaszy et al 2016).

In a collaboration with the Jenner Institute, Oxford University, Bristol University and the Pirbright Institute, we demonstrated that a novel universal flu vaccine could be effectively delivered by aerosol. Work was led by an ex-PhD student of APHA Virology (Morgan et al 2016).

We reported the detection of a low pathogenicity avian influenza virus subtype H9 infection in a turkey breeder flock in the UK (Reid et al 2016). Though designated as low path, morbidity was as high as 90% and mortalities rose through the course of the infection. Occupational health risks were assessed, and preventative measures were taken.

Our Newcastle disease (ND) research programme continues. APMV-1 *in vivo* studies in gamebirds (pheasants and partridges) have been successfully completed, including specialist designs for animal accommodation and welfare requirements. Seasonality issues of bird supply were successfully negotiated. The susceptibility to NDV infection and its ability to transmit between gamebird species was assessed using two NDV isolates which resulted in minimal/complete absence of clinical signs but was highly infectious, causing systemic spread of virus, and high levels of virus shedding for up to three weeks. Transmission studies demonstrated that of the two strains only the pigeon variant isolate was capable of onward transmission, and only in the pheasant group. These birds pose a significant risk pathway for introduction of ND to the galliforme production species.

As part of the ND 'toolbox' work stream the MGB (minor groove binder) probe real-time RT-PCR assay for detection of avian paramyxovirus-1 was added to scope.

Mammalian Virology

Working in private public partnership with stakeholders we have supported the cost-sharing initiative to make porcine epidemic diarrhoea virus (PED) notifiable. For this, we used our

international collaborations as centre of excellence for new and emerging viral diseases, particularly to increase our threat awareness and developing diagnostic tests for PED virus, advising Defra and UK stakeholders. We provided assistance to countries such as Cyprus regarding suspected outbreaks of PED, which gave us the ability to successfully test our procedures and full genome sequence was available on the fourth day. We were invited to share our knowledge in a review article for the prestigious scientific journal *Virus Research*, which allowed us to provide a comprehensive review of the European situation and which in turn was used by European colleagues to build their advice.

To sustain our ability to combat notifiable diseases, we worked closely with colleagues across Europe and carried out inter-laboratory proficiency trials for equine diseases and swine fever viruses, which backed up a laboratory simulation exercise, Exercise Peanut, held in collaboration with Defra to test our capacity to respond. The exercise simulated a medium scale outbreak of classical swine fever (CSF) and while we could demonstrate our ability to respond the exercise also highlighted the risks of continuous understaffing.

Autumn 2016 saw the emergence of Schmallenberg virus (SBV) across GB, which poses a threat to breeding and international trade of semen. Investigations were undertaken on a cost-sharing basis in collaboration with industry, enabling us to advise stakeholders on how to assess and minimise the impact. The risk of emergence and incursion of vector-borne diseases like SBV has significantly increased in recent years. In collaboration with an international consortium, we identified similar orthobuynaviruses from countries bordering Europe, which represents a potential threat of incursion via vector dissemination.

Working in partnership with colleagues from PHE to combat threats to food safety and food security, particularly Hepatitis E, we contributed to an EFSA/FSA workshop on foodborne viruses. Following on, our research in collaboration with the European Co-Vet Lab partners continued to investigate the strains circulating in Europe. The intention is to expand this work, which also supports EU trade ambitions through H2020 project on One Health.

Working with stakeholders and charities to protect wildlife and endangered species, we continued work to assess red squirrel health. We also informed the public about the GB status for a new deadly strain of rabbit haemorrhagic disease virus (RHDV-2) working with the APHA Wildlife Expert Group.

We continue our collaborations with several UK universities, which for example provide training opportunities for undergraduate and postgraduate students as well as apprentices. These training opportunities include sandwich/placement opportunities to experience the research and development environment at our centre of excellence as well as Erasmus programme supported training exchanges, for example with German federal state reference labs.

These training collaborations also support international development projects and in November 2016 colleagues from APHA supported a Newton Researcher Links workshop in Cairo Egypt, organised by the University of Surrey and Cairo University to *Improve food security for Egypt's poorest communities*.

Other collaborations with UK Universities were used to enhance our research and through a consortium involving the University of Surrey, the Royal Veterinary College and the University of Oxford, we succeeded to characterise antigen presenting cells in pigs responsible for initiating an effective immune response that will support an improved design of vaccines not only for pig diseases.

Wildlife Zoonoses and Vector Borne Diseases

Rabies virus and other lyssaviruses

Rabies virus (RABV) can be transmitted by bats, but only in the Americas. This has puzzled rabies researchers for years particularly because it is believed that dog rabies was introduced in the Americas by Europeans when they discovered the 'New World'. Diagnostic testing of four bat brains from Sri Lanka confirmed the presence of a new lyssavirus which has been named Gannoruwa bat lyssavirus, after the region where the bat colony was located. The results showed that this virus is most closely related to RABV and is the closest ancestor to terrestrial RABV found in bats outside of the Americas. More work is underway to investigate the relationship between the two lyssaviruses and to further our understanding of how these viruses evolve and adapt.

Two bats found at sites in the North of England tested positive for European Bat Lyssavirus type-2 (EBLV-2), a genetic variant of RABV. In both cases, antigen detection on brain tissue confirmed that the bat was positive for a lyssavirus and RT-PCR demonstrated the species as EBLV-2 within eight hours of receipt of the sample.

Field trials of oral rabies vaccine in Ethiopian wolves, Africa's most threatened carnivore and the world's rarest canid, are the first ever conducted in wild populations of an endangered carnivore. The trials undertaken in the Bale Mountains of Ethiopia showed that oral vaccine offers a cost effective, safe and proactive approach to protect the wolf population at risk of distinction. It also provides proof-of-principle for the use of this approach in wild canids.

Hantaviruses

As part of further investigations into three linked haemorrhagic fever with renal syndrome (HFRS) cases in Wales and England, 21 domestic rats from a breeding colony in Cherwell, and three pet rats from a household in Cheltenham were screened for hantavirus. Hantavirus RNA was detected in either the lungs and / or kidney of 17/21 of the Cherwell rats tested (81%), higher than previously detected by blood testing alone (7/21), and in the kidneys of all three Cheltenham rats. The partial L gene sequences obtained from 10 of the Cherwell rats and the three Cheltenham rats were identical to each other and the previously reported UK Cherwell strain. SEOV RNA was detected in the heart, kidney, lung, salivary gland and spleen (but not in the liver) of an individual rat from the Cherwell colony suspected of being the source of SEOV. Serum from 20/20 of the Cherwell rats and two associated HFRS cases had high levels of SEOV specific antibodies (by virus neutralisation). The high prevalence of SEOV in both sites and the severity of disease in the pet rat owners, suggests that SEOV in pet rats poses a greater public health risk than previously considered, particularly amongst those who handle rats.

Arboviruses

In collaboration with PHE, a study was carried out to understand more of mosquito species diversity, their host predilections and their potential as reservoirs and vectors of viral disease. Blood-fed female mosquitoes (n=134) were collected from sites in southern England and identified based on morphological criteria. Two species, *Anopheles maculipennis s.l.* and *Culex pipiens*, could not be identified morphologically. In total, we positively identified the blood meal in 59 specimens (44%), with the main hosts being cow, human, dog, European rabbit (*Oryctolagus cuniculus*), great tit (*Parus major*), magpie (*Pica pica*), blackbird (*Turdus merula*), and barn swallow (*Hirundo rustica*). Analysis of ITS2 and COI barcoding region sequences in *Anopheles maculipennis* revealed the presence of two species, *An. atroparvus* (33 specimens) and *An. messae* (7 specimens), with one sample being mis-identified by morphological means. The ITS2

and COI revealed that specimens identified as *Cx. pipiens*/*Cx. torrentium* were all *Cx. pipiens f. pipiens*. This study greatly expands the known host vertebrate range of mosquitoes in the UK. Evidence of feeding on both resident and migratory bird species by potential arbovirus vector species including *Cx. pipiens f. pipiens* and *Cx. modestus* indicates the potential for enzootic transmission of an introduced arbovirus between migratory and local bird species by local mosquito species.

Following the report of a cluster of cases of babesiosis in dogs from Essex with no history of foreign travel, a tick removed from one of the dogs was investigated for the presence of babesia. Based on morphology the tick was identified as an adult male *Dermacentor reticulatus*, a species that has been reported from a number of locations in England and Wales, including Essex. A DNA sample was prepared from the tick and sequence obtained using primers specific for a partial fragment of the *COI* gene. The sequence generated was 100% identical to existing *D. reticulatus* sequences. The same DNA sample was also tested by PCR using pan-piroplasm primers directed against the 18s ribosomal gene. An amplicon was generated of the correct size and sequencing confirmed that this was 100% identical to *Babesia canis* and distinct from other Babesia species that infect dogs including *B. vogeli*, *B. rossi* and *B. gibsoni*.

Following outbreaks of bluetongue in France in 2016, a cross-agency bulk milk survey was undertaken to determine the background level of bluetongue antibodies in cattle dairy herds in the South East and East of England to assess if this method could be used for detection of an incursion of bluetongue into the UK. This was followed up by a telephone survey by APHA Field Services of a small number of tested farms to explore if historical vaccination against bluetongue status was associated with presence of antibodies in the bulk milk. Both surveys were submitted to policy customers to confirm that bulk milk testing was not currently an appropriate method for early detection of bluetongue incursion in the UK.

2.2 PORTFOLIO: Bacterial Diseases and Food Safety

Our strategy is aimed at providing scientific evidence, assurance and biosecurity advice to Government; to enable effective control of exotic bacterial disease threats to livestock, and to protect public health through control of zoonotic diseases, chemical toxicity and antimicrobial resistance in livestock and the food chain.

Highlights

- APHA *Brucella* multilocus typing scheme being widely used globally
- Patents filed for novel *Brucella* DIVA vaccine and diagnostic technology
- New test introduced for porcine brucellosis to resolve non-negative serological reactors
- Intervention studies demonstrated sow *Salmonella* vaccination; enhanced cleaning & disinfection; and movement of outdoor pigs to new sites significantly reduce *Salmonella* prevalence in pigs
- Successful interventions to control emerging threats posed by high priority *Salmonella* serovars including multi-drug resistant *S. Kentucky* that has spread widely elsewhere in Europe
- Quantitative *Campylobacter* monitoring in broiler caeca and carcasses demonstrated a reduction in carcass contamination in 2016. Cross-contamination between slaughter batches is minimal and some abattoirs are more effectively controlling contamination.
- Scientific evidence used to assess threat posed by novel transferable colistin resistance in enteric bacteria in GB pigs with implications for the use of colistin as antimicrobial therapy in food animals.

- APHA contributed evidence and expertise to expert groups nationally and internationally and communicated science widely including via a wide range of scientific publications.

Exotic Bacterial Diseases

We provide a unique national capability focused on assurance of disease freedom, contingency planning and emergency response capability. Research is focused around our International Reference Centre functions and includes development of diagnostics, pathogen characterization and international partnerships to sustain skills, and support control efforts in other countries, reducing the global threat.

A new serodiagnostic assay for the detection of porcine brucellosis using a rough lipopolysaccharide antigen developed through APHA research is being used to assist resolution of non-negative serological reactions. The success of this assay underpins the achievements of our research and the benefits delivered to policy in reducing the impact of non-negative serological reactors.

APHA, in collaboration with the University of Alberta, has developed ELISA assays using synthetic oligosaccharide antigens that are based on the key immunodominant structures of *Brucella abortus*, *melitensis* and *suis*. Some of these structures have proven to be highly effective serodiagnostic antigens and they are generating considerable commercial interest. This knowledge was successfully applied to complete a *Brucella* vaccine development project funded by the Bill & Melinda Gates Foundation that enabled the development of a new DIVA (Differentiation of Infected from Vaccinated Animals) vaccine technology, paving the way towards resolution of many of the outstanding issues of brucellosis control. Patents for the vaccine and diagnostic technology have been filed so that further investment in these developments can be protected. The proposed DIVA diagnostics are also those that best address our national requirement as they offer improved specificity in the serodiagnosis of bovine brucellosis

The Brucellosis team has provided on-location or remote technical support to a number of countries in Africa and Central Asia, supporting implementation of locally adapted, sustainable programs to understand and reduce the prevalence of brucellosis. These activities, funded variously as part of BBSRC-led initiatives including the Zoonoses in Emerging Livestock Systems initiative as well as other government department programs, help maintain expertise as well as contributing to reducing the global disease threat.

We have published an improved multilocus typing (MLST) scheme and applied it to understanding the global population structure of *Brucella* in the most comprehensive study of its type to date (Whatmore et al., 2016). A website has been developed hosting all APHA data to allow others to interrogate the data and, as the APHA MLST tool has become widely used globally, to deposit their own data (<http://pubmlst.org/brucella/>). APHA has contributed to knowledge on the ongoing expansion of the *Brucella* genus, formally describing another new species, *Brucella vulpis*, isolated from red foxes (Scholz et al., 2016a) and further describing novel *Brucella* isolates apparently widely distributed in exotic frog species (Scholz et al., 2016b). Such work ensures APHA maintains involvement in global developments and can better assess potential implications of emerging *Brucella* for animal health in the UK.

We carried out a quantitative import risk assessment to consider the impact of removing the pre-movement test for brucellosis for cattle from Northern Ireland on the risk of introduction of the disease into GB. As Northern Ireland is now Officially Brucellosis Free (OBF), it was concluded that there is currently a very low probability of importing brucellosis into GB from Northern Ireland

and removal of pre-export testing would have no effect on this probability. This evidence led to a policy decision to discontinue pre-movement testing.

A review of approaches to molecular confirmatory testing for glanders has identified some improved assays that are currently being validated before implementation in the APHA diagnostic repertoire.

A three year research project on exotic mycoplasma diseases that are an economic and welfare threat to the UK farming industry was concluded. The contagious agalactia causative organism present in mainland Europe that poses the greatest risk to the UK is *Mycoplasma agalactiae* (*Ma*).

A previously developed molecular typing method was applied to *Ma* disease situations in Sicily and highlighted that related molecular types dominate infections in a geographic region and that reduced susceptibility to antimicrobials used on-farm can develop. A molecular method that will determine if mycoplasmas are present in a biofilm state has also been developed to help ensure appropriate treatment.

We evaluated the current available tests for contagious caprine pleuropneumonia (CCPP) and developed a new molecular test (Recombinase Polymerase Amplification) that can be further developed as a field test and investigated proteins that may help develop improved antibody tests. During the course of the project a commercial test (CCPP cELISA) was modified and re-launched, showing good performance on comparative analysis.

Endemic Zoonoses and Food Safety

This area is focused on control of public health risks with a major role in the national control of *Salmonella* in livestock. The research programme and National Control Programme (NCP) have successfully controlled serovars of high public health impact in chickens and turkeys and resulted in a large reduction in human disease, but continued effort is needed to maintain this situation and to contain potentially epidemic drug resistant non-resident strains as well as controlling *Salmonella* in other livestock.

Salmonella Enteritidis is now rarely reported in chickens following the success of the NCP. However, following a large outbreak of *Salmonella* Enteritidis (SE) PT21 (phage type) and related PTs, predominantly PT35, that occurred in broiler flocks in 2015 further epidemiological analyses using whole genome sequencing (WGS) have investigated the international dissemination and possible origin of the organism, which is thought to have been imported hatching eggs. WGS was successfully used to investigate a number of other *Salmonella* outbreaks; including trace-back of eggs from a farm source potentially implicated in two *S. Enteritidis* PT4 outbreaks and a human outbreak of *S. Enteritidis* PT8, thought to be linked with importation of table eggs from Eastern Europe. This facilitated trace-back inquiries in an egg-supplying country.

Other incident responses included investigation and control of *Salmonella* Kentucky sequence type 198 with multi-drug resistance, including high-level fluoroquinolone resistance, on a broiler farm. This African strain of *Salmonella* has spread widely in Europe, and is a cause for concern. A case of MDR *S. Oslo*, with resistance to most regularly used antimicrobials, including third generation cephalosporins, was investigated in equines. Transfer of MDR plasmids from *E. coli* to *Salmonella* was identified and remedial action taken. There appears to be an increasing trend in penta-resistant *S. Typhimurium* DT104. This is being investigated to identify possible sources and assess and mitigate risk of spread.

APHA is developing methods for reference laboratory typing of *Salmonella* in animals, animal feeds and livestock production environment using WGS-based serotyping and downstream molecular analyses. The ambition is to generate and allow real-time sharing and use of WGS data for outbreak identification and investigation across the veterinary, food and human sectors and between countries. Other WGS-based work is exploring the diversity and epidemiological potential of the APHA *Salmonella* strain collection and aims to define future archiving strategies.

The prevalence of *Salmonella* in UK pigs is amongst the highest in Europe. Control programmes are currently focused on abattoir hygiene and testing to demonstrate acceptable standards for control of *Salmonella* at slaughter and in further processing. Reducing the prevalence of highly infected pigs at slaughter contributes to minimising contamination of pig meat, as well as by-products used in raw pet food. Pig farms are also a source of *Salmonella* contamination of the environment and infection of other animal species, including wildlife. To address these risks, research has been undertaken to define the best and most cost-effective control measures on pig farms and motivational communication methods.

An investigation of farms which maintained consistently low prevalence of *Salmonella* in pigs showed that minimal infection was achievable over several years. The low prevalence farms were more likely to apply a number of protective management practices, highlighting the multi-factorial nature of effective *Salmonella* control and demonstrating that control is economically feasible, given appropriate industry support.

Three interventions were trialled on pig farms: the use of sow *Salmonella* vaccination; enhanced cleaning and disinfection of finisher buildings; and the movement of outdoor pigs to new sites. All trials demonstrated a significant reduction in *Salmonella* prevalence from the interventions but results varied between farms and *Salmonella* was rarely reduced to a low level (<5% positive samples). The introduction of *Salmonella*-positive pigs onto farms undermines control strategies and improved control within the pig breeding pyramid is required, which will be researched in a new project. A review of feeding strategies found strong evidence that specific feed types and ingredients can assist in *Salmonella* control, although there can be a negative impact on growth efficiency.

A cost-benefit analysis of five *Salmonella* control strategies found that even under the best case scenarios (full implementation of effective intervention across the UK), the estimated cost of implementing any intervention currently exceeds the estimated financial benefit to pig productivity and human health. Other factors, not considered in the analysis, may suggest additional benefits, such as synergistic interventions, dissemination of *Salmonella* from pigs, control of other diseases and targeting control measures.

Pig movement data were analysed to identify farms and other locations (e.g. markets) with greater risks of introducing or spreading *Salmonella* that could be targeted for enhanced surveillance. A between-farm pig transmission model was designed to test interventions, such as reducing the number of pig suppliers, which are impractical to field test.

The study provided evidence of the effectiveness of a number of on-farm controls and added to the toolbox from which farmers and vets can select the most relevant package for their production system. Farmers noted that a lack of information about their *Salmonella* status may hamper their ability to monitor improvements and discourage them from applying controls, so reintroduction of a surveillance scheme would be beneficial. However, it is unlikely that farm-level controls will be cost-efficient for farmers and financial incentives may be needed for significant progress in tackling *Salmonella* in primary pig production in the absence of regulatory controls.

The study included a large and successful knowledge transfer element, with industry roadshows, advisory leaflets, articles and scientific publications completed. An educational tool was designed to assess farmers' knowledge of biosecurity, relevant to *Salmonella* control in pigs, to support active learning. The developed tool will be incorporated in an on-line system by the pig industry levy body to disseminate information on a platform that has previously been successful at engaging farmers. This was successfully trialled at producer roadshows and the Pig and Poultry Fair.

Evidence from the study fed into a working group drafting an OIE Terrestrial Animal Health Code for *Salmonella* control in pigs chaired by APHA, along with a similar cattle code, which are planned to be published in 2017.

A series of papers was published in a special issue of the journal Risk Analysis on the Quantitative Microbiological Risk Assessment work that was undertaken for EFSA (report published by EFSA) to provide scientific evidence for the consideration of EU policy to control *Salmonella* in pigs; <http://onlinelibrary.wiley.com/doi/10.1111/risa.2016.36.issue-3/issuetoc>. The study informed decisions on current *Salmonella* control policy in pigs at EU level.

A new poultry research project is investigating resident sources of *Salmonella* within feed mills, hatcheries and broiler farms. A key finding so far is that improved temperature and condensation control in several feed mills implemented in recent years has had a substantial impact on resident contamination. In hatcheries, the proposed formaldehyde ban in Europe will necessitate development of alternative rapid hatcher incubator decontamination approaches.

A paper (Petrovska et al., 2016) was published describing results of a collaborative research project with the Sanger Institute, IFR, PHE and IZSVe on the microevolution of monophasic *S. Typhimurium*. Comparative WGS and phylogenomic analysis of isolates from UK and Italy since the emergence of this clonal complex in 2005/6 showed that the isolates formed a single clade, distinct from recent monophasic epidemic clones previously described in North America and Spain. The UK isolates showed a novel genomic island encoding resistance to heavy metals and a composite transposon encoding antimicrobial drug resistance genes which may have contributed to epidemiologic success. The findings indicated that the current monophasic *S. Typhimurium* clone in the UK arose recently and subsequent microevolution within a short timescale has resulted in considerable genotypic variation affecting antigens, virulence factors, and resistance loci. The epidemiology of *Salmonella Typhimurium* has been characterized by successive waves of dominant multidrug-resistant clones and understanding the molecular basis for the success of epidemic clones has implications for the surveillance and management of the pathogen.

Campylobacter control in chickens is a high priority due to the large human disease burden. APHA provides national monitoring of broiler chickens at slaughter on behalf of FSA and is seeking to apply similar research approaches to develop practical on-farm controls that have proved successful for *Salmonella*.

APHA has been carrying out quantitative *Campylobacter* monitoring in broiler caeca and carcasses at abattoirs to measure changes in *Campylobacter* load in response to implementation of interventions and progress towards a voluntary target to reduce highly contaminated carcasses from 27% to 10%.

The average prevalence of highly contaminated carcasses from 2012-2015 was 28.5%. Significant evidence of a reduction was noted in final 10-months of monitoring (24%) and may have been influenced by the removal of neck-skin from carcasses prior to sampling. The reduction in carcass contamination continued in 2016. Multivariate analysis identified variables relating to farm

production, transport and abattoir processing practices associated with highly contaminated carcasses, providing evidence for best practice.

The prevalence of *Campylobacter* in flocks at slaughter was 74.8% and no significant reduction in the prevalence was observed in 2012-15. The level of colonisation in flocks is strongly correlated with *Campylobacter* contamination on the carcasses produced, and the contribution of cross-contamination between positive and negative slaughter batches is minimal. Mathematical comparisons of the data from caecal contents and carcasses within batches demonstrated that some abattoirs are significantly more effective at controlling carcass contamination than others.

A MALDI-ToF test (accredited to ISO 17025) for confirmation and identification of *Campylobacter jejuni* and *Campylobacter coli* from poultry samples has been introduced, reducing the cost of testing in the survey.

An APHA study published in 2016 demonstrated that 95% of *Campylobacter*-positive flocks at slaughter are colonised with *C. jejuni*, which is the predominant species associated with human disease, however 33% of positive flocks are co-colonised with *C. coli* (Rodgers et al., 2016).

An earlier study has shown that while some sequence types (STs) of *Campylobacter* are widely distributed within and among farms and flocks, analysis of molecular variance (AMOVA) revealed a high degree of genetic diversity among farms for *C. jejuni*, where farm effects accounted for 70.5% of variance, and among flocks from the same farm (9.9% of variance for *C. jejuni* and 64.1% for *C. coli*) demonstrating the complexity of the population structure of *Campylobacter* in broiler production. However, we have provided evidence (Vidal et al., 2016) that supports meta-analysis of studies on *C. jejuni* populations even when laboratory and sampling methods are not identical.

APHA maintains a watching brief on a wide range of other zoonoses with a focus on risk assessment and outbreak control and integrated delivery, particularly with public health bodies. We provide a national veterinary capability to investigate and respond to potential public health threats linked to animal infections or toxins, led by veterinary and microbiology specialists and supported by epidemiologists. Multi-agency responses to public health incidents in 2016 included investigations of the involvement of family pet dogs in toxigenic *Corynebacterium ulcerans* infections in humans and a high profile outbreak of cryptosporidiosis in agricultural students in Wales.

We have reviewed animal diagnostics for emerging non-O157 strains of *E. coli* and have developed a sensitive test for *E. coli* O55, based on the IMS method used for detection of *E. coli* O157.

Our experts contributed to an ACMSF report on the microbiological risk from shell eggs and their products, which showed major improvements in the safety of UK eggs (<https://www.food.gov.uk/sites/default/files/acmsf-egg-reportv1.pdf>).

Internationally, our experts reviewed the EFSA Community Summary Report (CSR) on *Salmonella* serovars and their trends (<http://ecdc.europa.eu/en/publications/Publications/zoonoses-trends-sources-EU-summary-report-2015.pdf>) on behalf of the EFSA Biohazards panel. APHA expertise, publications and data also contributed to a number of EFSA scientific opinions including those on the risk of use of waste milk containing antibiotics for calves and an ongoing opinion on zoonotic Hepatitis E, as well as three detailed EFSA factsheets on notifiable *Salmonella* serovars. Updates were provided for several chapters of the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals <http://www.oie.int/en/international-standard-setting/terrestrial-manual/access->

[online](http://www.oie.int/international-standard-setting/terrestrial-code/access-online/) and the Terrestrial Animal Health Code <http://www.oie.int/international-standard-setting/terrestrial-code/access-online/>.

APHA experts contributed to several training sessions across Europe as part of the EC Better training for safer food (BTSF) initiative, and to invited lectures and webinars on food safety.

Disinfectant Approval Testing and Farm Disinfection

Laboratory and field trials investigated the effectiveness of disinfectant products against *Salmonella*, due to the importance of disinfection in breaking the cycle of infection between batches of pigs. Glutaraldehyde-based products were the most effective for a number of on-farm scenarios, particularly surface disinfection. Chlorocresol-based products were most suitable for boot dips because of their stability and rapid action in a faecally-contaminated liquid environment. Similar findings were observed for Shiga-toxicogenic *E. coli* (STEC).

Knowledge acquired from the laboratory and field trials with disinfectants have informed the development of industry information leaflets to educate farmers on the key issues regarding cleaning and disinfection.

Antimicrobial Resistance

Antimicrobial resistance (AMR) is recognised as an emerging issue in the National Risk Register for Civil Emergencies. We are at the frontline of AMR surveillance in GB livestock and key priorities are to maintain this monitoring evidence stream and provide statutory data for EU requirements.

Following detection of a novel antibiotic resistance in enteric bacteria from pigs, we have investigated the mechanism of the identified resistance to colistin (a last line human antibiotic) and its prevalence in the food animal population. This included large scale screening of archived material, primarily from pigs, for evidence of wider distribution of the plasmid mediated colistin resistance gene (*mcr1*) in *Escherichia coli* to put the finding in context. The results suggest dissemination of resistance through different horizontally transferrable elements, which may account for its global dissemination. Occurrence of *mcr-1 E. coli* in caeca from healthy pigs at slaughter from unique farms in GB in 2015 was found to be 0.6% (95% CI 0%–1.5%) suggesting *mcr-1* is currently uncommon in *E. coli* from pigs in GB. A high sequence similarity was found between *mcr-1* plasmid draft genomes in the pig *E. coli* and plasmids found in human and livestock isolates globally and this requires further investigation to understand the full implications. A previous quantitative risk assessment for *Salmonella* in pigs was modified to provide insight to the risks of human exposure to *mcr-1 E. coli* via consumption of pork products.

In response to the findings, the VMD in conjunction with other agencies, including PHE, assessed the implications of colistin resistance for public health ([veterinary medicines](#)). Following the detection of the *mcr-1* gene, the Pig Veterinary Society re-categorised colistin in its [Prescribing Principles for Antimicrobials](#) as an antibiotic of last resort, where use must be supported by susceptibility tests. The surveillance findings, coordinated by the APHA Pig Expert Group, were reported in the Veterinary Record ([Surveillance focus](#)) and the work to characterise the resistant bacteria and the occurrence in GB pigs has been published ([Anjum et al](#), [Duggett et al](#)). APHA has introduced a pre-diffusion test for colistin resistance in Gram negative bacteria from pigs to support practitioners as the standard disc diffusion test is insufficiently robust.

Detailed investigation of two pig herds with colistin-resistant *E. coli* (conferred by *mcr-1*) enabled APHA to comment on several aspects of the emergence of colistin resistance. APHA findings were

submitted to the European Medicines Agency which has [updated advice on the use of colistin products in animals](#), recommending these medicines should only be used as a second line treatment in animals and sales should be minimised to reduce the risk of resistance.

A second type of colistin resistance gene *mcr-2* was detected in *E. coli* from pigs and cattle in Belgium <http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=22525>; and it was reported that the resistance and associated plasmid was more transmissible than the *mcr-1* gene. APHA screened archived WGS data from Gram negative bacteria isolated from pigs for the gene and set up a PCR to enable rapid detection of this new type of colistin resistance. The *mcr-2* gene has not been detected in any *E. coli* isolates.

APHA, in collaboration with PHE, AFBI and Universities of Ghent and Brussels, by assembling and studying a collection of European MRSA isolates, demonstrated likely multiple incursions of MRSA into the UK from different continental sources. The findings underline the importance of good biosecurity and were published in 2016 (Sharma et al. 2016).

As part of EU mandatory monitoring for AMR, APHA undertook testing of caeca from broilers and turkeys at slaughter and retail meat from UK supermarkets and smaller retailers in 2016. Samples were examined for a range of bacteria, including selective culture for ESBL and AmpC-producing *E.coli* in fulfilment of the EU regulations. Similar surveillance of retail pork and beef in 2015 identified a low prevalence of resistance, which compared favourably with results from other European countries.

APHA has been selected to chair the EFSA/ECDC/EMA Group which is producing a Joint Interagency Antimicrobial Consumption and Resistance Analysis (JIACRA) report. The report has been requested by the European Commission and will investigate possible associations between antimicrobial consumption and the occurrence of resistance in both food-producing animals and man in the EU.

We contributed to the national annual surveillance report on the antimicrobial susceptibility of veterinary bacteria (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/571146/UK-VARSS_2015.pdf) and our experts contributed to the analyses of the EU Summary Report on antimicrobial resistance in zoonotic and indicator bacteria (<https://www.efsa.europa.eu/en/efsajournal/pub/4380>).

Our experts participated in an OIE working group to develop a global system to collect antimicrobial sales / usage/ consumption data which was presented at the OIE General Session and is being further developed. An APHA expert was appointed to an EFSA Working Group on AMR and waste milk and a further expert contributed to a joint EFSA/ EMA opinion to reduce overall need for use of antimicrobials (RONAFA).

Toxicology and Chemical Food Safety

We provide advice across government, and to many other external groups, on chemical hazards and toxicology in relation to animal health and food safety. We identify and investigate potential on-farm chemical food safety incidents on behalf of FSA.

Two incidents in quick succession highlighted risks to ruminants from gamebird feed. One incident involved medicated partridge feed being fed on moorland co-grazed by sheep; the second involved medicated pheasant feed to which beef cows and calves had access. Unintended exposure to

medicated feed is unacceptable for several environmental and animal related reasons and, with VMD, advice was provided to veterinary practices and game bird organisations and shoots to remind them of their responsibilities.

A severe incident of polycyclic aromatic hydrocarbon (PAH) toxicity due to exposure to petroleum pitch or coal tar was diagnosed in nursery pigs investigated for lethargy, weakness, ataxia, wasting and which was unresponsive to antimicrobial treatment. Hundreds of deaths occurred. Pigs were moved and a voluntary restriction placed on the group to protect the food chain and allow ingested PAHs to be excreted.

We continue to promote awareness of risks associated with chemical exposures through various means such as teaching at veterinary schools, speaking at events such as BCVA and the London Vet Show and through industry liaison and the provision of guidance material.

2.3 PORTFOLIO: Bovine Tuberculosis

APHA performs surveillance for bovine tuberculosis (bTB) in order to meet legal obligations, demonstrate freedom from disease, and permit international trade. We support the government's statutory obligations via reference laboratory activities, also maintaining our expertise and the appropriateness of our tests and their interpretation. We provide expert advice and consultancy on bTB in support of government policy. We also provide data for epidemiological analysis, including the geographical location of *Mycobacterium bovis* and identify gaps in diagnostic capability and develop new tests where necessary.

APHA maintains a strong and innovative research portfolio on bTB of importance to GB government, in support of policy and in order to maintain competency and up to date knowledge of the disease. In line with the APHA Science Strategy, our research is predominantly applied, translational and customer focussed. The key research activities are focussed around:

- Early and accurate detection of infection and pathogen
- The most effective deployment of existing diagnostic methods, and the development of new ones
- The use of mathematical modelling to help identify optimum control options
- Data collection to track the spread of disease and to monitor progress of disease control
- Epidemiological understanding of the disease from the molecular to the macro level
- Development of intervention tools such as vaccines and improved diagnostic tests.

The applied science is underpinned by more fundamental research of host-pathogen interactions, pathogenesis and disease transmission.

Highlights

- Annual surveillance reports on the epidemiology of bTB in England, Wales and GB published on GOV.UK.
- Report of the incidence of bovine tuberculosis in cattle in 2014-2015 in the areas of Somerset and Gloucestershire exposed to two years of industry-led badger control published on GOV.UK.
- Descriptive analysis of the effect of badger vaccination on the incidence of bovine tuberculosis in cattle published on GOV.UK.
- Report of activities of APHA's OIE reference laboratory for bTB published.

- Version 2 of iBTB released and analysis of its usability, social and technical limitations and challenges submitted for publication.
- Use of whole genome sequencing (WGS) expanded to support specific incidents of epidemiological significance and good progress made on the development of WGS pipeline including collaboration with PHE.
- Significant progress made on the development of a skin test for cattle that detects *M. bovis* infected animals amongst those vaccinated with BCG.
- A bait system for oral delivery of BCG to badgers has been developed that has been shown to be attractive and palatable to captive badgers and retains viability of BCG under various storage conditions.
- Collaborative studies with Exeter University have indicated the significant impact of demographic processes and kinship on TB persistence in badgers. These findings relate directly to the epidemiological and demographic responses of badger populations to management interventions such as culling and vaccination.
- APHA contributed evidence and expertise to expert groups nationally and internationally and communicated science widely including via a wide range of scientific publications and reports published on GOV.UK.

Epidemiology, risk analysis and data sciences

A new format annual report on the epidemiology of bTB in England was published on GOV.UK (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/549062/tb-epidemiology-england-2015.pdf) that now explicitly comments on epidemic behavior in the context of policy and controls and presents individual county reports. An executive summary and boxed summaries at the start of each section have been added to assimilate the detailed information.

The annual TB surveillance report for Wales was delivered to Wales in June (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/548711/tb-epidemiology-england-lra-ec-2015.pdf), and a combined analysis of the epidemiology of bTB in England, Wales and Scotland was used to produce the GB Bovine TB surveillance report for 2015 which was published on GOV.UK in December. (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/569603/tb-gb-surveillance-report-infection-cattle15.pdf). Some major findings in this report were:

- In GB, the rate at which new farms became infected with bTB (incidence) plateaued from 2011 to 2014, but increased slightly in 2015. Within GB, the Edge Area of England largely accounted for this increase, while Scotland remained officially free of bTB, and incidence has decreased in Wales since 2012. There are substantial differences in the behaviour of the epidemic at country, risk area and county level, and likely reasons for changes will differ; these are discussed in the separate Wales and England Epidemiology reports.
- In GB in 2015, over half (52.2%) of breakdowns involved herds which had previously been infected with bTB in the last 36 months (53% in England, 50% in Wales and 10.3% in Scotland). The odds of a recurrent breakdown in herds with a history of bTB were significantly higher than in herds with no bTB history in all three countries. Similarly, herds with a history of bTB had significantly higher odds of an incident in 2015 regardless of herd size, and in both dairy and beef herds, typically with odds about four fold higher. Some herds had multiple repeat infections; 60 herds in England and Wales that were found to be infected in 2015 had experienced three breakdowns in the previous 36 months and one had experienced four. The proportion of herds found to be newly infected, that had a history of bTB in the previous 3 years, has increased steadily in both England and Wales since 2006, rising from 36% to 50% in Wales, and from 42% to 53% in England, in 2015.

AHPA published a report of the incidence of bovine tuberculosis in cattle in 2014-2015 in the areas of Somerset and Gloucestershire exposed to two years of industry-led badger control (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/574290/tb-badger-control-second-year-analysis.pdf). The analysis showed different distributions of bTB incidents in the two intervention areas over time. The incidence rate was lower in the Gloucestershire intervention area than the average rate across its comparison areas (9.2 versus 12.4 respectively), but more similar in the Somerset intervention area to the average rate across its comparison areas (14.0 versus 14.4 respectively) following a decrease in incidence in the Somerset area over the last two years. There were no statistically significant differences in incidence rate between both the combined central intervention areas and their combined comparison areas or between the combined intervention buffers and their combined comparison buffer areas across all reporting periods.

APHA also published a descriptive analysis of the effect of badger vaccination on the incidence of bovine tuberculosis in cattle within the Badger Vaccine Deployment Project (BVDP) area, using observational data (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/548140/bvdp-badger-vaccine-report.pdf). The BVDP study area covered 100 km² in Stroud, Gloucestershire with deployment of BadgerBCG within this area taking place annually between July 2010 and October 2014. The results of the analysis suggest that badger vaccination had no effect on cattle bTB incidence, as demonstrated by the decrease in OTF-W incidence rate in both the BVDP area and the comparison areas since the start of the BVDP. Although these results offer initial information on the situation, the effects reported need to be interpreted cautiously due to the limitations and potential bias and the lack of power associated with having only a single intervention area.

Mid-year reports for bTB epidemiology in low risk and edge areas of England were published on GOV.UK at (<https://www.gov.uk/government/publications/bovine-tb-area-epidemiology-reports-2016>). Key findings were:

- Patterns of disease were similar to the first half of 2015 except in the south-east where there were substantially more, though similar levels to 2014
- Many cases can be traced to purchased infected cattle and occur in beef fattening units
- Breakdowns in Cheshire have notably fewer reactors than previously suggesting earlier disclosure of infection within herds as a result of more frequent testing.

Information bTB (ibTB www.ibtb.co.uk) is our interactive tool mapping bTB outbreaks in England over the previous five years. Version 2 was released this year, which included a Welsh language option of the tool. ibTB is a response to the farming industry's wish to be better informed with regard to local TB risks. The tool allows farmers, vets and the general public to access information on local bTB incidents ('breakdowns') and their status. A paper describing the development of these disease maps in collaboration with researchers at Oxford University and an analysis of its usability amongst vets in England and Wales in collaboration with social science researchers at Cardiff University has been submitted for publication. Results show ibTB scored highly on different measures of usability. However, the trials also revealed a number of social and technical limitations and challenges facing the use of online disease maps. The paper considers the challenges facing disease prevention initiatives.

Laboratory testing

APHA is the national and OIE Reference Laboratory for bTB. The OIE annual report for APHA submitted in 2016 can be found at http://www.oie.int/fileadmin/Home/fr/Our_scientific_expertise/reflabreports/2015/report_48_2015_B

[ovine tuberculosis UNITED KINGDOM.pdf](#). A number of tests are carried out in support of TB control, including gamma interferon testing, *Mycobacterium bovis* culture and camelid serology testing.

Gamma Interferon Testing Delivery - 103,744 tests were carried out in 2016. The Carmarthen gamma interferon testing laboratory passed its UKAS audit in January ensuring that testing could be continued with appropriate accreditations. The expansion of laboratory capacity will also help underpin increased use of gamma interferon testing in both Wales and the high risk areas of England in support of Defra's TB Eradication strategy for England. Private cattle gamma testing was launched in April to support TB control England.

As part of Enhanced Case Management, a large persistently infected dairy herd from Devon was gamma-tested, with 77 positives out of 469 tested. These cattle would have been missed by the skin test, underlining the value of the gamma test in cleaning up long-term problem herds and so removing a continual source of infection.

Culture of *Mycobacterium bovis* - over 2,500 *M. bovis* isolates were obtained from over 10,000 tissues submitted from animals suspected of being infected with *M. bovis*.

Alpaca/Camelid serology tests - these were established at our laboratory in Starcross and 1,674 tests were performed. The major antigen used in these assays, MPB83, was discovered by our TB Research Group in the 1990s. It is one of the major antigens used internationally for serodiagnosis of TB in a wide range of species including badgers, camelids, cattle and man.

Application of supplementary serological testing in farmed red deer - A report has been submitted to the Veterinary Record describing the control and eradication of *M. bovis* infection in a farmed red deer herd following sustained tuberculin testing supplemented with serological testing over a period of two years. This case supports the use of ancillary diagnostic serological tests to speed up the resolution of incidents of bTB caused by *M. bovis* infection in captive deer herds.

***M. bovis* Genotyping** – 4,977 *M. bovis* isolates were genotyped in 2015. *M. bovis* home-range genotype maps were updated with 2011-15 data and a system developed to create automated out-of-homerange alerts to support contact tracing of TB breakdowns caused by cattle movements.

We have developed methods to perform WGS of strains of *M. bovis* directly from stored samples and expanded our use of WGS to support the investigation of specific incidents of epidemiological significance such as human cases, cattle dispersals, badger isolates and TB in pets. We have continued our validation of WGS and developed an algorithm that converts WGS data to conventional genotype thus allowing linking of WGS to legacy genotyping data and the maintenance of current homerange analysis.

APHA have been working closely with PHE to develop a WGS analytical pipeline that is able to incorporate data from both human and animal *M. bovis* isolates to improve the investigation of TB zoonoses.

Cattle vaccines and diagnostics

Field surveillance of British cattle using the single intradermal comparative cervical tuberculin (SICCT) test shows a higher incidence rate of bTB in dairy compared to beef herds, but a lower probability of post-mortem examination confirmed (PMC) *M. bovis* infection in dairy herds. A cross-

sectional study was conducted to compare animal level differences in bTB detection between dairy and non-dairy cattle in Great Britain. During the period from 2002 to 2005, 200 (41% dairy) reactors in the SICCT test (standard interpretation) were randomly selected, and 200 in-contact cattle (43% dairy) were purposively selected from bTB-infected herds. Gamma interferon responses in blood to bovine and avian purified protein derivative (PPD), and early secretory antigen target 6 kDa and culture filtrate protein 10 (ESAT-6/CFP10), were measured. The post-mortem examination included gross pathological examination, mycobacterial culture and histopathology. Highlights from the findings of this study published in the Veterinary Journal include:

- Dairy reactor cattle in Great Britain are less likely to have *M. bovis* infection confirmed than non-dairy cattle.
- Tuberculin-based tests are less predictive of post-mortem confirmed *M. bovis* infection in dairy than in non-dairy cattle.
- Defined antigen interferon- γ blood tests may be more specific for *M. bovis* infection than tuberculin-based tests.

Accurately identifying *M. bovis*-infected cattle is critical for bovine tuberculosis prevention and control. One method for identifying infected cattle is an OIE accredited ELISA developed by IDEXX laboratories, which detects antibodies to two *M. bovis* proteins, MPB70 and MPB83. The assay's sensitivity varies by geographic region, with sensitivities of 77%, 45%, and 9% in bovine serum samples from the United Kingdom (n = 126), the United States (n = 146), and Mexico (n = 128), respectively. APHA was part of an international collaboration established to address the hypothesis that geographically-biased sequence variation in *mpb70* and *mpb83*, or in the genes that regulate their expression (*sigK* and *rskA*), may explain these differing sensitivities. This hypothesis was tested by comparing the sequences of these four genes in 455 *M. bovis* strains isolated from cattle in the aforementioned countries. For each gene, a single, common sequence was identified in most genomes of the *M. bovis* strains collected in all three countries. Twelve of the 455 strains were isolated from infected cattle for which the IDEXX ELISA was also performed. Five of the seven ELISA-positive genomes and three of the five ELISA-negative genomes contained the most common sequence of all four genes. Thus, sequence variation in *mpb70*, *mpb83*, *sigK*, and *rskA* does not explain the geographic disparities in IDEXX ELISA sensitivity.

The development of improved vaccines for cattle forms part of the Government's comprehensive eradication strategy for bTB. To enable BCG vaccination to be used alongside conventional test and slaughter control policy, a BCG compatible DIVA test (a test that Detects Infected among Vaccinated Animals) is required. During previous projects, DIVA skin test (DST) reagents based on recombinant proteins of antigens not recognized by animals vaccinated with BCG have been developed. Experimental work this year concentrated on the further evaluation of this DIVA skin test to demonstrate sufficient specificity to warrant taking a DIVA test forward into field trials. To date experimental work has demonstrated 100% specificity for the DIVA skin test reagents which meets this gating criteria. Experiments conducted at APHA also showed that repeat injection of the DIVA skin test did not give a positive skin test response in BCG vaccinated calves. This data is also an important component of the data set required for OIE validation of a DIVA skin test.

A number of scientists at APHA made important contributions (including chairing the groups) to a number of cattle vaccine working groups tasked by Defra and Welsh Government to design field trials to obtain a Marketing Authorization (MA) for cattle BCG and OIE validation and an MA for the associated DIVA test. These reports formed important components of an evidence dossier to support decision making on the future of cattle vaccine and DIVA test development in GB.

A number of papers were published by APHA scientists describing aspects of the immune response associated with an enhanced protection against *M. bovis* infection following vaccination (see section 8 for more details).

Work was successfully completed on a commercial contract with Serotec to validate and characterize their anti-bovine IL-22 monoclonal antibodies. This is important because IL-22 has shown potential as both a predictor of vaccine success and as a correlate of infection.

Genetic Resistance of Cattle to bTB

Our data on cattle location and TB status was supplied to the Roslin Institute who in collaboration with University of Edinburgh and Scotland's Rural College used it to identify a number of genetic signatures associated with TB resistance in cattle that remained unaffected. This work was recently published in the Journal of Dairy Science and describes the findings used to underpin last year's launch of 'TB Advantage'. This is a new genetic index published by AHDB Dairy, to help dairy farmers make informed decisions to breed cows that have an improved resistance to bTB. Initially, the TB Advantage will only be available for the Holstein breed, but work is under way to establish if the index can be extended to other dairy and beef breeds, in the longer term.

Badger vaccines and diagnostics

A bait system for oral delivery of BCG to badgers has been developed that has been shown to be attractive and palatable to captive badgers and retains viability of BCG under various storage conditions. The findings have been accepted for publication in *Vaccine*.

Results from the most recent oral BCG vaccination experiment failed to show a statistically significant level of protection against experimental challenge of badgers with *M. bovis*. A systematic analysis of all the oral BCG vaccination experiments in badgers revealed that the most plausible explanation for the variation in protective effect of oral BCG vaccination in badgers is that protection requires a threshold dose of BCG below which animals are not protected against *M. bovis* infection. Consequently work has concentrated on producing high titres of BCG in order to test this hypothesis.

Collaboration between APHA and PHE Porton has resulted in the growth of BCG in fermenters resulting in the production of fermenter grown seed stock cultures of BCG which will be used produce the high levels of BCG required for the development and testing of an oral BCG vaccine for use in badgers.

Wildlife

Work of APHA's National Wildlife Management Centre (NWMC) included collaboration with academic partners to analyse data derived from the unique badger capture-mark-recapture study at Woodchester Park. Publications emerged from an RVC collaboration to use combined diagnostic test results from captured badgers to explore the development of probabilistic approaches to determining infection status. This study has laid the foundations for future interpretation of diagnostic test results from this study population and potentially others.

Collaborative studentships and post-docs with Exeter University yielded further outputs from the Woodchester Park database indicating the significant impact of demographic processes and kinship on TB persistence in badgers. These findings relate directly to the epidemiological and

demographic responses of badger populations to management interventions such as culling and vaccination.

The last year saw the conclusion of two significant field projects, one investigating the impact of small scale culling on badger social networks (NERC funded) and the other using a novel genotyping approach to estimate the proportion of animals vaccinated with injectable BCG in the Intensive Action Area in Wales (Welsh Government funding). In both cases analysis of the data is ongoing and results will be disseminated to policy colleagues given their clear links to TB control interventions. Other policy-facing work during the last year has included the provision of advice and modelling outputs to DAERA-NI on selective and non-selective culling scenarios, support for Defra TB policy initiatives on herd biosecurity and the estimation of badger numbers in intervention areas, and an assessment of the accuracy of farmer-led surveys for badger activity.

Understanding *M. bovis* Zoonosis in Developing Countries

We have been collaborating with researchers from Ethiopia and the UK to understand the risk pathways for *M. bovis* infection in cattle and humans in Ethiopia, a high tuberculosis burden country, which reports one of the highest incidence rates of extra-pulmonary TB dominated by cervical lymphadenitis (TBLN) and to provide evidence to the Ethiopian Government to develop effective interventions for TB control. This work has been ongoing for 13 years and has been funded by the Wellcome Trust, DIFD, The Bill and Melinda Gates Foundation and the BBSRC and DIFD through the recent ZELS initiative. The latter proposal is a collaborative project lead by Cambridge University and builds on our previous work. A Bill and Melinda Gates/DfID Foundation grant to develop a BCG challenge model and conduct transmission challenge experiment in Ethiopia has been extended to continue exciting work on host biomarkers to predict if a cow can be vaccinated successfully with BCG before the actual vaccination has taken place.

APHA has also played a leading role in putting together an international consortium led by Penn State University to evaluate the role BCG vaccination and DIVA skin testing could play in the control of bovine TB in India. This proposal arose as a direct result of requirements identified at the Bill and Melinda Gates Foundation-Sponsored Workshop on 'Accelerating bTB Control in Developing Countries' that we highlighted in last year's report. The proposal has now passed the major gateway for funding by the Bill and Melinda Gates Foundation and we will now be developing a detailed project plan for this work in conjunction with our international partners and the Bill and Melinda Gates Foundation.

2.4 PORTFOLIO: Plant and Bee Health

UK plant and bee health services are delivered in an integrated manner using skills from the GB Government policy teams (the Chief Plant Health Officer sits in Defra), with input from our devolved authorities. APHA supports this for England and Wales and is supported by Fera's diagnostic laboratories based at Sand Hutton in North Yorkshire. Within APHA delivery comes from the Plant Health & Seeds Inspectorate (PHSI), Plant Varieties & Seeds (PVS) team, the Genetic Modification Inspectorate (GMI) and the National Bee Unit (NBU). In doing so they collectively help protect the country's plants and bees by providing world class inspection, quarantine and certification services. They do this by providing surveillance, testing, training and outreach awareness campaigns for existing, new and emerging EU quarantine pests and diseases and assess GMO events and issues as they arise. Further, the PHSI, GMI and NBU collaborate with Fera and others to improve capability of front line staff, using new technologies to provide rapid and effective field identification and to further understand epidemiological and biological aspects of plant and bee pests and disease. The work also helps contingency planning for future outbreaks by raising awareness of biosecurity and communicating science to UK stakeholders, the general public, government and non-government organisations and inspectorate services

throughout Europe. The latter includes active involvement in the EU Better Training for Safer Food programme.

Plant Health Imports

PHSI operate at 20 points of entry with some, including Heathrow and Gatwick, having 365 day cover. Most activities are performed to meet EU statutory requirements; however others are to meet wider plant health biosecurity threats such as against new and emerging pests and diseases. Strong links are also maintained and developed with other regulators operating at our borders including customs.

- This year a total of 41,127 inspections were carried out on controlled plant material entering the UK (a 7% increase on 2015) and failed 336 consignments as a result of the plant health check (0.8% failure rate of those inspected) and 48 failure (0.05%) following document checks. A further 9,086 inspections were carried out on non-controlled material.

Certification

Inland PHSI maintained another prolific year certifying domestic propagating stocks to ensure they meet domestic and international standards. For example:

- Seed potatoes.
 - 2016 continued a 10 year trend of expansion of the Seed Potato Classification Scheme (SPCS). Area entered was up 7% at 3,566 Ha, and a 6% increase in the number of stocks entered to 1,091 stocks. Much of this expansion is in Yorkshire where 60% of production area is now centred.
 - The number of stocks downgraded was up (293) compared with the previous season (145), due to the presence of bacterial “blackleg” (*Pectobacterium atrosepticum*) and levels in the inspection area.

Exports

To enable the international movement of plants, planting material and plant products PHSI issued over 13,000 phytosanitary certificates for England & Wales (similar to 2015 figures).

Plant Passporting

This EU scheme is a cornerstone of European plant health biosecurity enabling the free movement of regulated plant material around the EU. It is based on monitoring of material entering and moving through the scheme. PHSI on behalf of Defra oversee this scheme in England and Wales.

- The number of registered plant pass-porters rose from 750 to over 800 in 2016. This is primarily due more growers and traders having to be registered to meet new EU emergency measures for controlling the spread of the quarantine bacterial plant pathogen *Xylella fastidiosa*.

Surveillance and Action

Inland PHSI continued to perform a wide range of activities looking for and dealing with quarantine pests and diseases.

- EU and Defra commissioned surveys were performed including: 7,174 inspections for *Phytophthora ramorum* and *P. kernoviae*. With 23 new *P. ramorum* outbreak sites identified. Others included looking for potato cyst nematode, Epitrix and *Xylella fastidiosa*.
- Potato brown rot (*Ralstonia solanacearum*) was found *during water sampling* in the Cambridgeshire Fens which will have implication for potato production in the area.
- Red palm weevil (*Rhynchophorus ferrugineus*) larvae were identified in a recently imported palm purchased from a retailer in Essex.
- Over 2,500 inspections were performed looking at 5,640,000 plants/trees of *Prunus* for a range of pests and diseases including the bacterial plant pathogen *Xanthomonas arboricola pv pruni*, nine sites tested positive where quarantine action was taken.
- 2016 surveys for Asian long horn beetle (*Anoplophora glabripennis*) following an outbreak in 2012 in Kent revealed no further findings following extensive monitoring including the use of tree climbers, pheromone traps and sentinel trees.
- Mature trees were found infected with sweet chestnut blight fungus (*Cryphonectria parasitica*) in Devon. Surveillance for this quarantine fungus in the wider environment and trace back activities for its source are on-going. This is the first *Cryphonectria parasitica* outbreak in mature trees in England

Engagement

Public Engagement Events

The principal message of these shows was to raise awareness of plant pest and disease to the general public and the work UK government is doing alongside the Plant Health and Seeds Inspectorate.

- Four targeted shows including RHS Cardiff, which was funded by Welsh Government. A “bug Hunt” at Yorkshire Arboretum to engage children in biosecurity and citizen science activities.
- Publication of a featured biosecurity article in RHS The Garden Magazine.

Cross Government Events

- Working with Ministry of Justice and Ministry of Defence training various groups in plant biosecurity good working practice. This enhanced understanding of plant and tree pest and disease pathways and risks, behavioural change and implementation of plant biosecurity across wider government with ministry’s who have responsibility for very large areas on national estates.

Trade Engagement.

- Eight trade show exhibits each targeting a specific sector of the industry including landscape, horticulture, agriculture and fresh produce. The purpose was raising awareness of plant passporting, tree notification scheme and the responsibility of growers and general plant health awareness.
- Publication of articles in Plant Heritage magazine and British Association of Landscape Institutes magazine.
- Publication of new leaflets, postcards and quarantine inspection cards for use with engagement activities.
- *Xylella* awareness day run for the multiple retailers.
- Presentation and stand at RHS plant collection holders day at RHS Wisley.
- Speakers provided for: PlantNetwork Conference, NFU South East Regional Conference, Plant Heritage Conference, HTA Conference.

Biosecurity Awareness Engagement

- Two professional training events delivered to Society of Garden Designers. Over 70 people attended and 100% of attendees reported an uplift in biosecurity and plant pest and disease knowledge. The events were highly praised by the Society.
- Two professional training events delivered at Barcham Trees to a mixed audience of design and tree professionals.

Conferences

- British Society for Plant Pathology Conference (BSPP).
- Stand at APSE (local government) parks conference.
- Horticultural trade association conference.

Academia

- Gatsby summer school - plant pathology led practical directed at key achievers from over 40 UK universities. The aim was to raise awareness of plant health and encourage students to pursue careers in plant pathology. The practical is rated highest of all the practical activities of the week and many enquiries for internships in plant health are made.
- Grand Challenges in Plant Pathology – Oxford University
 - a) A challenge was set to Doctoral and Post-Doctoral multi-disciplinary students to answer “How do we stem the tide of plant pests and diseases entering and establishing in the UK?” Students were also mentored during the week and presented their conclusions at the end.
 - b) Days training in diagnostic approaches to plant pest and diseases at RHS Wisley gardens.
- Days training in diagnostic approaches to plant pest and diseases at RHS Wisley gardens.
- MSc. in plant pathology – developed through collaboration of PHSI, Fera science Ltd and Harper Adams University. A new Plant health biosecurity module was written and agreed for launch in 2017. Two further PHSI students have enrolled in the course from in 2016

Future Proofing Plant Health Project

- **Origins of Asian long-horned beetles (isotype analysis)** - pilot study highlighted differences in isotope ratios between specimens from different locations, although the results showed significant sources of variation. Further work has been completed but has yielded widely variable results. This is most likely due to the limited amount of testing material. There is uncertainty whether this approach would be viable to ascertain origin, however the work will continue as access to 300 samples of known origin has recently come available..
- **Quality testing of wood under ISPM15 (assurance of treatment)** - review indicated no methods are currently available for monitoring heat treatment of wood. The project has tested chemical and isotope profiling, however results are not consistent and inconclusive, so no further work will be carried out in this area.

Other PHSI projects

Export Enquiry tool - the first phase of this project was to design and publish a tool that inspectors could use to establish what tests are required by law prior to exportation of seed to 3rd Countries was launched successfully. This project has major resource savings as identification of

necessary tests for exporting seeds is now automated. Over the next year, this work will be extended to cover other key commodities with the future aim to launch to the trade.

Unmanned Aerial Vehicle (UAV) – three PHSI have completed official pilot training. Limited trials were carried out to test effectiveness of using UAV to improve efficiencies in bulb inspections, plant passporting and the seed potato classification scheme. With the current UAV and camera system, bulb inspection use appeared most effective of all three trials for use in the field as the resolution of the camera was not suitable for the latter trials. Further trial work will be performed in 2017.

iPads - the use of iPads continues to be extended, with additional apps such as the export enquiry web app, and the CABI crop compendium. Other apps used by inspectorate on a regular basis include QP&D (a quarantine pest and disease database), SOP Finder (to access APHA SOPs), Huddle (a file sharing portal), Tree Alert (Forestry Commission tree pest and disease alert notification app), Plant Finder (Google image finder for plants), iPflanzen (a plant identification tool) and enabling access to eDomero (our specific data entry software).

Soil Associated Italian Potted Trees

Plant Health Risk Group commissioned a survey to analyse the potential risks posed by arthropods and invertebrates introduced in soil associated with large potted trees traded from Italy to the UK. The survey was set up to target large potted trees originating only from Italy. The survey will continue until the end of 2016/17.

Observatree EU Life Project

Further workshops for Observatree volunteers took place in October 2016 across England, Scotland & Wales. These provided hands on field experience, re-enforcement of previous learning, and an opportunity for plant and tree health teams to share expertise and good practice with volunteers.

The Westminster parliamentary reception shared successes of the project and facilitated discussions on next steps to the project once funding comes to an end in September 2017.

Phyto Threats Project

The PHYTO-THREATS project aims to address the risks to UK forest and woodland ecosystems from phytophthora by examining the distribution and diversity of *phytophthoras* in UK plant nursery systems. APHA have encouraged participation of a number of clients for the in depth sampling aspects of this project. The method development and refinement of the sampling methodology protocol has been undertaken at Johnson of Whixley in Yorkshire. It is intended that this will then be used more widely by APHA & SASA to source plant and water samples at trade premises for this metabarcoding project.

Genetic Modification Inspectorate

European Coexistence Bureau (ECoB)

In May 2016 the GM Inspectorate (GMI) joined representatives of 22 Member States and Associated Countries for the final meeting of the Technical Working Group on potatoes, with the aim of agreeing EU-wide guidelines for the coexistence of GM and non-GM potato crops. The GMI contributed to background information on potato biology and cultivation, promoted the UK's position in discussions, and assisted in drafting the best practice document (currently in preparation, Jan 2017). Measures agreed in order to maintain effective segregation (if GM potato is commercialised in the EU) include isolation distances, crop rotation, and volunteer monitoring.

Previously, ECoB has issued best practice guidelines on maize, soya bean and honey production, although the only GMO currently authorised and available for commercial cultivation is MON810 insect-resistant maize. More information on the work of ECoB can be found at <http://ecob.irc.ec.europa.eu/index.html>.

European Enforcement Project

The European Enforcement Project (EEP) is a network of GM Inspectors across the EU that shares ad hoc information and comes together at an annual meeting to share experience and develop best practice. The annual meeting in 2016 was held in Utrecht and the GM Inspectorate presented papers on the practical issues in dealing with an unauthorised environmental release of GMOs and the ongoing development of our approach to contingency planning for GM incidents. The Inspectorate also led break-out sessions demonstrating tools we have developed to aid with managing the risk of adventitious GM presence in seed.

Genome Editing Review Paper

In collaboration with colleagues from the Czech Republic the Inspectorate published a review paper on new genome editing techniques - Tereza Sovová, Gerard Kerins, Kateřina Demnerová and Jaroslava Ovesná (2017) *Genome Editing with Engineered Nucleases in Economically Important Animals and Plants: State of the Art in the Research Pipeline*. *Curr. Issues Mol. Biol.* **21** (2017): 41-62. <http://www.caister.com/cimb/tocs/v21toc.html>

Understanding of these new techniques is important as they are fast replacing “traditional” genetic modification techniques and they present interesting regulatory issues as they challenge the current EU definition of what constitutes [regulated] genetic modification and in certain circumstances may be impossible to detect.

Plant Varieties & Seeds

Variety and Seeds Delivery are based in Cambridge and look after the statutory National Listing and Plant Breeders Rights work for the UK. The decisions on National Listing are made by the National List and Seeds Committee (NLSC) which is chaired by APHA and decisions are made by consensus with the Devolved Administrations, SASA, AFBI and the Welsh Government. APHA also take the lead in EU representation at CPVO for all matters of DUS (Distinctness, Uniformity and Stability) testing in the UK and on the world scale where APHA represent the UK in the Editorial Committee and the Technical Committee of UPOV, Geneva.

We also look after the statutory work for England and Wales for seeds certification and the Seed potato certification Scheme and the Fruit Plant certification scheme.

APHA had a successful audit in 2016 for CPVO Entrustment of all our DUS work. This means that we can exchange reports with any other Entrusted Office in Europe for the species in scope. Seeds marketing had a successful outcome of the new EU plant population experiment with the first certification and marketing of a plant population this year. We also continue with our seeds marketing enforcement work for seed crop quality and have introduced the new EU marketing standards for seed potatoes.

National Bee Unit

The National Bee Unit (NBU) delivers bee health programmes on behalf of Defra and Welsh Government (WG) in England & Wales. It has been involved in the management and control of bee

pests and diseases, along with training and dissemination of information to beekeepers for over 60 years. It is co-ordinate by APHA through the central NBU office based at Sand Hutton in North Yorkshire. Here the work of our 60 home-based bee inspectors is coordinated, who in turn are managed by a National Bee Inspector (NBI) and our Regional Bee Inspector (RBI) network. Their work and that of the central team delivers a national apiary inspection programme and providing consultancy and research services and extensive training and advice to Defra, Welsh Government, The Scottish Government, commercial enterprises and beekeepers. They also work with Fera Science Limited who provide our bee health diagnostics at Sand Hutton as well as on various research programmes. Wider research is also performed by the NBU with other universities and institutes both at home and abroad.

Summary information for the NBU for 2016 is given below and more detailed information can be found on the NBU website BeeBase: www.nationalbeeunit.com).

Apiary inspection programme

In the 2016 season (April-Sept) statutory risk based apiary inspection programme (England and Wales), comprised: 6,075 apiaries, 27,873 colonies. Of these 3,053 apiaries were additionally inspected for exotic threats such as the Small hive beetle *Aethina tumida*, and *Tropilaelaps spp.* Mites under the Exotic Pest Surveillance (EPS) survey.

Diagnostics and research

Molecular typing of both American and European foul brood infection detected during the year was carried out by Fera Science Ltd.

We carried out further development of new range of diagnostic protocols for the Asian hornet, e.g. LAMP and microsatellites /DNA assays were also achieved.

Outbreak management and contingency planning

Two field based two-day contingency exercises for the Small hive beetle (*Aethina tumida*) (Southern Region and North East) were completed.

As part of the Asian hornet (*Vespa velutina*) incursion/outbreak October-November 2016, the nest was found and eradicated. Modelling and genetics information suggests a wider spread and potential undetected population. Plans for 2017 are in place.

Events / public engagement / trade engagement

159 events were delivered in 2016 to 5,661 attending beekeepers. Various workshops/events on the management and detection of honey bee pests and diseases and good colony management around the country but important national events also attended including:

- Tradex bee equipment and appliance show
- British Beekeepers Association Annual Convention
- Welsh Beekeepers Annual Convention
- The National Honey show

Bee press articles / general dissemination

Various advisory and general articles produced for the main bee press journals in the UK during 2015.

- **Bee Craft**
Asian Hornet Identified in Gloucestershire, September 2016, Learner, J.
The History and Biology of a Honeybee Disease Chronic Bee Paralysis, September 2016, Budge, G., Stainton, K.
The Need To Change Comb. Learner, J. July 2016
A Follow Up to the Hive Count. A Big Thank You Learner, J. May 2016
- **BBKA News**
Chronic Bee Paralysis: The History and Biology, Budge, G., Stainton, K., December 2016
Small Hive Beetle Distribution, Brown, M., Learner, J., June 2016
The Effect of Dietary Pollen on the Health and Behaviour of Honeybees, Jones, B., June 2016
Making Sense of the Hive Count, Learner, J. March 2016
- **Bee Farmers Association Journal**
Hygiene and Barrier Management, Learner, J. December 2016
The Effect of Dietary Pollen on the Health and Behaviour of Honey Bees, Jones, B., October 2016
The Arrival of the Asian Hornet, Learner, J., October 2016
Bee Health Professional Development, Morgan, K. June 2016
A Smart Bees Update: Season One. Roberts, K., Learner, J., June 2016
- **Advisory leaflets updated**
Key advisory information updated and available on the public pages of BeeBase
The yellow-legged or Asian hornet (*Vespa velutina*).

2.5 PORTFOLIO: Surveillance Intelligence

APHA's mission is to develop and manage integrated veterinary scanning surveillance activities, and evaluate the effectiveness of the surveillance system, to enable the timely detection, investigation, characterisation, assessment and management of animal-related new and re-emerging threats and associated risks in livestock and wildlife in Great Britain¹. This work is mainly led and coordinated by the APHA Surveillance Intelligence Unit (SIU).

Over recent years, veterinary scanning surveillance in England and Wales has been subject to several reviews, including the independent Surveillance Advisory Group (2012)² and 'Surveillance 2014'³. This resulted in the development of a [new surveillance model](#), placing greater emphasis on

¹ APHA Vet Gateway – Scanning surveillance: <http://ahvla.defra.gov.uk/vet-gateway/surveillance/index.htm>

² Surveillance Advisory Group Final Report, March 2012:
<http://webarchive.nationalarchives.gov.uk/20140707135733/http://www.defra.gov.uk/ahvla-en/files/pub-sag-final-report.pdf>

³ Surveillance 2014 - Changes to the delivery of Veterinary Scanning Surveillance in England and Wales, December 2013:
<http://webarchive.nationalarchives.gov.uk/20140707141417/http://www.defra.gov.uk/ahvla-en/files/surv-changes-delivery.pdf>

shared responsibility and partnership working between government, universities, vets in practice and the livestock industries. This includes partnerships between APHA and non-APHA providers for post-mortem examination (PME) services and sources of animal health information and data.

Our strategic objectives:

- To coordinate activities enabling the timely detection, investigation and characterisation of animal-related new & re-emerging threats (NRTs) to agri-food supply chains, providing actionable intelligence for our customers and stakeholders across Great Britain (GB).
- To develop and maintain an integrated and sustainable 'early warning' scanning surveillance system for animal-related NRTs that delivers required outcomes through partnership between government and industry.
- For APHA to provide impartial, high quality veterinary scientific evidence, expertise and consultancy that supports and informs assessment and decision-making, and adds value to the activities of a wide range of stakeholders within and outwith Government, supported by appropriate levels of expertise.
- To enable the management and mitigation of the risks and impacts arising from animal-related NRTs, by Government and/or the livestock industries.

During 2016 there has been ongoing review, development and implementation of the scanning surveillance network in England and Wales, and associated activities and requirements following on from 'Surveillance 2014'.

Outcomes & Impact during 2016

The work of the SIU and all those working in the physical and virtual networks of expertise and delivery that make up the scanning surveillance system in England and Wales results in the identification, investigation and characterisation of a wide range of NRTs of which 75 were present in GB. We have developed a systematic and standardised method of categorising these NRTs for each of the main livestock species and wildlife (Table 1) and this is coordinated by each of the Species Expert Groups (SEGs).

Information from surveillance partners, horizon-scanning or non-submission data sources detected 64 of the 116 threats (~55%). Of the 75 threats present in GB, a total of 40 (53%) were detected by post-mortem examination (PME) submissions to APHA, SAC-CVS or one of the five non-APHA PME providers. A further 12 threats were detected from analysis of scanning surveillance submissions data or non-PME submissions. Approximately half of all threats detected (53/116) were raised with the Veterinary Risk Group⁴ as either Threats or Points for Information. Summary information that describes the identified threats by species is provided in Table 2, and two specific examples are described below:

- **Cattle:** During 2015 horizon scanning activities by the Cattle Expert Group identified a potential new and emerging threat to the GB cattle industry of a genetic disorder, newly described in Germany, called Cholesterol Deficiency of Holstein cattle (CDH). This gives rise to fatal low levels of cholesterol. In the first quarter of 2016, a case of CDH was identified in through scanning surveillance by APHA Penrith Veterinary Investigation Centre (VIC). The diagnosis of CDH was confirmed by genetic testing in collaboration with the University of

⁴ Anon (2016) Identifying new and re-emerging animal-related threats to the UK. *Veterinary Record* 2016;178:41, available online: <http://veterinaryrecord.bmj.com/content/178/2/41.full.pdf+html>

Liege, Belgium and was reported in the Veterinary Record⁵. Awareness of this new condition was also raised within the veterinary profession and farming industry.

- **Pigs:** The potential disease threats to UK pigs investigated in 2016 included Seneca Valley Virus (SVV). A vesicular manifestation of SVV infection reported in Brazil and the USA is of concern because the lesions closely resemble those caused by notifiable vesicular diseases, most notably Foot and Mouth disease. In collaboration with The Pirbright Institute, the APHA pig disease scanning surveillance project developed a SVV diagnostic PCR test, the methodology of which was then published⁶. The test is primarily for use on vesicular disease report cases once negated for FMD and other notifiable vesicular diseases and will allow early detection of vesicular disease associated with SVV in UK pigs. Another newly detected viral infection investigated as a potential threat in 2016 was atypical porcine pestivirus (APPV). This virus was detected in healthy pigs and in pigs affected with congenital tremor in the USA followed by Germany and the Netherlands. Through practitioner contacts in GB, the Pig Expert Group obtained diagnostic material from a contemporary congenital tremor case in England and Virology, APHA Weybridge established a diagnostic PCR test for APPV. Testing revealed the presence of APPV in both current and archived congenital tremor cases in England suggesting that this virus may be well established in the UK and global pig population and has previously gone undetected, although this needs to be verified. A survey of pig practitioners was undertaken to obtain evidence on the prevalence of the clinical disease in the UK, and determine demand for validated diagnostic tests for disease control and epidemiological investigations. Both the above threats were raised with the Veterinary Risk Group and were the subject of focus articles in the monthly APHA surveillance reports published in the Veterinary Record to raise disease awareness.

The activities and outputs of the SIU, SEGs and APHA scanning surveillance activities encompass a very broad range of people and organisations that exist in the surveillance value chain⁷. Each SEG acts as a focus for veterinary investigation, collaborative surveillance intelligence gathering and analysis in their species, and for disseminating findings within APHA⁸, with SAC, UK government policy officials and CVOs, vets in practice, BVA and the BVA species divisions, universities, the livestock sector groups, NFU and FUW, AHDB and farmers. This leads to action at a range of scales, from industry-wide initiatives to individual farmers and vets adopting health planning and/or disease prevention, treatment or control measures on-farm. During the year this

⁵ Duff, J.P., Passant, S., Wessels, M., Charlier, C., Hateley, G., Irvine, R.M. (2016). Cholesterol deficiency causing calf ill-thrift and diarrhoea. *Veterinary Record* 178, 424, available online: <http://veterinaryrecord.bmj.com/content/178/17/424.3.full.pdf+html>

⁶ Fowler V L, Ransburgh R H, Poulsen E G, Wadsworth J, King D P, Mioulet V, Knowles N J, Williamson S, Liu X, Anderson G A, Fang Y, Bai J (2016). Development of a novel real-time RT-PCR assay to detect Seneca Valley virus-1 associated with emerging cases of vesicular disease in pigs. *Journal of Virological Methods* 239, 34-37, available online: <http://dx.doi.org/10.1016/j.jviromet.2016.10.012>

⁷ Irvine, R.M. (2015) A conceptual study of value chain analysis as a tool for assessing a veterinary surveillance system for poultry in Great Britain. *Agricultural Systems*, Vol.135, pp143-158.

⁸ Within APHA the work of the Veterinary Investigation Centres (VICs) and the Surveillance Laboratory Services Department (SLSD) is integral to NRT detection and investigation through its veterinary diagnostic and laboratory testing roles. Links with other areas of scientific expertise within APHA have been essential in investigating and characterising identified NRTs, specifically: Virology, Bacteriology, Sequencing, Pathology, Antimicrobial Resistance, Toxicology/Food safety, Non-statutory zoonoses, International Diseases Monitoring and Exotic Diseases Teams. Expertise, knowledge and skills from outwith APHA, including vets in practice, academia, policy officials, SAC and industry sector/stakeholder groups also contribute to and benefit from scanning surveillance and NRT detection and investigation.

information has been communicated by a number of different channels to a range of different audiences, including:

- Fortnightly surveillance digest to APHA veterinary and scientific staff, non-APHA PME service partners, SAC-CVS veterinarians and GB policy customers.
- Monthly Threats report to the UK government's Veterinary Risk Group (VRG).
- Veterinary Record monthly surveillance report, continuing the new format developed during 2015⁹ and published online: <http://veterinaryrecord.bmj.com/content/178/2.toc#Surveillance>.
- Quarterly GB Emerging Threats reports, by species, available online: <http://ahvla.defra.gov.uk/vet-gateway/surveillance/reports.htm>.
- Information notes and disease alerts on specific issues to farmers, vets, NFU/FUW, AHDB and livestock industry sector groups.
- Letters and other items in the Veterinary Record.
- Presentations at BVA species division meetings, livestock industry/sector group and other agri-food stakeholder conferences and meetings.
- Peer-reviewed publications and non-peer review articles.
- National and international veterinary and scientific conferences and symposia: presentations & posters.
- Training and CPD meetings – internal and external to APHA, including with non-APHA PME partners.
- The Livestock Demographics and Data Groups (LDDG) for cattle, sheep, pigs and poultry. These groups help to enhance understanding of livestock demographics and data interpretation.
- The Surveillance Intelligence Forums which bring together colleagues involved in surveillance from across APHA to discuss and learn about existing and new surveillance initiatives and methodologies. This cross-cutting initiative helps to improve communication about surveillance across the agency and is being further developed to include a shared knowledge bank for publications and project reports.

In addition to the identified NRTs, the outputs of the scanning surveillance network provide an improved understanding of production-limiting or endemic diseases, as well as threats relating to the emergence of novel or unusual antimicrobial resistance patterns. Taking actions to control endemic diseases also helps protect herds and flocks from exotic and notifiable diseases. Examples include new approaches to the prevention and control of diseases like Porcine Epidemic Diarrhoea and BVD that are being driven forward by vets and industry. The APHA SEGs continues to work closely with the livestock industry sector groups and BVA species divisions to support these efforts.

⁹ Irvine and others (2016). Changes to the monthly APHA disease surveillance report in *Veterinary Record*. *Vet Record*;178:50, available online: <http://veterinaryrecord.bmj.com/content/178/2/50.1.full.pdf+html>

APHA SIU THREATS SUMMARY: JANUARY- DECEMBER 2016 (Cattle, Small Ruminant, Pigs, Avian, Wildlife)

¹SS = scanning surveillance

Type of threat	Number of Threats detected and described	Threats present in GB	Threats detected from ¹ SS data analysis or non PME submissions	Threats detected from ¹ SS PME submissions	Threats detected by horizon scanning, other data source or surveillance partner	Number of Threats raised to UK Veterinary Risk Group (VRG)
Notifiable disease-related	16	5	0	0	16	5
New disease or pathogen	17	12	0	5	12	12
New pathogen variant	9	2	0	1	8	7
New, rare or emerging AMR	5	5	1	3	1	3
Public health-related	14	6	0	2	11	10
Changes in endemic disease trends	33	28	8	18	8	5
Unusual diagnoses or presentations	13	12	1	9	3	5
Other	9	5	2	2	5	6
TOTALS 2016	116	75	12	40	64	53

Table 2: Summary description of animal-related threats detected by APHA Scanning Surveillance and Species Expert Group activities, January - December 2016

Summary Description of Threats: January – December 2016				
Avian	Cattle	Pigs	Small Ruminants	Wildlife
H5 HPAI and LPAI outbreaks in France	Lumpy skin disease emergence and spread in Europe	Recombinant TGEV-PEDV virus strain in historic pig samples, Italy & Germany	Plant poisoning in ewes, due to Galega or 'Goats rue' (<i>Galega officinalis</i>), GB	Usutu virus (USUV) as cause of death in wild birds in France (exotic zoonosis)
Role of <i>E. coli</i> in Salpingitis-Peritonitis, layer/breeder hens, GB	Bluetongue virus (BTV) re-emergence & spread in Europe	African Swine Fever (ASF) extends in Eastern Europe, with spread to Moldova	Horizon scanning and surveillance, Schmallerberg virus in sheep, GB	RHDV to be used as a biological control pathogen in Australia
Astrovirus infection associated with 'White Chicks' syndrome	Lead poisoning in cattle associated with collars	New sapelovirus strain with nervous disease in USA	Emergence and spread of BTV-1 in Europe & risks to UK	<i>Dermacentor reticulatus</i> tick status in the UK and spotted fever rickettsia
IBV-like virus associated with runting and stunting, broiler chicks	Influenza type D in cattle (and pigs)	Porcine haemagglutinating encephalomyelitis virus in China	Re-emergence of Schmallerberg virus in Europe and risk to the UK	New species, <i>Brucella vulpis</i> sp. nov. isolated from wild foxes in Austria
Spread of H5N8 HPAI in Europe & risk to UK	Recrudescence of Schmallerberg virus (SBV), Europe: UK risks	Influenza type D in pigs (and cattle)	Increased detection of paramphistomosis (rumen fluke) in sheep, Ireland	Detection of H5 HPAI clade 2.3.4.4 virus in multiple wild bird species, Russia
H5N8 HPAI in chickens in USA and Korea	Influenza type D in cattle (and pigs)	Transferable betalactamase resistance, putative isolates of <i>Haemophilus parasuis</i>	Suspect macrocyclic lactone (ML) resistant <i>Psoroptes ovis</i> (sheep scab)	First human, locally acquired, case of tick borne encephalitis (TBE) encephalitis, Netherlands
Tetratrichomonosis causing liver granulomas in layers	LA-MRSA in a beef herd in central England	Food safety incident: Coal tar toxicity from tarmac residue, GB	BTV8 – risks to UK sheep population and variable immune status nationally	Tularemia in Australian wildlife detected by molecular testing of archived tissue
Newcastle disease	Haplotype cholesterol deficiency (HCD) – first detection, calf, England	Haemorrhagic bowel syndrome incidents linked with home-mix diets, GB	Alopecia in lambs, GB	Anthrax outbreak in Russia affecting reindeer and a child
Transmissible Viral Proventriculitis, broiler chickens, GB	Abscesses associated with <i>Mycoplasma bovis</i> (caseonecrotic)	Leptospirosis confirmed causing reproductive failure	Epidermolysis bullosae in lambs, GB	First cases of spongiform encephalopathy in free-living European cervids, Norway
Duck circovirus identified in GB for the first time	<i>Aspergillus clavatus</i> mycotoxicosis in cattle	Increase in swine influenza diagnostic rate, GB	Agalactia in newly-lambled ewes	Rabbit Haemorrhagic Disease (RHD) affecting hares (<i>Lepus europeaus</i>) in Southern Europe
Increase in severity and incidence, game bird mycoplasmosis, GB	Increased pneumonia cases in Wales due to <i>Mycoplasma bovis</i>	Seasonal rise in Porcine Reproductive and Respiratory Syndrome	Hepatic encephalopathy caused by haemolytic anaemia, GB	First detection of USUV in the Netherlands in wildlife
Concurrent blackhead and colisepticaemia in organic layer chickens	Use of recycled manure solids as cattle bedding (update)	Porcine circovirus 2 genotyping reveals more PCV2d strains	Exposure of ruminants to gamebird feed - toxicity	Spread of H5N8 HPAI in Europe & risk to UK
H5N1 LPAI confirmed in one broiler breeder flock in Scotland	Exposure of ruminants to gamebird feed - toxicity	Atypical porcine pestivirus associated with congenital tremor type All	Suspect oxyclozanide toxicity	Human psittacosis incidents in Denmark and exposure to wild birds and poultry
Adenovirus Gizzard Erosion in layer chickens and pullets in GB	Scanning surveillance coverage in England-update	Coal tar toxicity concern due to old clay pigeon fragments, GB	Unusual presentation of Orf, GB	<i>Dermacentor reticulatus</i> tick status, UK: canine babesiosis and equine piroplasmosis
ESBL- and AmpC beta-lactamase-producing <i>E. coli</i> in broilers, GB	Increased detection of paramphistomosis (rumen fluke)	Upward trend in the VIDA diagnoses rates of certain pig bacterial diseases, GB	Confirmed diagnoses by APHA of SBV in lambs in England and Wales	<i>Elisabethkingia</i> : likely to be arthropod borne or a zoonotic disease?
Infectious respiratory disease, backyard chicken flocks, GB	Confirmed diagnosis by APHA of SBV in a calf in England (& lamb cases)	Swine dysentery outbreaks in northern England	<i>Salmonella</i> Typhimurium DT104: cluster of cases in Wales	Changes to Lyme disease epidemiology in the UK
"Wooden breast" in broiler chickens		Possible anthelmintic resistance in sows, GB	Recrudescence of SBV in sheep (and calves)	Oral non-BCG vaccine wild species (e.g. boar, deer)
Enterococcal infections in broiler chickens		<i>Streptococcus gallolyticus</i> as an unusual cause of endocarditis in pigs, GB		Increasing populations in scattered locations in southern Scotland of feral wild boar
Adenovirus infections in broiler & layer chickens		Scrotal swelling in boars due to Glässer's disease		Significant expansion of <i>Culex modestus</i> in England - principle WNV vector in Europe

Summary Description of Threats: January – December 2016				
Avian	Cattle	Pigs	Small Ruminants	Wildlife
<i>M.gallisepticum</i> causing respiratory disease in turkeys, chickens, game		Vaccine-like PRRSV strains detected		Importation and first detection of a <i>Hylomma lusitanicum</i> tick into UK on a dog
Management factors affecting mortality in gamebirds		Streptococcal diagnoses show upward trend (VIDA), pigs, GB		Biodiversity threat - ranavirus infection of amphibians
Confirmation of Chicken Proventricular Necrosis Virus in GB		Erysipelas serotyping investigates increased VIDA diagnostic rate in GB pigs		Lead poisoning in water birds from shot with potential for secondary poisoning of people.
H5N8 Highly Pathogenic Avian Influenza outbreaks in GB		Putative beta-lactam resistance in <i>Pasteurella multocida</i>		Biodiversity threat to cetacean species from high levels of PCBs in European coastal waters
Marek's disease impact		Septicaemia in weaners due to <i>Streptococcus suis</i> type 6		RHDV-2 considered to be causing widespread declines in wild rabbits in England & Wales
Novel viruses identified in runting-stunting syndrome (RSS) in broilers		PRRS VIDA diagnoses reach a quarterly high (Oct-Dec 2016)		Snake Fungal Disease (<i>Ophidiomyces ophiodiicola</i>) – first detections in the UK
				European Bat Lyssavirus 2 detected in two bats in England
				Recently identified bacterium <i>Suttonella ornithicola</i> pneumonia, wild passerine sp.

Threats that are shown as shaded in blue are those identified as being outside the UK at the time of the report.

The total number of threats in Table 2 will not be the same as in Table 1 as some threats continue to be assessed by the VRG.

Enhancing Surveillance

A draft technical paper on the impact of alternative testing strategies on surveillance system sensitivity and confidence in freedom from Aujeszky's disease has been submitted to policy customers, which informs the design of proposals to enhance laboratory surveillance. Further work involving the Pig Expert Group was conducted on diagnostic submission data to better understand the volume of samples the APHA laboratory network receives annually from pig holdings which might be used for 'Enhanced Passive Surveillance' (EPS). The output summary of this data will be used for a pilot of EPS.

The final report on the risk of exotic (notifiable) disease incursion into a smallholding in Great Britain was submitted to the Head of Evidence for Animal Public Health and Traceability. This reactive request, which will feed into other projects, drew on expertise from across the APHA and addressed the risk smallholders pose with respect to disease incursion and helped to clarify the key introduction pathways and consider difference between commercial farms and smallholders.

Annual population reports for cattle, sheep, goats and poultry for 2015/16 were published on a new dedicated APHA-wide SharePoint site, which was launched to promote the work of the Livestock Demographic Data Groups within APHA. In preparation for publication of the 2016/17 population reports, work has been ongoing with the APHA Open Data Publishing Team about data sharing as part of Defra's open data policy, with the aim to get the LDDG population reports openly shared in the public domain, ensuring that APHA's work is accessible.

Sixteen disease profiles have now been republished on the D2R2 animal disease prioritisation tool to ensure this comprehensive database is up-to-date and fit for purpose. Work has also been ongoing to promote D2R2 including presentations and posters at veterinary conferences, which

has prompted a definite upward trend in use and an increase in the number of visitors based on Google analytics data. An article on the D2R2 system has also been published in the *Veterinary Record*, further promoting awareness of D2R2 to a wider audience (<http://veterinaryrecord.bmj.com/content/early/2016/10/04/vr.103684.full.pdf>).

As part of a group of initiatives to share surveillance knowledge across APHA, a Surveillance Intelligence Forum has been established to share knowledge, methodologies and best practice, and to develop collaborative work across APHA and with other collaborators, including the Veterinary Epidemiology, Economics and Public Health group at the Royal Veterinary College. The forum meets every quarter and has featured presentations from the Plant Health team and the National Bee Unit to further develop links and share expertise. The forum is complemented by a Surveillance Knowledge Bank, which has been developed to share information on surveillance activities throughout APHA.

Building capability for notifiable disease outbreak preparedness

Exotic disease outbreak preparedness is supported by the National Emergency Epidemiology Group (NEEG). The NEEG has been mobilised twice in 2016 for the avian influenza outbreak in Scotland in January and the avian influenza outbreak in Lincolnshire in December. These outbreaks relied on expertise, specifically scientific project management, analytical epidemiology and risk analysis to provide timely epidemiological analysis and advice that is used to inform disease management and control decisions at both a local and national level.

NEEG training this year has included training on amber telecoms and a review of the NEEG mobilisation process, which led to recommendations for improving the process, including the inception of 'NEEG Lite'. The latter potentially saves up to two days' time gathering epidemiological information from infected premises, which could be critical in terms of providing timely advice on tracings for disease control. NEEG Lite is based on a rapid proportionate response and can be scaled back rapidly if infection is not confirmed.

NEEG members also took part in a workshop to determine the NEEG requirements for the National Resilience Capability Assessment for a large-scale foot and mouth disease (FMD) outbreak. The data provided from this exercise contributed to the larger national capability exercise which is being led by Defra and the Cabinet Office to identify any gaps or duplication in APHA's capability. Expert modelling advice was also provided on the Exodis model for FMD to help complete the National Risk Assessment (NRA) exercise for the identified animal disease risk (Hazard number 25) and help complete the National Risk Capability Assessment, further enhancing APHA's outbreak capability.

Work has been undertaken to replace the Field Epidemiology Report forms with a new version of interactive pdf form for VIRDO¹⁰. These forms are easier for field staff to complete and will allow data to be keyed once and automatically transferred into the VIRDO database, eliminating the need for data entry, saving time for both field staff and Data System Group. This work provides a stepping stone to improve the use of technology in the field as part of a project which is now underway to introduce a Field Service Management (FSM) tool. This project will develop the use of a tablet and 'app' to support field visits and allow for the electronic completion of forms, including during outbreaks.

¹⁰ VIRDO is a database which captures epidemiological information from infected premises in notifiable exotic disease outbreaks.

A series of regional Veterinary Risk Assessment (VRA) workshops were delivered by the Intervention Epidemiology group, with 265 attendees, across APHA and the Scottish Government and Welsh Government. Future VRA training workshops are now part of the annual training plan programme.

A national FMD table top exercise, Exercise Willow, took place in December 2016. Exodus-FMD simulations were used to plan the exercise based on the National Risk Assessment work, which was a large and challenging, GB-wide FMD outbreak.

2.6 PORTFOLIO: TSE

The TSE National Reference Laboratory expertise provided by APHA is currently maintained through Defra funded research and surveillance activities, and through our role as an EU and OIE reference laboratory. As overall requirements and funding for TSE work decreases, in line with diminishing disease prevalence and reducing regulated surveillance requirements, the size of the APHA team remaining active in this field has also decreased substantially. Internal restructuring has consolidated the key remaining staff into a multidisciplinary core focussed around the delivery of the continuing statutory and policy advisory work.

Our scientific effort is now coordinated through a single research project that complements the existing surveillance contracts, adds scientific value to both existing and completed projects, and facilitates the communication of relevant scientific and policy outcomes. Importantly, this new work underpins policy, maintains the skills of the remaining staff and sustains the specialist and technical core while building the body of knowledge on topics such as tissue distribution, test sensitivity, agent stability/variability, and surveillance sensitivity in the field. The project is delivered through four themed work packages: 'Bioassay and Strain Typing', 'Large Animal and Clinical Studies', 'Molecular Studies', and 'Epidemiology and Risk'.

The TSE active surveillance programme requirements are set by the EC regulation 999/2001, to monitor TSE prevalence in the EU, concentrating predominantly upon 'risk' animals (i.e. clinical suspects and fallen stock). As prevalence declines the current scientific and policy priorities are increasingly focussed on classical BSE BARB (Born after the Reinforced Ban) animals, and whether or not these cases can still be attributed to the consumption of infected feedstuffs. Analysis of the data relating to these cases is being approached through several routes including a case-control study, undertaken collaboratively with the RVC, and an examination of the UK BARB data in the context of European-wide case occurrence. These studies provide reassurance that BARB cases can still be attributed to the 'tail' of the epidemic rather than representing the emergence of a new TSE problem. APHA is represented on the EFSA working group currently looking at BARB cases at a European level.

There have been no cases of classical BSE or classical scrapie detected in the UK this year, although atypical scrapie continues to present with very low prevalence. This means that UK timescale for BSE negligible risk status is unchanged. APHA contributed to the independent applications to the OIE for negligible risk status from both Scotland and Northern Ireland this year.

Being able to export beef to countries outside the EU is one of the main priorities of Defra Ministers and the UK industry, with the potential value of certain markets being over a hundred million pounds a year. The UK is currently classified as 'controlled BSE risk' by the OIE, and we are increasingly invited to present to international trade delegations seeking the scientific reassurance that would enable them to confidently recommence the importation of beef from UK. This year has

seen visiting delegations from the United States and China. APHA staff have also been invited to present to Food Safety Committee Japan, and also to international conferences such as Prion 2016 and a workshop on prion diseases and research co-hosted by the Alberta Prion Research Institute and the Canadian Food Inspection Agency.

The OIE are still intending to separately classify classical and atypical BSE, which would reflect atypical BSE as being considered irrelevant to determining the BSE risk status of countries where atypical cases occur, and therefore excluded from the calculation. However, the zoonotic potential of these atypical forms is still unclear, as is the origin of BSE, so some competent authorities are more in favour of the precautionary principle with regard to these cases. APHA contributed to a multi-agency/multidisciplinary workshop on identifying the knowledge gaps associated with atypical BSE hosted by the FSA in September 2016.

This year saw the completion of a further human appendix study which was a collaboration with APHA, PHE, the Department of Neurodegenerative Diseases at the UCL Institute of Neurology, the National Creutzfeldt-Jakob Disease Research and Surveillance Unit, the Histopathology Department of Derriford Hospital in Plymouth, and the MRC Prion Unit. In summary, the survey data identified cases in both the cohort sampled before the BSE epidemic and in the cohort born after control measures were implemented, therefore the question of whether abnormal prions detected by IHC in the British population is limited to those exposed to the BSE epizootic remains unclear. Our direct involvement with these epizootic issues is supported by APHA membership of both the ACDP TSE subgroup, and the CJD oversight committee.

Important scientific information with respect to scrapie pathogenesis, diagnosis and prevention in goats has been obtained or disseminated through Defra-funded projects and EURL Work. A manuscript describing scrapie transmission via goat milk has been published in BMC Veterinary Research, which finally provides the necessary evidence for the 2013 amendment of Regulation (EC) No 999/2001 in relation to the feeding of milk and the milk products from scrapie-affected goat farms.

Detailed postmortem examination of 151 goats culled in 2016 as part of a scrapie eradication program has again confirmed that the surveillance testing regime as currently applied to goats across the EU is not very sensitive for case detection. This also gives us more accurate data on disease prevalence in herds with endemic scrapie which will inform any further surveillance work looking at re-populated premises to assess the efficacy of cleaning and disinfection regimes. In parallel, studies at the APHA Rectory 'scrapie-affected farm' have shown that the remaining sheep on the 'decontamination' project all developed evidence of infection within two years of introduction/exposure despite the decontamination procedures applied. A new cohort of susceptible animals has been introduced to the premises after further disinfection to improve our understanding of the requirements for effective field decontamination.

An ongoing study on a scrapie-affected farm has for the first time shown a reduction in the number of confirmed scrapie cases following selective breeding for scrapie resistance based on the K222 allele of the caprine prion protein gene. We have also published collaborative work with the Cypriot Veterinary Services where the resistance to scrapie conferred by specific genotypes has been demonstrated in field situations, and APHA is represented (chairmanship) on the EFSA working group looking at the feasibility of breeding for resistance in goats.

The EURL-AP working in collaboration with a number of NRLs (including APHA) have successfully validated a real-time PCR method for detection of porcine protein in complex animal feedstuffs.

The introduction of the porcine PCR alongside the existing ruminant specific test will greatly strengthen the detection capability of the National Feed Audit.

Improvements to the scrapie monitoring scheme carcass submission protocols means that fallen stock can now be submitted to National Fallen Stock Company (NFSCo) approved sheep/goat sampling centres as well as to surveillance centres. The new method of operation gives SMS clients more choice and will reduce 'road miles' in moving fallen stock for testing, with the resultant carbon savings. APHA has also had an active role in the EFSA working group assessing and reviewing the reporting system for TSE surveillance in cattle and small ruminants in the EU.

APHA were requested by industry and Defra policy to investigate whether changes could be made to EC 21/2004 to the individual livestock recording and reporting requirements for farms, the implementation of which has been incurring significant costs to industry. A risk assessment was conducted on the risk posed to our traceability system during an outbreak situation of a statutory livestock disease if changes were made to the system as proposed. The risk assessment found that whilst trace back for FMD was not significantly affected, the traceability system for scrapie would be negatively impacted. Such evidence was then presented to Defra to inform their discussion with stakeholders.

A major new area of interest in TSE surveillance arose this year with the detection of five cases of chronic wasting disease in reindeer and moose in Norway, with APHA input to the confirmation of the index case through our EURL role (see also the Wildlife Portfolio at section 2.7). The TSE NRL at APHA have had substantial input to the review of Defra risk assessments and stakeholder discussions about the scientific and logistical issues that might shape future surveillance approaches. These discussions were greatly facilitated by a two day discussion workshop at the University of Newcastle in July 2016, which was a collaboration between APHA, the University of Newcastle and Alberta Prion Research Institute in Canada. APHA were represented (chairmanship) on the EFSA working group that produced an outline surveillance strategy that could be used for disease detection in other member states.

As part of our ongoing EURL/OIE reference laboratory activities we have provided EQA, referral advice, and reference and training material through TSE-LAB-NET. Over recent years there have also been several issues identified with the rapid tests currently listed in the EU regulations. These test performance issues relate mainly to test sensitivity and the EURL coordinated troubleshooting activities with the test manufacturers to identify root causes for these performance issues. We continue to offer comprehensive isolate characterisation using transgenic mouse bioassay, both through our leading role in the EU strain typing expert group and also for third countries within our OIE remit. We also contributed to the revision of the OIE manual chapters for BSE and scrapie, and the updating of the Discontools BSE pages, thereby maintaining APHA's international profile in this area.

2.7 PORTFOLIO: Wildlife

The National Wildlife Management Centre (NWMC) provides evidence, primarily to Defra, to support policy and decision making, together with services to assist delivery. It provides scientific support and advice to help resolve human-wildlife conflicts, drawing on expertise in wildlife disease; wildlife control methods; invasive non-native species, population modelling, and welfare. The team has also provided assistance to other parts of the agency during disease outbreaks. The NWMC includes the work done at Woodchester Park on badgers and bTB (see TB Portfolio at section 2.3), and also works with Virology, TSE, the modelling team in the Department for Epidemiological Sciences and the National Bee Unit on wildlife related issues.

Invasive Species Actions

Following identification by APHA's Bee Health Unit (NBU) of an Asian Hornet nest in October 2016 the Wildlife Eradication Team were deployed to Tetbury and successfully removed the only nest found. This was the first ever record of Asian Hornet in Great Britain (see NBU section). The staff obtained high quality thermal cameras which were able to spot the nest in the tree and confirmed that such cameras can be used in the future to find active nests. A contingency model of spread and control was developed as a personal development plan for one of our GIS staff and was used as a template for how to collect data from the field teams on the effort to find and eradicate nests. The Non Native Species Secretariat (NNSS) sat on the LGD (the lead government department) group – the strategic group in charge of overall policy and command, we led on re-drafting the ID and alert posters and then were responsible for alerting a wide range of stakeholders.

Following last year's successful capture of the escaped beaver, this year confirmed the presence of a racoon in urban Sunderland. We would not normally investigate reports of a single animal. However, the frequency of the Sunderland reports and the high risk to biodiversity posed by this species should it establish a self-sustaining population led to further investigation. The presence of a racoon was confirmed by camera trapping. The householders gave permission to trap and the animal was captured unharmed in February. It was transferred to Sand Hutton to be health checked and neutered. A local wildlife park has agreed to home the animal.

A final report to the British Virgin Islands was submitted detailing the successful removal of about 90% of the feral goats on two of the islands as part of an EC funded BEST project. This work was performed by our very experienced marksmen, a unique asset with Wildlife. As part of the project, local staff were trained to complete the eradication.

A report on the progress of the Ruddy Duck eradication has been submitted to the *Oxyura* Project Advisory Group (OPAG). This indicated that we have reduced the national population from about 30 birds last year to about 19 widely dispersed birds, of which six are female. Successful breeding last summer was reported in only two regions and we believe that all the young were culled and limited breeding was reported this year. We continued to react to any sightings and prioritized the removal of females. This is a reduction from about 6000 birds in the year 2000 and represents the largest invasive vertebrate eradication ever performed. Talks continue with European neighbours to increase their level of control as it is estimated that some 300 birds exist across France, Belgium and the Netherlands. We hope to be able to announce the success of this campaign within Britain in the near future.

Research

A systematic assessment of British mammal density and population size was performed by combining presence data (from a public source – the National Biodiversity Network - NBN) and published geo-referenced density data. The resultant estimates were fairly accurate for species with high recording rates (e.g. badgers and deer) and have been used in discussions on deer surveillance for CWD. This work has also led to running workshops on species distribution modelling, discussion with the Joint Nature Conservation Committee (JNCC) on the output and was a primary factor in getting EFSA funding for a six-year project to assess the distributions and abundance of all European mammals. The output is also feeding in to a number of other APHA projects.

A simulation model was constructed to investigate the potential to eliminate an outbreak of *Echinococcus multilocularis* if this zoonotic parasite were to enter Great Britain. Outbreaks detected within five years had a 40-86% chance of being eradicated with the widespread and frequent anthelmintic baiting of foxes in the area dropping to 0% to 56% if control is delayed until 15 years after introduction, depending upon the prevalence equilibrium.

Research on badgers and TB is presented in the TB Portfolio in section 2.3, however working with Exeter University we also completed work on density-dependence within the badger population, immune response and aging, an investigation into seasonal contact rates and the application of statistical network models.

We also published a summary of badger sett exclusion outcomes and recommended that all vegetation is removed around a sett to increase the chances of a successful legal exclusion.

Non-Native Species Secretariat

The GB NNSS ran Invasive Species Week (Feb 29 – March 4) to raise awareness of invasive non-native species and their impacts, and encourage people to help prevent their spread. Over 160 organizations helped to support Invasive Species Week, sharing online content, producing materials, putting on talks and events, writing blogs and articles, carrying out practical management, enlisting celebrity support and much more. A few highlights included:

1. Over 1220 posts on Twitter under #InvasivesWeek, with 2140 retweets.
2. Over 1000 people “talking about” #InvasivesWeek on Facebook.
3. The 43 Twitter posts by the NNSS reached over 118,500 feeds alone.
4. Lord Gardiner, Minister for Biosecurity, visited Thames Water Walthamstow Reservoirs with the NNSS, EA and Royal Yachting Association to see Thames Water’s excellent work on biosecurity.

The Secretariat attends the Monthly Biosecurity Meetings with Defra Ministers - leading on technical matters related to invasive species. As part of the MBM process NNSS has also established and runs a monthly risk identification process which is analogous to what exists in Plant and Animal Health.

Other Associated Work

Following the detection of Chronic Wasting Disease (CWD) in Norway, an international workshop was held at Newcastle University to discuss the knowledge gaps for a European outbreak. This brought together experts from the US and Canada with scientist working in Norway and APHA experts in prions and deer biology. Discussion included how to focus a surveillance scheme and how to predict the longer term consequence of this disease in Europe.

The Welsh government received support for the work in the Intensive Action Area (IAA) in Wales where badger vaccination was performed from 2012 to 2015. Extensive hair sampling and genetic fingerprinting was carried out to estimate total badger population size and the proportion of badgers which had been vaccinated at some point during the trial. The total population size was estimated at between 1645 and 2457 (95%CI) and approximately half the badgers had been vaccinated in 2015 and about 70-85% had been vaccinated at some point during the trial. The APHA badger model was used to examine the effect of the lack of availability of BCG during 2016, and concluded that the fifth year of vaccination would add very little to the reduction in the medium

term prevalence of bovine TB in the badger population, and thus the lack of vaccine in the last year of the trial would not compromise the effort put in in previous years. A report on the assessment of the lack of BCG for badger vaccination was presented to the Welsh CVO, the Deputy Minister for Food and Farming, opposition Assembly members and a stakeholder's forum of farmers unions and the badger trust. The report has been published on the Welsh government website and received a number of mentions in the local press.

Wildlife staff attended the outbreak of low pathogenicity AI in Dunfermline in January 2016 to determine the species groups and numbers of wild birds present that may have contributed to the outbreak. This evidence supported risk assessments of the likelihood of the infection being introduced by wild birds, or of wild birds contracting and spreading the infection from the infected premise.

Following a final visit to Kosovo, we have collated the results from an extensive camera trapping exercise performed by local staff to produce estimates of the local density and population size of foxes, wild boar, wolves, wildcats and brown bear. This is the first systematic mammal estimate on the Balkans, and we confirmed the first record of a golden jackal in Kosovo, indicating its continued spread through the region.

The National Reference Laboratory (NRL) function for *Trichinella* and *Echinococcus* has been moved to the wildlife portfolio within APHA to capitalise on the expertise and technical capability of the York Parasitology group, who have been carrying out *Trichinella* and *Echinococcus* testing of wildlife for >10 years. Transfer of testing from Bury to York is underway subject to accreditation status transfer which is ongoing.

Surveillance work as a result of the first *Trichinella pseudospirallis* record in a UK fox in 2013 was completed and no evidence of a local cycle of infection in wildlife was found, nor were any further positive cases found.

We have increased our level of teaching at Universities by running a third year undergraduate module at Newcastle in Animal Behaviour in addition to the ongoing commitment to run the Wildlife Management MSc.

3. SCIENCE DISCIPLINES

3.1 DISCIPLINE: Animal Sciences

APHA is working in partnership with others to promote high standards in Animal Sciences. As the South/ South East Ethics Hub (appointed by the Animals in Science Committee under the Animals (Scientific Procedures) Act 1986) APHA hosted a meeting of the Ethics Chairs in the hub at Weybridge in combination with South East Ethics Hub. An RSPCA/APHA meeting was held on the welfare of wild animals used in regulated procedures (fourth in a series of joint workshops dealing with various species/topics) and also hosted the second Large Animal Research Network meeting.

APHA is a member of the successful VetBioNet consortia for a five-year EU Horizon 2020 grant. APHA is leading co-ordination and networking of all similar institutions with farm animal high containment across the EU and also with some partners in 3rd countries (USA, Canada and Australia). This will cover preparedness and planning for (re) emerging outbreaks, best practice for biosafety and biosecurity, ethics and training and technology transfer. Joint research activities

are focussed on exotic viruses but we are looking at experimental model development, novel analytical tools and reagents to help interrogate the host pathogen interaction and the development of advanced approaches to monitoring experimental infections challenges, including in-vivo bio-imaging.

To maintain capability, we acquired an in-bred MHC (major histocompatibility complex) characterised pig herd 18 months ago. We manage this herd under contract for another research institute, and are re-establishing a breeding programme.

The Large Animal High Containment Unit underwent significant refurbishment, with £0.5 million replacement of the effluent treatment plant and upgrades to the Air Handling Units.

3.2 DISCIPLINE: Bacteriology

The number of submissions to APHA regional laboratories for both exotic e.g. brucella and mycoplasma, and routine diagnostic bacteriology has continued to decline. Discussions with our key customers (Defra, VMD) have progressed with separate projects to both define our surveillance requirements and the number of submissions that might be required to meet these. A variety of strategies may then be implemented to ensure sufficient surveillance material. Determinative bacteriology is a key technique in the regional laboratories for preliminary threat detection for more comprehensive molecular definition at Weybridge by WGS techniques. A workshop was held at Lasswade to review our capabilities in determinative bacteriology and how these are linking with the WGS approaches. Further work to better centralise and link up screening and WGS approaches will develop with the implementation of the Surveillance and Laboratories Services Review.

The joint post between Bacteriology at APHA and the School of Veterinary Medicine at the University of Surrey has been reviewed to better identify joint working activities to the mutual benefit of both organisations. This includes joint PhD studentships, joint funding applications such as the recent EJPs, and a common area of scientific interest (biofilms) where collaborative opportunities were identified. PhD studentships are a key area for the development and training of the next generation of APHA scientists and several opportunities are developing with both Defra sources and those from external funding. Reorganisation of the Weybridge estate is providing further significant opportunities to focus and consolidate scientific activities to make better use of our resources and provide contingency planning for key activities requiring high levels of biocontainment.

3.3 DISCIPLINE: Biomathematics

In the last year there have been substantial technical leaps in the application of scientific computing within Biomathematics. For example, the modelling team in the Department for Epidemiological Sciences (DES) have been the first in the Defra network to use the Cloud for a large scale research project. Having successfully addressed the procurement, data security, and local network reliability challenges, the team developed a large scale bovine TB model which can run on thousands of rented processors. The model has already generated outputs relating to TB cattle vaccination strategy by enabling analyses to be performed in days where previously the equivalent computational task would have taken decades. These approaches are allowing modellers to develop new methodologies and help steer Defra's technical approaches to Cloud IT for demanding analysis.

Progress has been made on the building of succession in key biomathematics areas; this is an ongoing challenge as the discipline covers several sub-disciplines (computational modelling, statistical modelling, classical statistics, wildlife and quantitative risk assessment), each of which comprise small teams. Resilience to staff departures has been increased by the enlarging of the computational modelling team, and by a concerted effort to provide training to junior staff in key areas.

3.4 DISCIPLINE: Epidemiology

We have continued to strengthen the partnership with the Veterinary Epidemiology, Economics and Public Health Group at RVC in 2016 with a number of joint events, such as the APHA Surveillance Intelligence forum and through the pursuit of joint funding opportunities.

Professor Dirk Pfeiffer continues, as Chief Epidemiologist to APHA, to support the development and challenge of epidemiology capability through the newly formed Epidemiology Oversight group which brings together the Heads of Epidemiology functions in APHA.

Epidemiology has gained expertise through the recruitment of additional veterinary and analytical epidemiologists to support both the epidemiological research and the critical functions of the National Emergency Epidemiological Group (NEEG) preparing for and during exotic disease outbreaks. However, staff retention continues undermine robust succession planning and within analytical epidemiology and demands for expertise regularly outstrip available staff resources. We are developing career pathways for analytical epidemiology and creating opportunities to develop existing staff within APHA.

3.5 DISCIPLINE: Molecular Biology

We are continuing to contribute to two large EU H2020 consortium grants - COMPARE and EVAg, both of which will develop molecular biology techniques for pathogen characterization. As part of EVAg, APHA are now offering a viral genome sequencing service, and within COMPARE we are comparing H5N8 avian influenza whole genome sequences from across Europe.

We are working closely with a number of external partners to ensure a unified approach to molecular biology, particularly in the areas of high-throughput sequencing and bioinformatics:

- A joint post between APHA and the Nuffield Department of Medicine, University of Oxford, has been set up to implement an analytical pipeline for *M. bovis* whole genome sequencing which is aligned to work being done for human tuberculosis.
- As part of the ENGAGE project APHA have started the process of benchmarking various bioinformatic tools for the analysis of whole genome sequence data from *Salmonella*.

State-of-the-art molecular biology techniques have been used to provide vital data in support of a number of outbreak and other high profile pathogen investigations, particularly H5N8 avian influenza.

We are participating in Oxford Nanopore's MinION Access Programme and are investigating various applications of this mobile sequencing technology. The MinION has now been used to

successfully sequence bacterial genomes, viral amplicons and H5N8 influenza from the UK outbreak.

3.6 DISCIPLINE: Parasitology

Babesia canis was confirmed by APHA as a cause of clinical disease in untraveled dogs in Essex. Further investigations identified the tick vector *Dermacentor reticulatus* and its infection with *B. canis* in an area frequented by affected dogs (see Animal and Zoonotic Viral Diseases Portfolio in section 2.1). Information was published to inform practising veterinary surgeons and advice was given to the local council to limit tick/ dog interactions. These were the first confirmed cases of *B. canis* in untraveled dogs in the UK and generated a large amount of media interest.

Post-mortem examination, histopathology and PCR by various groups within APHA were able to rule out infection with the metacestode stage of *Echinococcus multilocularis* in a dog suspected of being infected because of its travel history and clinical history see also Wildlife Portfolio in section 2.7).

The first detection of *Nematodirus lamae* in an alpaca outside South America was made and information was published.

New and emerging parasites - information following the multiple reports of *Linguatula serrata* in dogs imported from Romania was published to inform veterinary practitioners of possible treatment options and the potential zoonotic risk. Publication involved collaborators from academia, public health and private veterinary practice. Information on *L. serrata* was also supplied to the veterinary risk group

Information on the detection of *Dicrocoelium dendriticum*, a rare liver fluke in the UK was escalated to the Veterinary Risk Group following detection by APHA and University of Liverpool in sheep.

Numerous presentations were given throughout the year to government representatives, state veterinary surgeons, private veterinary practitioners and the farming industry on parasitology within APHA (*Nematodirus battus*, anthelmintic resistance, cattle ectoparasites, *Neospora caninum* causing arthrogryposis in a lamb and *Fasciola hepatica*). These investigations also incorporated input from the APHA Species Expert Groups, who gathered and communicated relevant information through their respective networks and contacts as well as in the Veterinary Record monthly surveillance report and quarterly species Emerging Threat reports.

Work is ongoing to investigate the possibility of targeted surveillance into *Besnoitia besnoiti* in cattle in UK and validation of an ELISA test by APHA, in collaboration with the cattle expert group.

3.7 DISCIPLINE: Pathology

We have continued to strengthen our strategic partnership with the Royal Veterinary College in 2016, by appointing our third joint Fellow (trainee pathologist) for three years. Our first Fellow has qualified, and has subsequently been employed in the commercial sector. We have also developed a four year part time training programme with RVC to enable our APHA veterinary pathologists to be mentored and equipped to sit RCPATH examinations. Our partnership has been recognised by an Honorary Professorship for Dr Marion Simmons.

As experienced pathologists retired from APHA Lasswade, we have transferred mammalian histopathology and histology capability to Weybridge. To strengthen resilience in disease surveillance, critical mass and business continuity we have appointed two trainee pathologists and agreed a diagnostic service and case review contract with Finn Pathologists who employ established farm animal pathology expertise (two qualified pathologists who originated from APHA). During the last year we have also developed robust career pathways for veterinary pathologists and scientists, and as staff retire, we are recruiting more junior pathologists and scientists to enable greater flexibility across the strategic requirements of research and surveillance. We have continued to ensure effective engagement with Veterinary Investigation Officers, and strengthen wider disease surveillance knowledge of histopathologists by enabling them to provide direct support at regional laboratories when suitable opportunities arise. Key issues continue to be maintenance and development of key core technical and specialist skills and knowledge.

3.8 DISCIPLINE: Virology

We supported the cross-government review of future interaction between the Pirbright Institute (TPI) and APHA. Enhanced working in the area of vector borne disease has been developed as part of UK capability with joint funding from Defra and we have continued to maintain partnerships with TPI in the area of swine influenza through a joint grant. We are continuing to maintain a strong UK network of partnerships, particularly with academia and have a number of joint PhD studentships with several UK Universities and formal collaborative agreements with other Universities such as Cambridge. A Jenner Fellow was in post in-year delivering on immunology of swine influenza.

We have continued to seek opportunities to work with PHE and have made substantive progress on Hepatitis E virus of pigs with joint funded grants and have supported ongoing work on Zika virus and fed into government decision making for UK preparedness providing expertise.

The development and review of disease consultants continues with strong training provided through APHA initiatives. Many members of staff working within the discipline are closely involved in industry stakeholder groups including boards and committees to provide influence and alignment of our science to take account of industry priorities.

We are continuing to maintain multidisciplinary programmes of work particularly in the area of influenza and hantavirus. We have worked with other discipline champions in particular molecular biology to enhance APHA capability through expansion of activities for example in the central sequencing unit.

We have established new partnerships through the OIE funding a project in India for rabies with ongoing commitment to UK capacity building projects in Georgia and Tajikistan. This has supported continuous professional development for our staff and gave us access to intelligence feeding our international network for UK preparedness. We have continued to add new tests and tools to scope formally accrediting to the UKAS ISO17025 standard.

Formal training and support has been provided to veterinary field staff for recognition and understanding of exotic disease including exercises for UK government. We have conducted three independent laboratory simulations for outbreak response. We have flexed our irreducible core across science groups to respond to emergencies in year i.e. outbreak response.

Greater team flexibility has been built within the discipline to support high profile emergency tasks facilitating a broad discipline skills base. We have received a number of visiting students and international visitors throughout the year who have provided added value to our international network of contacts but also have enriched the depth of science delivered.

4. QUALITY

We maintain several internationally recognised Quality Management Systems (QMS) for which we have accreditation or compliance.

- ISO17025 (applicable to routine testing).
- ISO17020 (covers inspection activities).
- ISO 17043 (for the management of proficiency testing rounds).
- Good Laboratory Practice (this is used to ensure the reliability of vaccine safety studies).
- Good Manufacturing Practice (applicable to quality control tests on vaccines).
- Good Clinical practice (for vaccine efficacy studies).
- Good Distribution Practice (manages the distribution of Tuberculins and badger BCG vaccine).
- Good Veterinary Pharmaceutical Practice (to monitor the safety of the badger BCG vaccine in the field).

In most cases these QMS are mandatory if we wish to continue to supply services such as *Salmonella* testing, compost testing and GLP/GMP regulatory tests on veterinary vaccines. We are obliged to maintain others because we are responsible for the distribution and pharmacovigilance of the badger BCG vaccine.

In addition to those above, we are certified to ISO9001 which focusses on business management. It provides a framework for management structure in businesses and as such is therefore an overarching QMS. We have compliance in both scientific and support service areas.

These QMS support our science, the quality of evidence, provide structure to our activities, enhance our reputation, manage risk and give customers confidence in the results of our services. They also provide quality assurance in court cases.

Our compliance with these standards is monitored by outside bodies. This year we have had routine assessments from UKAS (for ISO17025, ISO17020 and ISO17043) and LRQA (ISO9001). These have all been successful with the trend in many areas towards improvement. Some areas received plaudits for their QMS. We are managing a project for the migration next year from ISO9001:2008 to ISO9001:2015. Several training events have been run for staff and we are addressing all areas of the new standard which were identified in a gap analysis. Recommendations for an extension of scope of ISO17020 for the PHSI and Accreditation of the National Bee Unit were major achievements.

5. PUBLICATIONS & REPRESENTATION

We have maintained our strong publication rate during 2016 with the publication of 215 peer reviewed papers across all our science portfolios. Of these we were lead author on 111 (51.6%) papers. A full list of publications is published on [GOV.UK](#).

We also continue to develop our representation on appropriate national committees (205 representatives on 152 committees) and international committees (154 representatives on 133 committees) demonstrating the strong scientific reputation of APHA and our scientists.
