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Livestock Health and Food Chain Risk Assessment

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Abstract

The EUropean FOod Risk Assessment (EU-FORA) Fellowship work programme 'Livestock Health and Food Chain Risk Assessment', funded by EFSA was proposed by the Animal and Plant Health Agency (APHA), UK. A scientist with a PhD in Food Science was selected to work within the Biomathematics and Risk Research group, under the guidance of a senior risk assessor. The programme consisted of four different modules that covered a wide range of aspects related to risk assessment (RA). The aims, activities and conclusions obtained during the year are described in this article. The learning-by-doing approach in RA allowed the fellow to discover a broad pool of methodologies, tools and applications while developing his own knowledge in RA, as well as gaining scientific network for future collaborations in the field.

Keywords: risk assessment, risk ranking, livestock health, food chain

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1. Introduction

This Technical Report consists of a description of the activities conducted under the EUropean FOod Risk Assessment (EU-FORA) Fellowship work programme entitled: 'Livestock Health and Food Chain Risk Assessment', funded by the European Food safety Authority (EFSA). The work programme was proposed by the Animal and Plant Health Agency (APHA), UK. APHA is one of the four executive agencies working for the Department for Environment, Food and Rural Affairs (Defra) and also on behalf of the Scottish Government and Welsh Government. It is devoted to safeguarding animal and plant health in the UK, for the benefit of people, the environment and the economy, providing support for the delivery of their animal and plant health, welfare and bee health policies.

Within the EU-FORA fellowship, the fellow, Dr. Juan Manuel Martínez from the Food Technology Department of University of Zaragoza in Spain, was placed at the APHA, within the Biomathematics and Risk Research (BRR) workgroup, part of the Department for Epidemiological Sciences (DES). The workgroup is a nationally and internationally recognised group of risk analysts, modellers and statisticians providing high-quality scientific evidence for policy formulation and outbreak response, as well as specialist support to research and operations in the area of animal health. The work programme was supervised by Dr. Rachel Taylor, a Senior Risk Analyst within the BRR workgroup.

The Food Standards Agency (FSA) was a partner in the proposal. Its commitment is in protecting public health by making sure food is safe and is what it says it is. The Risk Assessment Unit (RAU) at FSA delivers risk assessment and technical advice relating to chemical and microbiological hazards of food and feed, food intolerance and allergy and radiological risk assessment.

The programme consisted of four different modules based on ongoing risk assessment (RA) project work and previous research interests at APHA, including the development of several RAs supported and funded by EFSA to underpin significant RA research work and European Commission policy support.

2. Description of work programme

The EU-FORA work programme 'Livestock Health and Food Chain Risk Assessment' designed by APHA was organised in four different modules that covered a wide range of aspects related to RA. Altogether, the modules aim to provide a broad overview of the various methodologies, tools and applications of RA. Each module built on the skills learnt in the previous modules and other training activities. Over the course of the year, Dr. Taylor monitored the progress of the programme and supervised the evolution of the project's activities. Furthermore, specialists were chosen to co-supervise each module based on their experience and relevance. Weekly meetings, both with Dr. Taylor and the co-supervisors, assessed in greater detail the progress of each module's deliverables and outcomes according to the programme schedule.

2.1. Aims

Each one of the four modules of the work programme consisted of a specific set of deliverables and outcomes, as follows:

Module 1: Principles and Terminologies of Quantitative and Qualitative Risk Assessment. The objective of this task was to complete and consolidate the RA knowledge of the fellow gained through the EFSA training, by getting practice in understanding the principles of qualitative and quantitative RA, the RA methodology and the different tools that can be used to perform RA. As part of this module, the fellow attended various courses and had access to learning materials and opportunities in meetings to improve his familiarity with RA.

Module 2: Hazard identification and Risk Prioritisation Methods. This module aimed to understand risk ranking methodologies and how risk ranking tools are implemented by adapting an existing risk ranking tool to the country of origin of the fellow. Specifically, the International Disease Monitoring (IDM) 'Risk of Incursion' tool (Roberts et al., 2011), was adapted to Spain. In addition, the fellow performed an updated overview of the risk ranking methods available regarding import of animal diseases in Europe and how they can be incorporated into the decision making process. The fellow reviewed ranking methods in literature, had the opportunity to use most of them, and explored horizon scanning methods and qualitative and semi-quantitative techniques for assessing food importation risks and other threats to animal and public health. The fellow also attended various meetings of different governmental groups and had a close collaboration with Defra, which facilitated progress on this module.

Module 3: Public Health and Food Chain Risk Assessment. This unit addressed the development of quantitative microbiological risk assessments (QMRAs) from farm-to-consumption. The fellow reviewed a farm-to-consumption *Salmonella* QMRA (Snary et al., 2016) and adapted it to data and conditions of Spanish pig farms. It is an individual-based stochastic model developed in Matlab programming language. In addition, the fellow had the opportunity to learn advanced visualisation techniques for spatial quantitative risk assessment.

Module 4: Import Risk Assessment. This module focused on the assessment of risk via importation of pathogens through different pathways. Specifically, the fellow considered the case study of importation of SARS-CoV-2 into the EU via human travel. This work was part of a European-funded Horizon 2020 project, the Versatile Emerging infectious disease Observatory (VEO), and built upon work from a previous project (Taylor et al., 2020). The fellow took into account uncertainty due to the lack of knowledge of new pathogens. The module involved learning how to extract and manipulate data from different sources, such as air passengers travel data from different countries to the EU and records of prevalence at different dates.

2.2. Activities/Methods

2.2.1. Module 1. Principles and Terminology of Quantitative and Qualitative Risk Assessment

The first module of the working programme was co-supervised by Dr. Louise Kelly, Senior Risk Analyst, part-time employee of APHA, Lecturer at University of Strathclyde and has previously provided consultancy to the World Health Organization, the Food and Agricultural Organization of the United Nations, EFSA and the OIE.

The module was dedicated to structured lectures and practical sessions on RA methodologies for both qualitative and quantitative RA. The lectures were part of the Royal Veterinary College (RVC)'s Master of Science (MSc) course in Veterinary Epidemiology. The qualitative RA lectures were undertaken in November 2019 at the RVC campus. The quantitative RA lectures were given online during May 2020, due to social distance guidance related to the COVID-19 pandemic. The training consisted of both theoretical and practical sessions. The practical exercises provided experience in how to produce a qualitative RA report and how to replace descriptive analysis of the risk pathways and qualitative risk estimates with their mathematical description and numerical risk estimates. As well as the lecture sessions of the Qualitative RA course, the fellow performed a rapid qualitative RA exercise at BRR for Crimean Congo Haemorrhagic Fever (CCHF) and discussed this with senior risk analysts in the workgroup. The RA assessed the annual risk of CCHF being introduced into the UK from Spain and infecting a human via ticks carried by wild birds. The Quantitative RA part of the RVC course also comprised lectures, and practical exercises, including the use of the @Risk software.

The fellow attended departmental training sessions, including the DES Taster Club and other seminars, where staff members or visitors present current research and it was possible to discuss and ask questions in a very interactive and rich debate. Likewise, the fellow also attended face-to-face and online meetings of various governmental groups. In November and December 2019, the fellow attended meetings of the National Emergency Epidemiology Group (NEEG), Human-Animal Infections and Risk Surveillance Group (HAIRS) and the Veterinary Risk Group (VRG). The NEEG coordinates and reports on the epidemiology of exotic notifiable disease outbreaks to describe and anticipate disease frequency and distribution, providing epidemiological advice and assessment on the determinants, level and distribution of disease to the National Expert Group (NEG) (Scottish Government, 2017). The HAIRS group is a multiagency and cross-disciplinary horizon-scanning group, comprising numerous governmental agencies such as PHE, Defra, APHA, Food Standards Agency (FSA) and the Department of Health and Social Care. The group identifies and discusses infections with potential for interspecies transfer (Welsh and Morgan, 2005). The VRG is a UK group managed and delivered by APHA and directly supported by a network of risk management teams. Its role is to identify, assess, escalate and prioritise new and re-emerging animal-related threats in the UK, in order to decrease their impact to society and the economy (Kosmider et al., 2017). During these meetings, various RA situations that were of importance at that moment were presented. The fellow was offered the opportunity to participate in the identification of the key elements of control and prevention of animal and human diseases and participated in the RA methodologies that were applied in these cases in real conditions. Likewise, the fellow understood how RA serves to support policy and the responsibilities of risk assessors and risk managers in these situations. Thus, the attendance at these meetings gave the

fellow the opportunity to understand the function of each group in identifying, assessing and prioritising new threats to the UK. The different members of the groups talked to the fellow about their roles, especially in outbreaks or emergencies of high-impact for health. In addition to these scheduled activities, the fellow participated in other meetings and consultations with colleagues over the course of the EU-FORA fellowship programme. The hosting institution provided additional training which played an important role in improving the fellow's knowledge of RA (Table 1).

Table 1: Supporting activities organised or facilitated by the hosting site, Animal and Plant Health Agency, during the EU-FORA fellowship

	Title	Date
Training sessions	Introduction to UK Civil service	October 2019
	Various Datacamp courses on R	October–December 2019
	Royal Veterinary College (RVC), Qualitative Risk Assessment (RA) Course	14 November 2019
	Qualitative RA exercise at BRR	11 December 2019
	Working from home and engaging colleagues course	5 May 2020
	RVC, Quantitative RA Course (virtualised)	May 2020
	Data visualization in R (Part I-III)	June 2020
Regular meetings	BRR workgroup meeting	Every month
	DES Team meeting	Every month
	DES Taster Club (talks of different topics)	Every two weeks
Other meetings	Meeting in Nobel House (DEFRA), IDM tool discussion with Helen Roberts (Advisor Exotic Disease Control)	21 October
	Veterinary Risk Group meeting in Nobel House	5 November
	HAIRS and EpiRisk meeting in Nobel House	4 December
Conferences	One Health European Joint Programme Annual Scientific Meeting 2020	27–29 May
	Society for Veterinary Epidemiology and Preventive Medicine conference	12 May–16th June (every Tuesday)
One Health Webinars	Managing a raging pandemic: a steep learning curve Risks of future pandemic threats and how to prepare	13 July 16 July

In addition, the EU-FORA training programme was supported by four training sessions provided by EFSA. Due to the unprecedented situation derived from the COVID-19 pandemic, two of these were performed as scheduled but the other two had to take place online. The fellow attended a 3-week induction training at EFSA headquarters in Parma, Italy and a 1-week training module at the Austrian Agency for Health and Food Safety (AGES) in Vienna, Austria. The training sessions due to be held at the German Federal Institute for Risk Assessment in Berlin, Germany and the Hellenic Food Authority in Athens, Greece were adapted to take place online during the month of August.

2.2.2. Module 2. Hazard identification and Risk Prioritisation Methods

Module 2 was co-supervised by Dr. Helen Roberts, Equine, Pets and New and Emerging Diseases, Science and Risk Adviser, within the Exotic Disease Control team of Defra. Defra is a UK ministerial department supported by 33 agencies and public bodies and is responsible for safeguarding the natural environment, promoting the food and farming industry and sustaining the rural economy (Defra, 2019).

This module focused on studying the IDM 'Risk of Incursion' tool (Roberts et al., 2011) and adapting this for Spain. This Microsoft Excel®-based tool was originally developed in 2009 to provide a rapid, semi-quantitative measure of the risk of disease introduction to the UK. The tool was based on the hypothesis that the primary routes by which an exotic animal disease (EAD) could be introduced into the UK would be legal or illegal trade, wild bird migration or vectors (e.g. mosquitoes, midges, ticks). The tool has been regularly updated, with further adaptions implemented, and the current version is still being used by the Veterinary Advice & Surveillance Group to assess the risk of incursions of EADs to the UK.

After having the opportunity to work with the tool, the fellow analysed and described the function, identified the strengths and drawbacks and studied the criteria and the inputs and outputs. Second, the fellow assessed the feasibility of adapting the IDM tool to analyse the risk of incursion of various animal diseases into Spain through an associated livestock or product of animal origin.

The list of diseases assessed by the tool was revised to be relevant to the Spanish situation. Diseases already present in Spain, such as Brucellosis (*Brucella abortus* and *B. melitensis*), West Nile Virus, Aujeszky's Disease, Contagious Agalactia, HP-PRRS, *Trichinella* and *Leishmania* were removed, while others of more relevance to Spain than the UK, such as *Salmonella abortusovis*, theileriosis and trypanosomosis, were added. The 2018 international trade data for Spain were obtained from COMEXT, a freely available online reference database for detailed statistics on international trade in goods run by Eurostat, and the Trade Control and Expert System (TRACES) European Union (EU) database (Eurostat, 2018; European Commission, 2019). The model included not only all the legal trade partners of Spain, but also countries where illegal trade may come from. The countries are separated into regions based on the volume of their trading with Spain. Each region is assigned a score based on its disease status, namely whether the disease is only found in wildlife, is sporadic in livestock or is endemic in the livestock population. This indicates the overall geographical distribution for each considered disease. Various risks of trade routes are taken into account, such as imports of livestock, products of animal origin (POAOs) (meat, milk and eggs), genetic material (semen, ova and embryos), biological material (serum and plasma), transport vehicles, food waste and zoo animals. Furthermore, the potential for movement of wild animals, vectors, or migration of birds is scored from each region. A negative score is included to indicate forms of mitigation actions against the targeted disease which are in place in the region of origin of the imported commodity. All the resultant scores are input into an algorithm to calculate the overall risk of incursion level for Spain of each disease, in relation to its geographical distribution. Of great relevance was the fact that the fellow included new factors in the pathway in order to consider the effect of the interaction of vectors and migratory birds. One of the main differences between the results of original UK IDM tool and the new version adapted by the fellow lies in the vector-borne diseases. This is likely due to the location of Spain in the southern part of Europe and its warm weather.

In addition, the fellow also considered other tools available and contributed to an extensive study of risk ranking methods and tools for prioritising animal diseases. The routine horizon scanning methods undertaken to ensure emerging issues are captured were investigated. This approach includes risk ranking, horizon scanning methods and qualitative and semi-quantitative techniques for assessing food importation risks and other threats to animal and public health. It increased the fellow's knowledge of risk prioritisation methods, data sources and incorporation of uncertainty into outputs.

Various tools were explored and used, some of which are maintained and designed specifically for the UK and others developed by EU countries and international agencies. These tools prioritise pathogens of highest risk, on a regular basis, and feed into the specific contingency plans within the Outbreak National Response. The tools available online were tested in order to identify their advantages and limitations. These risk ranking frameworks were assessed in order to identify their general recommendations for a prioritisation approach of animal diseases in the selected risk ranking tools. These accomplishments facilitated the completion of a comprehensive overview of a wide pool of tools developed within the EU over time to rank animal diseases. The fellow commented and provided his opinion to the study entitled 'Best practices in risk ranking animal diseases: An analysis of ten risk ranking tools' that is intended to be submitted for publication and whose main author was the former EU-FORA fellow.

2.2.3. Module 3. Public Health and Food Chain Risk Assessment

Module 3 was supervised by Dr. Catherine M^{c}Carthy, Risk Analyst within the BRR Workgroup of APHA.

The fellow had the opportunity to review and adapt a *Salmonella* QMRA for Spain, which was previously produced by APHA for EFSA and implemented for four European Union member states, but not Spain (Snary et al., 2016). The EFSA QMRA included a cost-benefit component to help aid decision makers as to the best control measures to implement (Gavin et al., 2018).

Salmonella is an important zoonotic pathogen that can cause human illness with potential hospitalisation and even may lead to the death of the patients in severe cases. Food-borne-outbreaks (FBO) and pork meat in particular are frequent sources of human infection. The fellow carried out a QMRA that could assist the development of national control plans for *Salmonella* in pigs in Spain. The

original farm transmission model (Hill et al., 2016) was adapted by the fellow using Spanish pig production parameters taking into account the particularities of the pig industry in the country.

The original farm model was an individual-based stochastic susceptible-infected-susceptible model (SIS) taking account of i) multiple changing populations and ii) intermittent shedding of *Salmonella*. The model was implemented using Monte Carlo simulation, where each iteration represents production from one farm over a 500-day period, incorporating farrowing, weaning, grower and finisher production. It considers sows, feed and external environment as sources of infection, as well as allowing for infection from bacteria in the pen environment. A range of different farm management practices were considered. The outputs obtained included within-batch prevalence along rearing and at the slaughter age and shedding rate. The farm management factors were estimated from different Spanish production databases. The weightings for apportioning farm types were taken from data collected from the EFSA baseline survey for breeding pigs (EFSA, 2009) and the Agriculture Spanish ministry survey 2016 (Spanish Agriculture, Fishing and Food Ministry). The breeding herd prevalence of Spain was taken from the EFSA breeding pig survey and compared with data from the literature (Andreoletti et al., 2008; Vico et al., 2011) and Agriculture Spanish ministry, as well as the within herd prevalence and the contamination of feed. The issues regarding sampling and data collection were addressed by taking into account the uncertainty and fitting distributions. Mass of faeces defecated by the pigs and amount consumed per day at different stages have been extracted from Spanish data from IRTA (Institute of Agrifood Research and Technology). Once a pig has been infected then the magnitude of shedding is assigned, by sampling from a distribution derived from observed values and according to the dose with which the pig was infected. It was assumed that infected pigs excrete intermittently during the whole time period of infection, with a highly variable profile between individual pigs.

The model adapted to Spain found that the breeding herd prevalence plays a major role as a source of infection. The results obtained were compared to an example of a high-prevalence Member State (MS) from the original model. The Spanish model estimated a higher level of *Salmonella* infection, highlighting the need to control this pathogen on farm. Sow prevalence was found to be a strong indicator of slaughter pig prevalence and this model is a promising tool to evaluate the effectiveness of interventions.

The fellow wrote a report and made a presentation to Dr. Robin Simons (acting lead risk analyst), Dr. Catherine McCarthy and Dr. Rachel Taylor at the end of the module, providing an opportunity to discuss and receive comments in order to improve the understanding and quality of the model. It is expected that the fellow will continue working on the model and submit an article.

Originally, within Module 3, the fellow intended to take a short-term secondment within the Microbial Risk Assessment team at FSA to work on the analysis of *Salmonella* Typhimurium data from human *Salmonella* outbreak cases. This would have allowed time to explore different 'what if' scenarios in order to feed this knowledge back into the quantitative model at APHA. However, this secondment could not take place due to the COVID-19 pandemic. Instead, the fellow was able to spend additional time learning detailed visualisation methods for spatial quantitative risk assessment. Using the R software package, the fellow produced maps such as one presenting the *Salmonella* prevalence in EU members states (Figure 1).

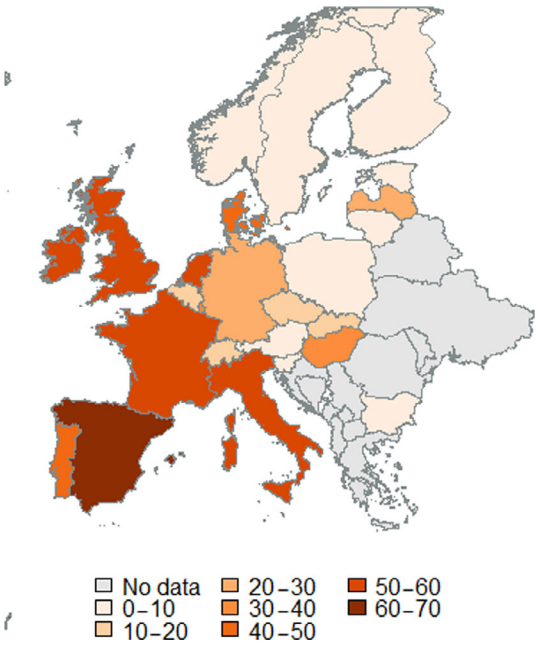

Figure 1: Mapping the 2016 EFSA baseline *Salmonella* prevalence in the EU member states using R

2.2.4. Module 4. Import Risk Assessment

In this module, the fellow has been involved in an on-going RA project at APHA, as part of the VEO Horizon 2020-funded project (https://www.veo-europe.eu/).

The role of the fellow in this project consisted of testing APHA's previously developed generic risk assessment framework (Taylor et al., 2020), in a Disease X scenario. Disease X is defined as a fast spreading exotic infectious disease (EID), with high case fatality by an unknown pathogen. In the light of the COVID-19 pandemic, it was decided to focus on the RA process of introduction of SARS-CoV-2 in the EU/EEA and the UK, specifically to address the question: In the event of an emergence, can we rapidly apply the tools developed to support pandemic response? In particular, the fellow performed a RA answering two questions:

i) What was the risk, as of 31 January 2020, of introduction of SARS-CoV-2 by human travel into the EU/EEA and UK taking into account the information that we knew at that time?
ii) What was the risk, as of 31 January 2020, of introduction of SARS-CoV-2 by human travel into the EU/EEA and UK taking into account the information that we know now (June 2020)?

The two different dates were chosen in order to understand the effect of uncertainty due to lack of disease knowledge in a newly emerging disease outbreak.

Given the short timeframe, this module only focused on the entry of the pathogen. The risk pathway of entry due to human travel was designed in line with the generic framework that has been previously developed at APHA (Taylor et al., 2019). Data on prevalence and human travel was collated. The data on prevalence, number of cases detected and new cases were extracted from the Johns Hopkins records (Johns Hopkins University of Medicine, 2020), health ministry reports (Spain and the UK), ECDC reports, WHO reports, published scientific literature and BBC news, Spanish news or social media. Travel data was extracted from Eurostat for official records of air passengers (Eurostat, 2020).

This module also involved attending online group meetings for the VEO project which took place during this time.

At the time of writing, the fellow is finalising the model and anticipates writing a short communication article on the work.

3. Conclusions

This EU-FORA fellowship has provided an opportunity to learn RA methodologies across a range of RA topics, such as chemical and microbial risk assessment, risk communication, import risk assessment and risk ranking tools. This intensive year of training, utilising the 'learning-by-doing' approach within a

hosting institute allowed for an increased knowledge of all areas of RA, and hands-on experience with different types of risk assessment projects and questions. The fellow learnt both qualitative and quantitative skills, such as data collation, data manipulation in R, plotting maps, understanding inputs and outputs of risk assessment, and effective risk communication. This was all helped by a dedicated hosting institute and the atmosphere of undertaking this learning when surrounded by experienced and knowledgeable risk assessors. Although the scope of work programme was impacted by the COVID-19 pandemic, the experiences and skills gained by the fellow are invaluable and have presented numerous opportunities for future research projects and collaborations.

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Abbreviations

AGES	Austrian Agency for Health and Food Safety
AMR	antimicrobial resistance
APHA	Animal and Plant Health Agency
BfR	German Federal Institute for Risk Assessment
BRR	Biomathematics and Risk Research workgroup
CCHF	Crimean Congo Haemorrhagic Fever
DEFRA	Department of Environment, Food and Rural Affairs
EAD	exotic animal disease
ECDC	European Centre for Disease Prevention and Control
EIDs	emerging infectious diseases
EU-FORA	European Union Food Risk Assessment
EUROSTAT	The Statistical Office of the European Union
FSA	Food Standard Agency
HAIRS	Human-Animal Infections and Risk Surveillance Group
NEG	National Expert Group
NEEG	National Emergency Epidemiology Group
OIE	World Organisation for Animal Health
QMRA	quantitative microbiological risk assessment
RVC	Royal Veterinary College
SIS	susceptible-infected-susceptible
TRACES	Trade Control and Expert System
VRG	Veterinary Risk group
VEO	Versatile Emerging infectious disease Observatory
WHO	World Health Organization