Institution: University of Salford		
Unit of Assessment: 7		
Title of case study: Strengthening national and international plant biosecurity surveillance policy and practice		
Period when the underpinning research was undertaken: September 2014 – December 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Stephen Parnell	Reader in Spatial Epidemiology	October 2014 – Present
Dr Alex Mastin	Research Fellow in Epidemiological Modelling	November 2011 – Present
Dr Frank van den Bosch	Research Fellow in Epidemiological Modelling	March 2019 – Present
Period when the claimed impact occurred: September 2014 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Rapidly emerging plant pests and diseases pose some of the greatest global threats to ecosystems and food production. More effective surveillance systems are urgently needed to detect new outbreaks and provide vital epidemiological intelligence. Research undertaken at the University of Salford provides a scientific and quantitative basis to plant pest surveillance and has led to major changes in law, policy and on-the-ground practice in the United Kingdom (UK), United States of America (USA) and across the European Union (EU). Through its integration of modern epidemiological analyses, the research now underpins revised risk assessment, national surveillance strategies and plant health policy in multiple countries including: new European-wide law on 'Europe's most deadly plant bacteria' Xylella, guidelines for EU Member States on surveillance undertaken throughout the EU for all quarantine plant pests, as well as changes in surveillance processes in the UK and USA for improved plant biosecurity.

2. Underpinning research

Salford researchers, led by Parnell, have developed a range of practical, epidemiological-based tools to determine effective surveillance strategies for detection of plant diseases in cropped and natural plant communities. The research, which Parnell initiated and has developed as an independent research programme since 2007, and at Salford since 2014, incorporates scientists from the UK and globally to combat the threat of emerging plant diseases, which are rapidly increasing with greater trade and travel, and associated movement of plants and planting material.

<u>A quantitative basis to surveillance</u>

A key practical question in the design of a surveillance programme is: How much surveillance effort is required to detect an invading disease before it gets out of control? Available statistical approaches to this problem had ignored epidemiology, treating epidemics as if they were static. Salford's research team was the first to show how the dynamics of a surveillance program relate to the dynamics of an invading epidemic. They developed a 'rule of thumb' **[3.1, 3.2]** to predict the prevalence that an epidemic will have reached when it is first detected. This allowed practitioners to identify the appropriate amount of surveillance to allocate to detect an epidemic at a controllable low prevalence. The team further showed that knowledge of disease dynamics makes it possible to not only know how much surveillance effort is needed, but also, which detection method will be most effective **[3.1, 3.3]**. This enables practitioners to maximise the probability of early detection of an emerging pathogen, within imposed sample sizes and/or cost constraints. Depending on the epidemiological characteristics of the pest, practitioners can use the methods to determine if visual inspections, sampling via diagnostic tests, or trapping and testing of vectors is the most effective strategy for a particular disease.

Risk-based surveillance programmes

In 2014, Salford's research team published a generic risk-based surveillance methodology that could be used to develop targeted large-scale surveys for plant pathogens **[3.4, 3.5]**. For the first time, the team made a generic but science-based framework available for the implementation of targeted surveys, i.e. using information on where and when a pest and disease was most likely to occur. Their flexible framework can be tailored to any plant pest. Even when available epidemiological information is relatively minimal Salford's researchers showed that their method has strong predictive value and can result in highly effective targeted surveying plans. Using stochastic optimisation methods, they showed how risk can be used to prioritise surveillance, identifying high-impact locations where resources should be focused **[3.6]**. Their research revealed that to maximise the probability of detecting an epidemic, resources should be spread evenly across all high-risk clusters, rather than focused only in the very highest risk areas **[3.6]**.

3. References to the research

3.1. Mastin, A, van den Bosch, F, van den Berg, F and **Parnell, S.** 2019. Quantifying the hidden costs of imperfect detection for early detection surveillance, *Philosophical Transactions of the Royal Society B* 374(1776): 2018026. https://doi.org/10.1098/rstb.2018.0261 **(REF2)**

3.2. Parnell, S., Gottwald T.R, Cunniffe N.J., Alonso-Chavez V., van den Bosch F. 2015. Early detection surveillance for an emerging plant pathogen: a rule of thumb to predict prevalence at first discovery, *Proceedings of the Royal Society B* 282 (1814): 20151478. https://doi.org/10.1098/rspb.2015.1478 **(REF2)**

3.3. Mastin, A., van den Bosch, F. Gottwald, T.R., Chavez, V.A., and **Parnell S.** 2017. A method of determining where to target surveillance efforts in heterogeneous epidemiological systems, *PLoS Computational Biology* 13(8): e1005712. https://doi.org/10.1371/journal.pcbi.1005712

3.4. Brown, N., van den Bosch, F., **Parnell, S.** and Denman S. 2017. Integrating regulatory surveys and citizen science to map outbreaks of forest diseases: acute oak decline in England and Wales, *Proceedings of the Royal Society B*. 284 (1859). https://doi.org/10.1098/rspb.2017.0547

3.5. Parnell, S., Gottwald, T.R., Riley, T.R. and van den Bosch, F. 2014. A generic risk-based surveying method for invading plant pathogens, *Ecological Applications* 24:4, pp. 779-790. https://doi.org/10.1890/13-0704.1 **(REF2)**

3.6. Mastin, A, Gottwald, T.R, **van den Bosch, F**, Cunniffe, N.C. and **Parnell, S.** 2020. Optimising risk-based surveillance for early detection of invasive plant pathogens, *PLoS Biology* 18(10): e3000863. https://doi.org/10.1371/journal.pbio.3000863

Between 2014 and 2020, Parnell secured GBP1,110,000 in funding for plant pest modelling and surveillance as PI at the University of Salford. Funding is from a wide range of sources, including: US Department of Agriculture for GBP479,685, BBSRC for GBP216,000, NERC for GBP148,000, European Union Horizon 2020 for GBP139,000; Defra (Department for Environment, Food and Rural Affairs) for GBP110,000; UK Forestry Commission for GBP9,295; Food and Environment Research Agency for GBP5,634; Royal Society of Plant Biology for GBP4,900. Note this includes all research funding obtained, of which a subset has directly led to the impact outlined here.

4. Details of the impact

Since 2014, research at Salford has led to the development of a range of new methodologies and tools to enable science-based surveillance and risk assessment. These research outputs have also directly led to changes in policy and implementation, most notably in the European Union (EU) as well as in the United Kingdom (UK) and the United States of America (USA).

4.1. Influencing policy and practice at European level

i) Informing changes in EU law

Within Europe, Salford's research **directly informed changes in EU law [5.1]** with regard to *Xylella fastidiosa*, a plant pathogen described as 'the most dangerous plant pathogen worldwide' by the European Commission. Xylella is a bacterial pathogen historically confined to the Americas, but which was discovered in the EU for the first time in 2013 in Italy on olive trees and has since spread to multiple outbreak areas across Italy, Spain, France and Portugal. It is a threat to the whole European region, with over 550 confirmed host species. These range from olive, almond, grapevine and citrus, which are grown in southern Europe, to ecologically important deciduous tree species such as beech and oak, and stonefruit crops such as cherry, that are grown in the north. The pathogen has been estimated to cost EUR billions in production and job losses.

Consequently, the EU has implemented severe regulations since 2013, including the mandatory removal of all host plants within 100m of detected infected plants. This has led to significant public and political protests, particularly in Apulia, Italy, where the affected olive trees are hundreds, or even thousands, of years old and have cultural and historical significance, as well as economic importance. An **EU-wide risk assessment** chaired by Parnell and published in 2019 **[5.2]** used modelling to demonstrate the importance of early detection surveillance for Xylella and **ultimately led to the reduction of the removal radius from 100m to 50m [5.1]** in 2020. Crucially, also based on Salford's work, this was coupled with **enhanced surveillance measures to facilitate improved detections** and thus **reduced impact of the plant removal measures [5.1, 5.3]**.

Surveillance for *Xylella fastidiosa* in the EU is now on a quantitative basis, with the new law **citing detection methods and required confidence levels** that are taken from Salford's research and guidelines Parnell co-authored with the European Food Safety Authority (EFSA) in 2020 **[5.3, 5.4]**. The Commission implementing regulation states that '…*surveys shall consist in the collection of samples and testing of plants for planting. Taking into account the European Food Safety Authority's (Authority) Guidelines for statistically sound and risk-based surveys of Xylella fastidiosa..*.' **[5.1, Article 2]**. Research at Salford **underpinned the implementation guidelines [5.3] for the new law [5.1]**; guidelines that were developed through the EFSA Working Group on Surveillance, on which Parnell is a member **[5.3 – 5.6]**. The research underpins and is **cited in multiple Articles within the new law that apply to Member States**, including:

- surveillance requirements to conduct annual surveys for Xylella **[5.1, Article 2]**
- to establish demarcated areas including buffer zones **[5.1, Article 5]**
- conditions to have demarcated areas and associated measures lifted **[5.1, Article 6]**
- annual surveillance intensities for demarcated areas **[5.1, Articles 10, 20 and 23]**
- requirements for third country surveys that must be conducted before import into the EU is permitted **[5.1, Article 28 and 29]**.

ii) Enhancing understanding of and approaches to surveillance

Changes in surveillance approach included the recommendation against the previously routine adoption of visual surveys for Xylella in Europe, informed by Salford's work on the effectiveness of different detection methods for early epidemic detection **[3.1, 3.2, 3.5]**. Salford's research helped **shape the direction of surveillance approaches for Xylella** from an early stage through Parnell's role leading the 'detection and surveillance' session during the Commission's seminal workshop on future research directions for Xylella in 2015, where he led the 'surveillance and detection' breakout group **[5.5]**. This also informed the research priority on Xylella surveillance and its emphasis in the subsequent EUR7,000,000 H2020 call on Xylella **[5.5]**. Parnell further shared research findings and the need for change through his participation in **multiple workshops with representatives across all EU Member States [e.g. 5.6]**. Feedback gathered confirmed the **Member States' agreement to adopt the guidelines** as well as **specific recommendations to co-develop the webtool** used to implement the statistical survey tool **[5.6]**. This tool is now being further tailored within the EFSA working group led by Parnell following a new mandate by the European Commission to EFSA.

This research uptake was enhanced further through Parnell's role in the design and delivery of surveillance training workshops provided to hundreds of plant health inspectors from National Plant Protection Agencies across the EU from 2016 onwards '*to increase the knowledge of the participants from Member States and the common understanding of the best practices of surveillance to allow efficient, effective and early pest detection supported by the administrative and financial resources EC are making available*.' Each of the eight workshops per year since 2016 involved approximately 30 participants across three days, with each hosted in a different EU country.

As well as the pest-specific guidelines on Xylella **[5.3]**, Parnell was tasked by the European Commission to provide **general surveillance guidelines that Member States use to design national level surveillance programmes for all quarantine plant pests [5.4]**. The guidelines cite Salford's work on early detection surveillance modelling, which determine the effectiveness of different sampling intensities and detection methods for pest detection **[e.g. 3.4]**. The guidelines focused on three pilot pests that were selected at an EU workshop through a voting procedure with Member States and included the economically and ecologically significant pests *Xylella fastidiosa*, Emerald Ash Borer and Citrus Blackspot **[5.4]**. Parnell has delivered a series of webinars, attended in some cases by over 200 participants from EU national governments and plant health inspection services to look at pest survey design and preparation, as well as seminars at meetings of the EU Plant Health Network of Member States hosted by EFSA in December each year.

4.2. Providing modelling capability to Defra

Parnell's research findings are also used **to provide Defra with ad-hoc survey design for emerging plant pests** as a member of the Defra Plant Health Modelling Services Framework (Dec 2019 to Nov 2022), which provides **quantitative modelling capability and tools** for plant pest and disease modelling in emergency response to outbreaks **[5.7]**. Salford's team has provided **input in the responses to the Ash Dieback epidemic, Oriental Chestnut Wall Gasp and Sweet Chestnut Blight** directly and work has **informed policy response to quarantine plant pests** more broadly **[5.7]**. For example, Salford's research on early detection *'is used routinely to kick start discussions with operational and policy colleagues around early detection'* by Defra **[5.7]**.

Salford's research team **developed the surveillance module of a Decision Support tool** commissioned by the Forestry Commission and Defra, which **incorporated Salford's surveillance models to determine the size of an outbreak on first discovery [5.7]**. This has been directly used in **the production of cost-benefit analyses to inform policy development** in plant health by Defra **[5.7]**. This is further supplemented by two iCase PhD projects at the University of Salford, which are funded and co-supervised by Defra to expand this work. Parnell has also conducted 'Challenge Sessions' with the Defra Chief Scientific Advisor alongside the UK Chief Plant Health Officer to present research on plant health surveillance **[5.7]**. Salford's team is additionally **advising Defra on the use of the EU 'Ribess+' tool for surveys to substantiate claims of pest freedom** that he developed with EFSA and which Defra will use from 2021 to support pest risk assessment for import and export purposes **[5.7]**.

4.3. Applying risk-based methodologies in the USA

Salford's risk-based methodologies have been applied more widely in the USA, including to Citrus Greening, a plant disease which has decimated the citrus industry in Florida since its introduction in 2005 (causing a 72% decrease in production of oranges used for juicing in Florida by 2019). The method led to **risk-based surveys being used routinely in Florida for citrus pests** by the US Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS) as well as for **state-wide surveys for citrus in other US states**, and for **other high-risk pathogens** e.g. Plum Pox Virus in New York State **[3.5, 5.8]**. This led to a paper co-authored with USDA-APHIS that outlines the method **[3.5]** and which **improved cost-effectiveness and detection efficiency of state-wide surveys [3.5, 5.8]**. Using regulatory data and simulations of Citrus Greening spread in Florida, Salford's research showed that a risk-based approach could achieve the same number of positive detections through surveying just 15% of the state citrus inventory as could only previously have been achieved by surveying 50%. Initial advice to APHIS on risk-based surveys initiated as far back as 2006 in Florida **has informed routine surveillance** (directing inspections of up to 20% of the commercial inventory in Florida on six-weekly cycles) and has developed through Salford's research in collaboration with APHIS **[5.8]**.

Salford's research team were also funded by the USDA for a three-year project to provide **a survey validation webtool developed for and now in use by USDA-APHIS [5.8]**. The research on risk-based surveillance **[3.5]** has also been adopted by the **EU mandated work to produce a 'pest survey card' for citrus greening in Europe**, written by Salford on behalf of EFSA **[5.9]**. The survey card outlines the recommendations for the design of surveys for Citrus Greening by EU Member States. The disease has not yet been discovered in Europe but is a quarantine plant pathogen and a significant threat to the continuation of citrus production in Europe.

5. Sources to corroborate the impact

5.1. Official Journal of the European Union: *'Commission Implementing Regulation (EU) 2020/1201 as regards measures to prevent the introduction into and the spread within the Union of Xylella fastidiosa'* (17 August 2020). This is an EU law which refers directly to Salford's Xylella survey guidelines – see Articles 2, 5, 6, 10, 20, 23, 28, 29 (4.1i)
5.2. EFSA (European Food Safety Authority) Scientific Opinion: *'Update of the Scientific Opinion on the risks to plant health posed by Xylella fastidiosa in the EU territory'* (28 April 2019). Pest Risk Assessment chaired by Parnell and which underpinned changes to EU law on Xylella in combination with Salford's Xylella survey guidelines (4.1i)
5.3. EFSA Technical Report: *'Guidelines for statistically sound and risk-based surveys of Xylella fastidiosa'* (27 May 2020), which cites Parnell as a co-author: Member States must follow these guidelines according to EU law on the plant disease Xylella (4.1i, ii)
5.4. EFSA Technical Report: *'General guidelines for statistically sound and risk-based surveys of plant pests'* (31 July 2020), which cites Parnell as a co-author: All Member States use these guidelines to design national surveys for quarantine plant pests (4.1i, ii)
5.5. Event Report: *'Workshop on Xylella fastidiosa: knowledge gaps and research priorities for the EU'* (20 June 2016), in which Parnell's session informed the research priority on Xylella surveillance and its emphasis in the subsequent Horizon 2020 call (4.1i, ii)
5.6. Minutes: 14th Meeting of *'Network on Risk Assessment in Plant Health: Toolkit for surveillance of Xylella fastidiosa in the EU Member States'* (30 April 2019), where Member States confirmed participation/co-design involvement in the statistical survey methodology (4.1i, ii)
5.7. Testimonial: Department for Environment, Food & Rural Affairs (Defra) (March 2021), on informing Defra policy and modelling capability (4.2)
5.8. Testimonial: US Department of Agriculture, Animal and Plant Health Inspection Service (March 2021), on risk-based surveys based on Salford's research and funding granted (4.3)
5.9. EFSA Pest Survey Card: *'Pest survey card on Huanglongbing and its vectors'* (31 January 2019). EFSA survey guidelines using Salford's research and adopted by Member States to conduct surveys of this globally significant and economically destructive pathogen (4.3)