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UKRI Natural Environment Research Council

Project Title	Knowing the odds: towards a quantitative approach to surveillance for invasive tree pests and diseases
University (where student will register)	University of Warwick
Which institution will the student be based at?	As above
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☐ Organisms & Ecosystems ☒ Dynamic Earth ☐
Key words	Tree health, pests and diseases, plant pathology, epidemiological modelling, citizen science.
Please explain how the project fits within the NERC remit	The project seeks to develop approaches to better protect terrestrial environments from plant pathogen threats. It supports the UKRI strategic theme Tackling Infections where improved understanding of the environmental drivers and monitoring of plant pathogen spread is needed for enhanced tree health. The project will also address NERCs research area on Survey and Monitoring.
Supervisory team (including institution & email address)	**PI: Dr Stephen Parnell, School of Life Sciences, University of Warwick.** **stephen.parnell@warwick.ac.uk** **Co-I: Dr Nathan Brown, Forest Research** **nathan.brown@forestresearch.gov.uk**

Project Highlights:

- This project will develop new understanding to improve surveillance for destructive tree pests and diseases.
- The student will gain a wide range of experience in both field ecology, plant health and population/epidemiological modelling approaches.
- The research is of direct policy relevance and the student will assess current surveillance policy and practice as part of the conducted research.

Overview (including 1 high quality image or figure):

Introductions of invasive tree pests and diseases are rising, inflicting severe economic and environmental consequences. Swift and efficient surveillance for early detection is essential for enabling eradication or cost-effective control measures. Surveillance typically relies on a diverse group of observers, ranging from members of the public to trained inspectors. Additionally, pests and diseases exhibit variation in their signs and symptoms, impacting the ease with which they can be spotted. While diagnostic sensitivity in the laboratory is routinely quantified, there is a critical factor often overlooked: the probability of an observer detecting the pest or disease in the first place, often known as 'sampling effectiveness'. Quantifying sampling effectiveness is crucial in answering essential questions such as the likely prevalence of a pest or disease when initially discovered and how frequently and intensively searches need to be conducted to detect a pest or disease before it gets out of control.

This project will collect data from a broad range of observer types from members of the public (i.e. citizen scientists) to trained professionals. It will select case studies from current tree pests and disease threats including Ash Dieback and current *Phytophthora* outbreaks in the UK. It will take a multidisciplinary approach utilising fieldwork and epidemiological modelling techniques to quantify sampling effectiveness and diagnostic sensitivity, ultimately providing valuable insights into the effectiveness of tree health surveillance programs in the United Kingdom.

Key Research Areas:

- Observer Diversity: Investigate how various observer types differ in their ability to detect invasive tree pests and diseases, and observers respond to training.
- Symptom Variability: Analyse how variations in pest and disease signs and symptoms impact detection by different observer groups.
- Sampling Strategies: Develop and refine sampling strategies for early detection, considering factors including the frequency, intensity, and spatial distribution of surveillance efforts.
- Epidemiological Modelling: Create models to assess the probability of detection and overall effectiveness of a surveillance program.

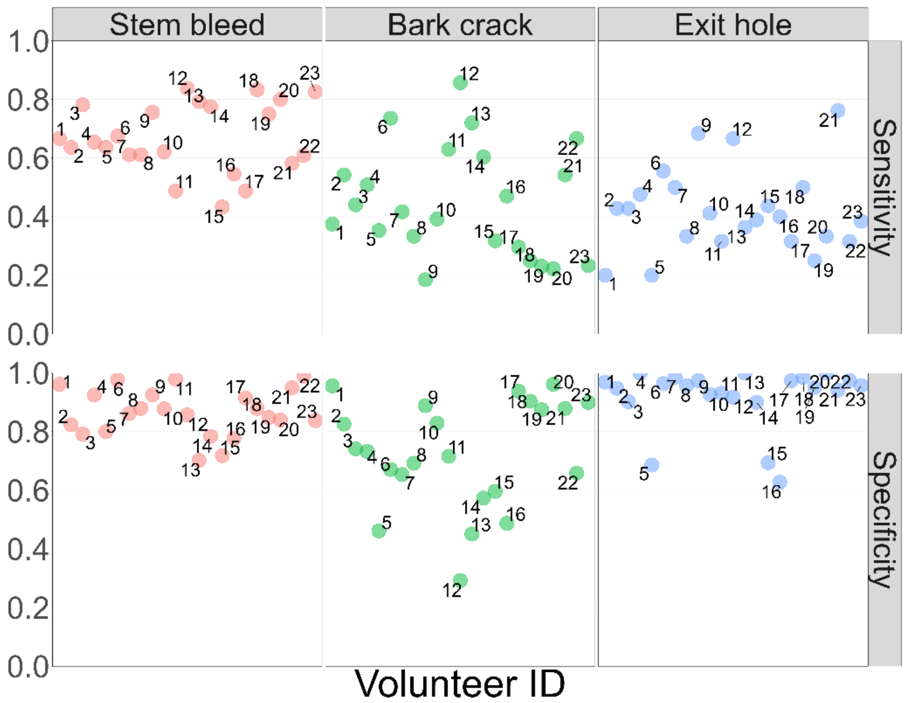

Figure 1. Preliminary data on the sensitivity and specificity of volunteers at detecting Acute Oak Decline symptoms based on experiments with volunteers conducted in summer 2022.

Methodology:

- Collect data using volunteers and professional surveyors on a variety of tree pest and disease symptoms. Case study pests will be seletected from current high profile examples in the UK including Ash Dieback Disease, Acute Oak Decline and *Phytopthora pluvilais* based their varied symptomology and economic importance.
- Collate validation datasets based on existing study sites for these diseases extended through intensive survey of trees at new sites.
- Develop and apply Bayesian statistical approaches to quantify sampling effectiveness in the absence of a validation dataset.
- Identify differences in sampling effectiveness across different symptom types and across the spectrum of different observer types, and the influence of training-prompts.

- Apply epidemiological models to identify the consequences of different sampling effectiveness for the optimal design of detection, delimiting and monitoring surveys in tree health.

Training and skills:

The project will provide the student with a range of both field ecology and quantitative skills. The student will be trained in the identification of plant species and the signs and symptoms of tree pests and diseases. They will learn experimental design as well as gain experience in the organisation and recruitment of volunteers. Data will be analysed using a range of approaches including Bayesian latent class analysis, and the student will be trained in R programming and in the design, development and validation of epidemiological models. They will learn effective communication with stakeholders in the tree health area.

Partners and collaboration (including CASE):
Further information on partners and collaboration (including CASE):

The project benefits from the inclusion of Forest Research on the supervisory team and builds on work co-designed with, and delivered to, Defra Plant Health with which the supervisory team have a long-term relationship. It will utilise preliminary data collected as part of our existing collaborations with Forest Research including their network of volunteers 'Observatree' and through their role in facilitating surveillance and outbreak response in the UKs forests.

Possible timeline:

Year 1: Collate existing datasets on tree health signs and symptoms and identify study sites for further data collection. Conduct severity assessments. Identify observer group types and recruit volunteers and professional observers. Using simulated data, develop initial statistical models to quantify sampling effectiveness.

Year 2: Design and conduct observer experiments across the different study sites and observer groups including questionnaires to assess observer characteristics and experience. Expand existing epidemiological models and parameterise for the case study pests.

Year 3: Apply statistical approaches to quantify sampling effectiveness based on the observer datasets. Identify differences in sampling effectiveness with different observer characteristics. Link surveillance modules to the epidemiological models and produce a user-friendly interface to optimise pest/pathogen surveillance for different observer groups.

Further reading:

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, 20170547.

Brown, N., Pérez-Sierra, A., Crow, P., & **Parnell, S**. (2020). The role of passive surveillance and citizen science in plant health. *CABI Agriculture and Bioscience*, *1*, 1-16.

Branscum, A.J., Gardner, I.A. and Johnson, W.O. (2005). Estimation of diagnostic-test sensitivity and specificity through Bayesian modeling. *Preventive Veterinary Medicine* 68, 145–163. doi: 10.1016/j.prevetmed.2004.12.005.

Mastin, A. J., Gottwald, T. R., van den Bosch, F., Cunniffe, N. J., & **Parnell, S.** (2020). Optimising risk-based surveillance for early detection of invasive plant pathogens. *PLoS biology*, *18*(10), e3000863.

Mastin, A. J., van den Bosch, F., Bourhis, Y., & **Parnell, S**. (2022). Epidemiologically-based strategies for the detection of emerging plant pathogens. *Scientific Reports*, *12*(1), 10972.

Mastin, A. J., van den Bosch, F., van den Berg, F., & **Parnell, S**. (2019). Quantifying the hidden costs of imperfect detection for early detection surveillance. *Philosophical Transactions of the Royal Society B*, *374*(1776), 20180261.

van den Bosch, F., McRoberts, N., Bourhis, Y., **Parnell, S**., & Hassall, K. L. (2023). The value of volunteer surveillance for the early detection of biological invaders. *Journal of Theoretical Biology*, *560*, 111385.

Further details:

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