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Mobile traps are better than stationary traps for surveillance of airborne fungal spores

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ABSTRACT

Eradication of invasive fungal pathogens that undergo wind-assisted dispersal can be extremely difficult. Many fungal pathogens can survive on multiple hosts and wind-assisted dispersal can rapidly spread inoculum over large areas, leading to wide-spread, multiple loci of infection. When eradication attempts are made, a surveillance system is required that can provide an early warning if the attempt has been unsuccessful. Therefore, there is a need for large-scale surveillance systems that can detect the movement of airborne inoculum, and which can be deployed over a large area. Traditional methods for trapping airborne fungal spores make use of stationary traps, however, traps can also be mounted on remote piloted vehicles, allowing the use of mobile traps, which can provide a far more flexible approach to the sampling of airborne spores. In this paper we compared a range of surveillance strategies based on stationary or mobile traps, and evaluated the ability of these traps to detect airborne spores. Using a computational model, we simulated a number of dispersal events, and the use of various surveillance strategies to detect these events. Results of our simulations showed that strategies based on mobile traps have a much greater probability of detecting airborne spores than strategies based on stationary traps, and that mobile trap strategies required a far lower number of traps to achieve a reasonable probability of detection. Surveillance strategies based on mobile traps can be effectively employed to define the extent of a pathogen outbreak, and also to monitor the reduction in airborne inoculum once eradication attempts have commenced. If deployed over suitably long time periods, continual no-detection results by surveillance strategies based on mobile traps can also provide a high level of confidence that eradication has been successful.

1. Introduction

Biosecurity can be seen as a continuum between pre- and post-border control (Nairn et al., 1996; Beale et al., 2008). While every effort is made to minimise the likelihood of exotic pests and diseases being introduced, biosecurity agencies recognise that national and state borders are not impermeable, and that post-border controls will inevitably need to be deployed (Nairn et al., 1996; Beale et al., 2008). Eradication is seen as the most extreme control method available to biosecurity agencies, involving the removal and destruction of infected hosts and their neighbours. The decision to make an eradication attempt is based on the invasive organism's potential cost to industry, it's assumed initial distribution and its potential for further spread (Olson and Roy, 2002; Breukers et al., 2008; Parnell et al., 2010). Where a decision is made to go forward with an eradication attempt, success is largely dependent on the time elapsed between detection and the initial incursion, the speed of the response and the accuracy of information relating to the organism's distribution and epidemiology.

Any attempt to eradicate a biosecurity threat requires a surveillance system that can provide evidence and confidence that eradication has been successful or otherwise. This surveillance system should be able to detect any survivors of the eradication attempt at either known or unknown infested locations. Importantly, the surveillance system needs to be able to detect any dispersal of the causal organism that takes it outside a designated quarantine area,

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as such dispersal poses a major risk to successful control or containment of the organism. Without a suitable surveillance system any spread of the organism beyond its pre-eradication distribution is likely to go unnoticed, and a failed eradication attempt may be incorrectly deemed a success, leading to serious negative consequences.

Eradication of fungal pathogens that undergo wind-assisted dispersal can be extremely difficult. While successful eradication is possible (Sweetingham et al., 1995; McKirdy et al., 2001), over time, the likelihood that every eradication attempt will successfully remove all inoculum greatly diminishes. Given the ability of many fungal pathogens to infect multiple hosts and to rapidly reproduce, even superficial levels of inoculum remaining after an eradication attempt may pose a significant risk. Where pathogens undergo wind-assisted dispersal, the potential exists for rapid spread over large areas, resulting in multiple loci of infection, and further attempts at eradication may quickly become unfeasible (Parnell et al., 2010).

Two classic examples of failed eradication attempts include the introductions of *Colletotrichum lupini* (lupin anthracnose) and *Ascochyta rabiei* (ascochyta blight of chickpeas) to Western Australia in 1994 (Sweetingham et al., 1995) and 1998 (Galloway and MacLeod, 2003), respectively. In the case of *A. rabiei*, eradication attempts were initially thought to be successful, however small isolated populations of the pathogen were able to survive and spread undetected into neighbouring regions, resulting in widespread disease in subsequent cropping seasons (Galloway and MacLeod, 2003). *C. lupini* was initially detected in trial plots at Mullewa, Goomalling, Nabawa and South Perth, and the infected plants were removed and destroyed (Sweetingham et al., 1995). However, in 1996, the pathogen was detected in commercial crops near Geraldton and Mingenew, which lie relatively close to Mullewa (Shea et al., 2008). It is not clear from the literature whether the initial eradication attempt at Mullewa was in fact unsuccessful, or whether the pathogen was reintroduced in 1996. However, *C. lupini* is able to survive on wild lupins that flourish on roadsides, and modelling of *C. lupini* dispersal shows that the presence of these roadside populations can greatly increase the rate at which the pathogen disseminates, and facilitates rapid spread over large areas (Bennet et al., 2011). The possibility of undetected spread from Mullewa to the surrounding regions via wild lupins was therefore a distinct possibility.

The examples of *A. rabiei* and *C. lupini* in Western Australia both illustrate how more effective, broader-scale surveillance could have dramatically improved biosecurity outcomes. In both of these examples, the use of a broad-scale surveillance systems could have provided an early warning that eradication had been unsuccessful, and that spread was occurring across the border of the original quarantine region. Knowledge of this spread could have allowed relevant agencies to alter the size of the quarantine area or, if further eradication attempts were deemed unfeasible, to more effectively contain and manage disease in subsequent years.

Surveillance for fungal pathogens undergoing wind-assisted dispersal requires the use of spore traps that can detect the presence of airborne spores. These traps may actively sample the air using a suction pump (e.g. Burkard Manufacturing Company Ltd., Rickmansworth, UK) or sample passively, such as those employed in the United States rust tracker program (Syngenta, USA). Many of the types of traps currently employed and the practicalities of their use are reviewed by Jackson and Bayliss (2011). Until recently, spore traps have generally been deployed in a stationary manner. However, mobile traps that utilise remote piloted vehicles (RPVs), can provide a far more flexible approach to the sampling of airborne spores (e.g. Maldonado-Ramírez et al., 1999; Schmale et al., 2006; Schmale et al., 2008; Gonzalez et al., 2009). In particular, the use of remote piloted aircraft allows sampling to occur over a much wider geographical area and at greater heights than would be feasible with stationary traps (Schmale et al., 2006). Traps mounted on RPVs can also be used to sample in areas that may be inaccessible using stationary traps, such as over large bodies of water, or in thickly forested or steep regions (Schmale et al., 2008; Gonzalez et al., 2009). In addition, the use of traps mounted on RPVs could allow the rapid deployment of multiple traps, and the coordination of sampling over multiple regions from the same location.

Given the advantages of mobile RPV mounted traps over stationary counterparts, it seems likely that the use of such traps would allow biosecurity agencies to deploy more flexible and comprehensive surveillance strategies than would be possible using stationary traps alone. In this paper, we tested this hypothesis, and compared the efficacy of surveillance strategies based on airborne traps with strategies based solely on conventional stationary traps. Comparisons were made using simulated dispersal events based on detailed meteorological data, and a computational model that calculated the number of spores detected by each trap over each hour in the simulation. Each strategy was then assessed based on its ability to detect the presence of airborne spores at differing rates of release.

2. Methods

In order to test and compare surveillance strategies we coupled an existing, well-established model of wind-assisted dispersal to a novel surveillance model, described in Section 2.4, that simulates the movement of RPV traps and calculates the number of spores sampled by each trap over time. We chose two sites for simulation, Northam (31.40 S, 116.9 E) and Merredin (31.29 S, 118.13 E), Western Australia. Both of these sites are located in important agricultural regions situated within the Western Australian grain belt.

2.1. Simulated scenario

For the purposes of this study, we assumed the following scenario. An infestation of fungal pathogens is detected, and a circular quarantine area with a radius of 15 km is set up around this initial detection site. It is assumed at this point that the pathogen may have spread beyond this initial detection site, but not beyond the quarantine area. A surveillance system is deployed on the boundary of the quarantine area, in order to detect the movement of any airborne inoculum across this boundary. An attempt is then made to eradicate pathogens within the quarantine area, reducing the level of infestation, and the subsequent level of airborne inoculum. Over the course of the eradication attempt, the surveillance system continues to monitor the boundary of the quarantine area, detecting any movement of spores across this boundary, which would indicate that the eradication attempt has failed. Depending on the ability of the surveillance strategy to detect airborne spores, a result of no detection could be considered strong enough evidence to demonstrate that the area is free of infection. However, if the surveillance strategy is expected to detect spores only some of the times that they are actually present, positive detection would indicate that the area remained infested, but a no-detection result could not be relied upon to demonstrate that the area was free from disease.

2.2. A model of wind-assisted dispersal

Simulation of dispersal events was performed using an existing, well validated and relatively detailed model of atmospheric transport, The Air Pollution Model (TAPM) (Hurley et al., 2005a, 2005b; Hurley and Luhar, 2005). TAPM consists of a dynamic, mesoscale,