Summer project report

The canary in the coal mine – how can surveillance for invasive plant pathogens be improved?

This summer I undertook a ten week research project in mathematical epidemiology under the supervision of Dr Robin Thompson, a junior research fellow at Christchurch College. In support of this project, I was awarded an undergraduate research bursary from the London Mathematical Society, and received additional funding from the Oxford Mathematical Institute. Merton College generously provided me with free accommodation and meals for the duration of the project, and so my thanks must go to all three institutions for facilitating this wonderful opportunity.

Infectious disease outbreaks in plant populations are responsible for devastating consequences, and mathematical modelling is increasingly used to aid detection and control of invading plant pathogens. Motivated by citrus greening disease, which is currently causing devastation in citrus groves in Florida, we considered whether or not more efficient detection could be achieved by introducing alternative hosts that are more susceptible and/or show symptoms more readily in an effort to find disease more quickly. Use of these so-called "sentinel" species would also have drawbacks; for example, sentinel plants may be less valuable or may become infectious more quickly than the original species. This sets up a trade-off, whereby there is an optimal proportion of sentinel hosts to plant amongst plants of the original species.

In this project, we extended a previously-used approach for modelling disease surveillance to include two host species, and further developed it to explore the optimal strategy for deploying sentinel species. This involved the analytic derivation of important quantities such as the expected incidence of disease at the time of detection, and the expected time until detection following primary infection. These quantities were built into a cost function, relating the relative overall gain to model parameters including the infectivity and susceptibility of the different species, detection probabilities, sample sizes, sampling intervals and costs and the values of healthy plants. By optimising the cost function, we found that under reasonable assumptions (such as a sentinel being more detectable than a crop), a non-zero proportion of sentinel plants is beneficial, and produced heat maps describing how this proportion and the respective cost changed with respect to varying different model parameters.

The model was then further extended to account for a 'cryptic period', a time frame after infection during which an individual plant is infectious, but asymptomatic, meaning that it cannot be detected by a monitoring program. The presence of such a period can have a marked influence on the effectiveness of monitoring programs, because being able to detect only a portion of infected plants when sampling will result in an increased discovery incidence. This is especially the case when considering our motivating example of citrus greening disease, which has a long asymptomatic period of 6 months to 3 years. Therefore, a sentinel species with a cryptic period shorter than that of the crop species has the potential to be exploited to greater advantage.

We subsequently made one further extension to make the model a more accurate reflection of a real life situation, introducing an 'exposed period', during which an individual has been infected, but is yet to become infectious or to display any symptoms. This delay period affects the disease dynamics; as these individuals are no longer susceptible and are not infectious, they cannot contribute to disease transmission and hence the epidemic growth rate is altered.

In summary, we showed that in certain situations the introduction of sentinel species into a population has the potential to shorten the discovery time of a disease, thereby reducing not only the incidence of disease upon discovery and consequently the loss in plant value, but also the cost of sampling leading up to detection.

Therefore, this project could lead to conclusions of practical relevance for policy makers for the detection of invading plant pathogens.

With the intention of continuing with mathematics to postgraduate study and beyond, I chose to undertake a research project this summer in order to gain insight into the reality of conducting mathematical research. My hope was that the project would confirm that I would be well suited to pursuing further research in this area.

At first I was apprehensive as the project felt very different to the more structured work I was used to. However, once I settled into it I found that I enjoyed working on my project much more than the work I would do during normal university term time. What I particularly enjoyed was the freedom to work on whatever I found interesting, in contrast to the sometimes formulaic learning necessitated by the need to pass an exam. Without the pressure of a deadline or needing to obtain the 'correct' answer, I found that I worked more freely and creatively and found the work rewarding rather than stressful. Therefore, I am optimistic that the working style required for postgraduate study would suit me better than that required for undergraduate study, which I think is a really positive outcome from having done the project.

The project has also allowed me to meet many new people. In addition to making friends with several other summer research students, being treated as an honorary postgraduate in the department for the summer has given me the opportunity to talk to doctoral students and other researchers in my university's mathematical biology research group. It has been really interesting to learn about their work, and helpful to hear accounts of their experiences of postgraduate study and details of some of the opportunities which are available.

Overall, undertaking this summer research project has been a fantastic way for me to experience mathematical research for myself, which has hugely encouraged me to apply for postgraduate courses this coming year. I am very grateful to have had this opportunity, and would highly recommend it to anybody who is interested in exploring mathematics beyond the scope of the undergraduate course.

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