Proposal: Modelling moth spread in an urban setting Jess Enright

Description of Project:
Oak Processionary Moth (OPM) is a major oak pest that has become established over the past half-century through most of mainland Europe [1,2], and since 2006 has been found in London. The caterpillars of this moth pose a threat to tree, animal, and human health: the caterpillars can cause defoliation in oaks, which may threaten trees already under other stresses, and the hairs of the caterpillars can cause airborne outbreaks of rash and respiratory problems in humans [3–5]. Since introduction to London in 2016 via imported urban trees, OPM have resisted eradication, and efforts are currently focused on containing and slowing spread of this pest, at significant cost to government and private stakeholders [6]. Should the pest reach the greenbelt surrounding London, it would likely become uncontrollable [6].

Despite the fact that good OPM spread prediction would be invaluable for targeted surveillance and strategic management, very little modeling work has been done. The only published work in the field makes use of a dispersal model based on the assumption of moth flight between adjacent patches of habitat, but was produced with limited access to data, and makes no use of road network information (it is thought that road vehicles are an important mode of OPM spread). I propose a studentship that will develop a multi-part epidemiological model of OPM, including spread via moth movement and road traffic, as well as moth population growth within a patch of habitat.

The Royal Botanic Garden at Kew (which we abbreviate as Kew) will be a key partner in this project: they will provide expertise and information to parameterize the model, as well as relationships with the OPM management team at Defra and London urban tree management stakeholders.

This project aligns with the university's **strategic plan** its goals of high-impact research, and increasing connectedness. Because the spread of OPM is thought to be partially climate-change-mediated, it fits within the university's Environmental Change research theme.

The **impact** of this project with be delivered by interaction with two main groups: Kew (and through them, Defra), and the new Scottish Centre for Expertise in Plant Health (and through them, Scottish Government). This project would make use of data and expertise at Kew, and ultimately produce a tool for modeling the spread of OPM, and the risk of OPM in different locations. The goal is to recommend targeted surveillance locations and evaluate treatment options to managers such as Defra, the London Tree Officers' Association, London Boroughs, etc. Potential partners at Kew have the relationships necessary for thus type of communication. While we propose to parameterize the model specifically for OPM in London, the majority of modeling framework and code should be relatively portable with respect to the type of pest: we hope to make it re-usable for other urban pests, providing a basic model that is available for use in a Scottish context (or elsewhere) by the CEPH in the case of an urban pest outbreak.

Proposed Research Programme:
We propose that the student develop the OPM model in the following five work packages (some of which may be concurrent):

WP1: Data acquisition and processing
It will take some time for the student to become familiar with the datasets required for this project. Key datasets include the species and locations of London trees [7], road traffic information [8], OPM outbreak information (via Kew and Defra collaborators), as well as OPM within-patch spread information from ongoing experiments at Kew.

WP2: Simple within-patch OPM model
The student will develop a simple within-patch population increase model, using an appropriate growth function (potentially including climate as an input). This phase of development will require knowledge from collaborators at Kew. This portion of the model will be an important component of the overall model, but is not the main objective of this project (which focuses on spread modeling). Future projects may expand on this component to allow more realistic cost and health impact studies modeling of OPM, and if the project is well-engineered, then expanding this component should be possible without re-implementing the remainder of the model.

WP3: Moth flight geographic dispersal model
Informed by data on the spread of OPM within Kew, the student will construct a geographic dispersal model, either using a smooth geographic dispersal kernel over the space of suitable adjacent habitat, or adapting part of the work in [10].

WP4: Road-traffic network dispersal model
Using road traffic data and London urban tree location data, the student will produce a network-based model of dispersal probability along transport corridors.

WP5: Validation of combined model
As is typical in epidemiological applications, our options for whole-model parameterization and validation are limited: we only have one real-life outbreak datapoint for comparison. We nevertheless propose that the student validate by comparison against real outbreak data, and by scenario production, in which they will produce a continuum of sample model outputs over a feasible parameter space for stakeholder inspection, along with a sensitivity analysis.

WP6: Code maintenance and documentation
Because we propose modular development of the model, and because it is important that the student follow good software engineering practices. This work will occur throughout the project, but we highlight it as a WP because of its importance. Well-maintained and re-usable public code is important for the longer-term impact of this project.

Supervisory Arrangements:
Because the proposed first supervisor (Dr. Enright) is an early-career lecturer who has not previously supervised a student, we propose Prof. Kleczkowski (who has both supervisory and plant health modeling experience) as a second supervisor. To formalize the relationship with Kew Gardens, we propose Dr. Paul Wilkin (Head of Science in Natural Capital and Plant Health, Kew Gardens) as an external member of the supervisory team.

External Partners:
Kew will be our main external partner in this project, and will support with expertise, data, and access to policy-makers in the area. Key staff members at Kew include Paul Wilkin and Sara Redstone (who manages OPM monitoring and treatment at Kew). Lisa Smith (Head of Tree Health Policy & Plant Health Evidence & Analysis) is a key contact at Defra, and we plan to consult with her team during the project. The University of Stirling has signed a Memorandum of Understanding with Kew – we propose this studentship as a way of jump-starting work with Kew, with the aim of developing larger long-term projects.

Follow-on funding:
Developing this first project with Kew into a series of larger, externally funded, collaborations is one of the primary motivations for this project. We anticipate further opportunities for funding via BBSRC, Defra tendering, and via the new Scottish Centre for Expertise in Plant Health. While the model we have proposed will advance the state of the art, and provide a challenge to an appropriate student, it has significant scope for improvement with further data and richer models. If this project provides a successful prototype (and associated manuscripts) there is scope to propose a project with more involved epidemiological, costing, and game theoretic decision-making components, likely suitable for a BBSRC or EPSRC targeted call. Beyond the topic of OPM, we intend that this project spark further collaboration with both Kew and the CEPH on a variety of topics, including data-driven plant health modeling, food chain supply modeling, and data science surrounding the mapping and impact of urban trees.

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