Disease Dynamics and Control in the presence of a reservoir.

Proposal for divisionally funded PhD studentships by Dr Anthony O'Hare.

Description of Project

Livestock diseases are often accompanied by a wildlife reservoir in which the disease is not managed or even often observed. These reservoirs can complicate the management or containment of disease outbreaks as they can encompass several farms facilitating an unobserved pathway of transmission between farms.

Livestock in the UK are routinely tested for several diseases and undergo pre-movement testing at an individual level (cattle) or batch level (sheep). The records of these tests and movements create valuable resource for understanding the transmission of infection during an outbreak. However, the presence of a wildlife reservoir adds a potential for transmission that is difficult to quantify and cannot be seen in these movement records. Testing and culling of infected livestock represents a considerable expense for the UK (it costs approx. £100M to deal with bovine TB each year in the UK) and any curtailment in the spread of infectious diseases will have a significant [positive] impact on the UK taxpayer.

The aim of this project is to develop a mathematical model of an infectious livestock disease, incorporating a network of farms and reservoirs, to determine the optimal vaccination, testing or eradication programmes to combat the spread of the disease. We will test this model against commercially important livestock diseases (bovine TB, avian influenza, foot and mouth disease) where the farm, movement and outbreak data are available. I have contacts within DEFRA and Scottish Government that can supply the disease outbreak data that we can test the model against.

There is understandable public interest in how wildlife is treated, especially when they are culled in favour of protecting livestock. This research will have a non-academic impact within the community of users of the countryside in that we aim to demonstrate regimens that provide maximum protection to livestock and minimum disruption to wildlife.

The mathematics group in Stirling have a wealth of expertise in modelling disease spread and this research project would be an easily align with this group. Furthermore, this research can be applied to a variety of commercially important diseases in the UK and so has the potential for very high impact within the industry as well as with policy makers within the UK government.

Given the commercial importance of agriculture to both food security and the economy of the UK there is potential for further funding off the back of this project that will help the university meet its impact and research funding goals.

Proposed research programme

This goal of this research is to model the dynamics of how disease spread in the presence of a reservoir and develop optimal control strategies (for both reservoir and livestock). We will test the model against several important livestock diseases. There are many scales of interaction involved in this approach:

- Within-farm transmission - We will use an agent based model to simulate the transmission between animals on the same farm.
- Between-farm transmission – We will model the transmission between farms via animal movements and an exponential transmission kernel to model *over-the-fence* transmission. Detailed records are kept for all animal movements within the UK which we will utilise in applying this model to real life situations. We will also simulate the pre-movement testing within our model.

- Within-reservoir transmission – we will model the transmission dynamics within the reservoir. The model may be different to the within-farm model (not least because the wild reservoir is not routinely checked).
- Between-reservoir – we will simulate the migration/territorial fighting of animals within a reservoir to simulate *over-the-fence* transmission between reservoirs.
- Reservoir-Farm/Farm-Reservoir transmission – we will also simulate the transmission of disease from farm to reservoir and vice-versa. Reservoirs will typically span several farms which gives an unobserved transmission pathway between farms.
- Seasonal effects will be considered as [some] farm animals are housed over winter allowing greater within-herd disease transmission, and animals that make up the reservoir may change their behaviour in each season.

Once we have a model that can simulate a realistic epidemic we will use it to investigate various control strategies given realistic inputs such as culling wildlife, increased testing, different testing strategies, improved test sensitivities, biosecurity (removing or decreasing the interaction between farm animals and the reservoir).

The first milestone will be the creation of a simple SIR model within the farm and an SI within the reservoir and will include farm-farm movements. We will use a deterministic model to observe the effect of the contact between the farm and reservoir and determine the most effective culling, biosecurity, and testing strategies. We will back this up by simulations and publish the results.

We will then apply this model to a specific livestock disease given available data to demonstrate the impact of different management/containment strategies and identify the most appropriate.

Supervisory arrangements (including any co-supervisors from other Divisions/Faculties)

The main supervisor will be Dr Anthony O'Hare and co-supervised by Prof Rachel Norman (both from CS&M). I would propose that this project also be co-supervised by Prof Rowland Kao from the University of Glasgow. Prof Kao and I have modelled bovine TB dynamics for several years and he has access to datasets of UK agricultural data that can be utilized in this research to verify our model predictions. Furthermore, he has a large network of contacts within the industry as well as within the governments of the UK, Scotland and NI which will provide appropriate avenues for dissemination of our results.

(Any) external (e.g. industrial) project partners/collaborators (including details of any committed financial or in-kind support, and the likely impact / value they will add to the PhD, e.g. arrangements for industrial placement(s), research and business skills training etc.)

See previous point. It should be noted that Prof Kao would only be acting in a supervisorial role and will be bringing support in the form of access to data and relevant agencies. He will not be bringing financial support to this project.

(Any) plans for follow-on funding (to build sustainable collaborations in this research area)

Many (production) animal diseases have a wildlife reservoir and we can see potential to apply the work to specific diseases to determine relevant control measures. We will incorporate Prof Kao's network of contacts to build disease appropriate teams to optimise the chance of obtaining funding to apply this research to diseases beyond those considered in this research. Identifying calls at this stage is premature but we envisage publications in the second year of this research that will provide the background for a response to any relevant calls that appear.