A model to explore the success of control and accreditation programmes in livestock

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Introduction

Control and accreditation schemes exist for a number of endemic diseases in Scotland. The motivation for the individual owner depends on the disease status of the herd; herds (and flocks) join control schemes to remove disease, or join accreditation programmes to reduce the risk of acquiring the disease and benefit from a 'high health status'. At a national level, criteria for assessing a control and accreditation schemes include its capacity to reduce or eliminate disease and its cost effectiveness. Here a model of this process is presented to ask three questions,

- What effort is required for control and accreditation to be successful, and how does current prevalence influence this?
- How does the net cost of disease and its control vary?
- Should most effort be concentrated at control or accreditation?

Background

Control and accreditation programmes can be regarded as a form of **surveillance**, where herds are tested for the presence of disease, and depending upon the test results, the herd is either **accredited** or placed in a **control programme**

Diseases in Scotland with control and accreditation programmes,

Cattle
- Bovine viral diarrhoea virus
- Infectious bovine rhinotracheitis
- Leptospirosis
- Johne's disease

Sheep
- Caseous lymphadenitis
- Maedi-visna
- Enzootic abortion of ewes

Definitions

Surveillance – monitoring of prevalence of disease in a population, and action being taken to control disease
Accredited – a herd has recent negative test results illustrating freedom from disease. It is assumed that accredited herds purchase animals only from other accredited herds, resulting in a low probability of disease incursion
Controlled – a herd has recent positive test results where test positive individuals are removed from the herd and further control measures implemented
Success – Either reduction in the prevalence of infected herds, or elimination of disease from a population so that further control efforts are no longer required, only control of incursions
Effort – the proportion of the total population each year which need to be recruited into a control or accreditation programme

Methodology

A compartmental model was designed to capture the dynamics of infection and control. Herds were assigned to one of four compartments; Susceptible, Infected, Controlled or Accredited (see Figure 1 and definitions). Analytic solutions to the set of differential equations were used to explore the objectives. Effort was defined as the combined rate to accreditation and control (at equilibrium)

$$\text{Effort} = v(\rho S^* + (1-\rho) I^*)$$

The cost of disease and control were assigned values where the total cost was;

b – cost of being diseased; a – cost of testing; c – cost of disease control

$$\text{Cost (per year)} = I^*b + C^*(a + b + c) + A^*a$$

The net cost is the cost of disease being present without control minus the costs of the reduced prevalence of disease and the costs of control

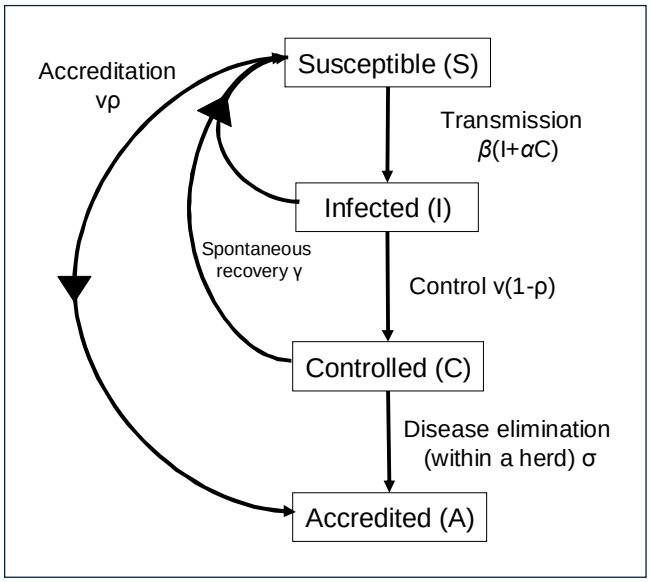

Figure 1; schematic of a model that describes the process of infection within a population and how herds may be join control or accreditation programmes.

Results

Default values in all results shown; prevalence 20%, β = 0.146, γ = 0.1, alpha = 0.1, μ = 1/60, σ = 0.25, v = varied, ρ = varied a = 140, b = 400, c = 8000

1. What effort is required to achieve a reduction in prevalence?
   A minimum amount of effort is required for control and accreditation programmes to result in a reduction in prevalence. If the initial prevalence is 20%, 0.0008 of the population per year need to be recruited to maintain a 50% reduction in prevalence (Figure 1a). With an increasing initial prevalence, more effort is required to achieve the same result. The net cost of a large reduction in prevalence is generally positive (Figure 1b). If only a small reduction in prevalence is achieved, this is usually at a loss as the costs of controlling disease are not outweighed by a reduction in prevalence and associated reduction in disease losses.

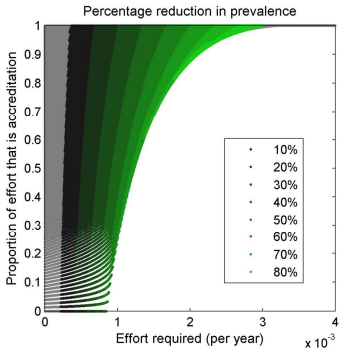

Figure 1a. The effect of changing the effort per year and the proportion of effort that is control on the percentage reduction in prevalence of infected herds (black – 10% reduction, l green – 80% reduction).

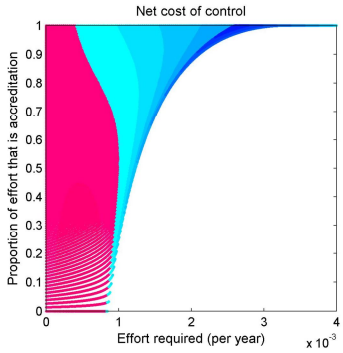

Figure 2b. The effect of changing the effort per year and the proportion of effort that is control on the net cost of implementing control. Pink – loss, cyan to blue – an increasing profit.

2. Should most effort be targeted at control or accreditation?
   With unlimited resources, accreditation appears to be the most cost effective option (Figure 2b). Control of infected herds has an associated cost, and so as more infected herds are controlled the overall costs are increased. A net benefit is observed when there is sufficient reduction in prevalence. Resources (in terms of available tests and farm visits) are likely to be limited, and so there is a trade-off between effort available and economic savings. This is achieved through a combination of accreditation and control.

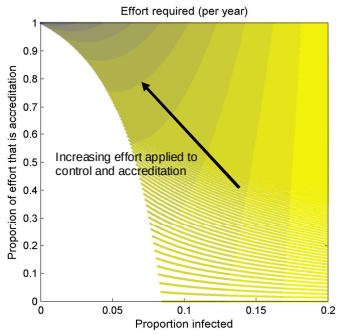

Figure 2a. The resultant change in proportion infected and the extent of effort that is accreditation per year, given the amount of effort per year (colour of plots).

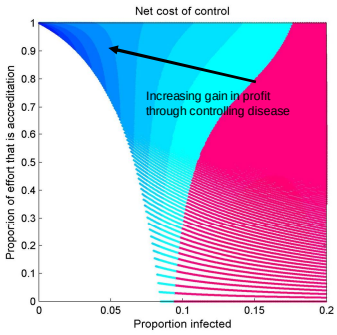

Figure 2b. The resultant change in proportion infected and the extent of effort that is accreditation per year, and the net cost of controlling disease (colour of plots).

Conclusions

- Herds enrolling into control and accreditation programmes benefit individually but given sufficient effort also benefit the total community
- Control of infected herds is more costly than accreditation of disease free herds. Consequently, it may be beneficial to recruit disease free herds into a programme. However if resources are limited, a combination of control and accreditation will result in a greater reduction in prevalence, and may be more cost effective
- Here, it is assumed that control of infected herds is more expensive than accreditation of disease-free herds. This may not be true for all diseases, and will effect model predictions.
- This simple model could be applied to specific diseases and aid the development of an optimal surveillance programme to reduce disease prevalence

This work was undertaken through the Scottish Government funded Centre of Excellence in Epidemiology, Population Health and Infectious Disease Control.