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Evaluating the efficacy of regionalisation in limiting high-risk livestock trade movements

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ABSTRACT

Many countries implement regionalisation as a measure to control economically important livestock diseases. Given that regionalisation highlights the difference in disease risk between animal subpopulations, this may discourage herd managers in low-risk areas from purchasing animals from high-risk areas to protect the disease-free status of their herds. Using bovine tuberculosis (bTB) in New Zealand as a case example, we develop a novel network simulation model to predict how much the frequency of cattle movements between different disease control areas (DCAs) could theoretically change if herd managers adopted the safest practices (preferentially purchasing cattle from areas with the lowest risk of bTB), if herd managers adopted the riskiest practices (preferentially purchasing cattle from areas with the greatest risk of bTB), or if herd managers made trade decisions completely at random (purchasing cattle without consideration for bTB disease risk). A modified configuration wiring algorithm was used in the network simulation model to preserve key temporal, spatial, and demographic attributes of cattle movement patterns. The simulated frequencies of cattle movements between DCAs in each of the three behavioural scenarios were compared with the actual frequency of cattle movements that occurred between 1st July 2010 and 30th June 2011. Our results showed that the observed frequency of cattle movements from high-risk areas into low-risk areas was significantly less than if trade decisions were made completely at random, but still significantly greater than if herd managers made the safest possible trade decisions. This suggests that while New Zealand cattle farmers may have adopted risk-averse trading behaviour in response to regionalisation, there are other underlying factors driving livestock trade, such as established supplier-buyer relationships and heterogeneous individual perceptions towards disease risk, which may reduce the potential efficacy of regionalisation as a disease control strategy. Physical constraints and socio-psychological factors that determine herd managers' livestock trading behaviour warrant further studies to better understand how herd managers respond to future livestock disease regulations. The flexibility of a network re-wiring framework presented in this study allows such a behavioural response to be incorporated into a disease simulation model, which will in turn facilitate a better evaluation of disease control strategies.

1. Introduction

1.1. Background

Many countries employ regionalisation as a measure for controlling economically important livestock diseases. This approach typically involves drawing geographical boundaries around subpopulations of farms with similar disease status and then imposing targeted control measures such as movement restrictions, testing, and/or vaccination, to minimise the risk of disease spreading from high-risk regions into low-risk regions (World Organisation for Animal Health OIE, 2015). Livestock trade within and between low-risk regions is generally unrestricted to minimise disruption to normal farming practices. The regionalisation approach is currently used as part of national disease control programmes for Johne's disease in Australia (Geraghty et al., 2014), bovine tuberculosis in New Zealand (Livingstone et al., 2006) and the United Kingdom (Bennett, 2009), and brucellosis in the United States (USDA, 2014).

As highlighted by analyses of national level livestock movement records, regionalisation can significantly alter livestock trading patterns (Vernon and Keeling, 2012). The change in trading patterns is, however, multifactorial. On one hand, negative pre-movement

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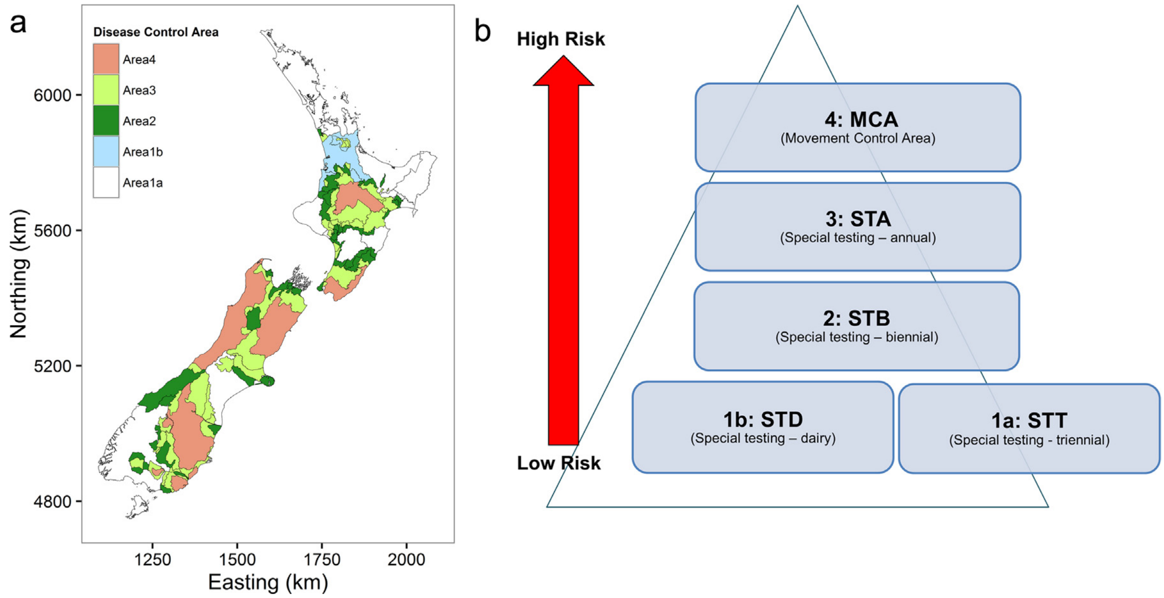

Fig. 1. Map of New Zealand showing the distribution of five disease control areas in the study period and diagram showing the relative levels of bTB transmission risk from wildlife in each disease control area.

test results may provide incentives for some herd managers to purchase livestock from high risk areas and increase the frequency of high risk movement from high to low risk areas (Christley et al., 2011). One the other hand, the frequency of high risk movement may reduce because some herd managers would be inclined to send livestock directly to slaughterhouse to avoid pre-movement testing costs (Bennett, 2009). The need for testing should also remind herd managers of the risk of disease introduction and this may discourage herd managers from purchasing livestock from high risk areas (Christley et al., 2011). Despite this complexity herd managers are, in general, risk averse (Botterill and Mazur, 2004; Valeeva et al., 2011) and there is some evidence that the frequency of high risk movement in the United Kingdom reduced after the introduction of regionalisation (Gates et al., 2013).

Although regionalisation may encourage herd managers' risk-averse (i.e. non-risky) trading behaviour, market opportunities are limited and herd managers have an inherent need to move livestock when sale prices are at a premium. These limited opportunities may in turn constrain how herd managers can alter their trading patterns in response to regionalisation. Should herd managers not have options for a feasible alternative trading pathway, regionalisation might not affect the livestock movement patterns. The impact of regionalisation on reducing the frequency of high risk movement should be therefore evaluated accounting for these limitations. By developing a novel network rewiring model, we quantified how much the livestock movement pattern can actually vary under these constraints, using regionalisation established in New Zealand for bovine tuberculosis control as a case example.

1.2. *Bovine tuberculosis in New Zealand*

Regionalisation was first introduced to New Zealand in the mid-1990s to aid in the control of bovine tuberculosis (bTB) (Livingstone et al., 2015a). The country is divided into Disease Control Areas (DCAs) that are assigned into one of five categories based primarily on the perceived risk of bTB spreading to livestock herds through contact with infected local wildlife populations. The DCA categories include special testing triennial (STT), special testing dairy (STD), special testing biennial (STB), special testing annual (STA), and movement control areas (MCA). For simplicity, we subsequently refer to these as Area 1a, 1b, 2, 3, and 4, respectively, with the higher number indicating a higher perceived risk of bTB transmission from wildlife. Areas 1a and 1b are considered to have an equally negligible risk. The boundaries of DCAs are defined and reviewed annually and details of each DCA can be found elsewhere (Ryan et al., 2006; Buddle et al., 2015). Fig. 1 shows the New Zealand DCA boundaries as of 2011.

As summarised in Table 1, each DCA has a different bTB testing and control regime that scales in intensity according to the disease risk. Cattle and deer moving off farms in Area 4 where the perceived risk of wildlife transmission is the highest must be tested within 60 days prior to the movement (Buddle et al., 2015). Previous surveys on the perception of New Zealand farmers towards regionalisation suggest that herd managers in low-risk areas recognise that purchasing livestock from high- risk areas carries an increased risk of introducing bTB to their herd, whereas herd managers in high-risk areas are either less aware of this risk or have a tendency to preferentially purchase animals from high-risk areas because of their discounted price (Sauter-Louis, 2001; Corner, 2002). If these perceptions translated into practice, we would expect to a see a reduced frequency of movements from high-risk regions into low-risk regions and an increased frequency of movements within high-risk regions compared to the patterns that may be expected if herd managers traded completely at random.

1.3. *Objectives*

In this analysis, we developed a novel network re-wiring algorithm that allows us to explore the range of possible movement patterns that could emerge under three different trading behaviour scenarios: (1) the 'safe' scenario where farms in low-risk regions preferentially source cattle from the lowest risk DCAs to prevent bTB introductions, (2) the 'risky' scenario where farms in low-risk regions source cattle from the highest risk DCAs to capture price advantages, and (3) the 'random' scenario where farms make trade decisions without considering the DCA origin of purchased cattle. The results from the re-wired networks were compared with the observed network of movements to determine how effective regionalisation has been in reducing the frequency of high-risk cattle movements in New Zealand.