# 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. 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, which may reduce the potential efficacy of regionalisation as a disease control strategy.

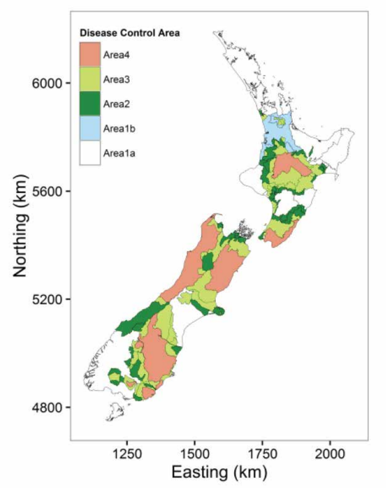
## Introduction
Many countries employ regionalisation as a measure for controlling economically important livestock diseases. This approach typically involves drawing geographical boundaries around subpopulations of farms with similar disease status and then imposing targeted control measures such as movement restrictions, testing, and/or vaccination, to minimise the risk of disease spreading from high-risk regions into low-risk regions.

As highlighted by analyses of national level livestock movement records, regionalisation can significantly alter livestock trading patterns (1). Given the need for testing should remind herd managers of the risk of disease introduction, regionalisation may discourage herd managers from purchasing livestock from high risk areas (2). Herd managers are, in general, risk averse (3) and there is some evidence that the frequency of high risk movement in the United Kingdom reduced after the introduction of regionalisation (4).

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.

New Zealand 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 (Area1a), special testing dairy (Area1b), special testing biennial (Area2), special testing annual (Area3), and movement control areas (Area4), with the higher number indicating a higher perceived risk of bTB transmission from wildlife. Boundaries of DCAs are shown in Figure 1.

**Figure 1.** Boundaries of DCAs in New Zealand (2011).

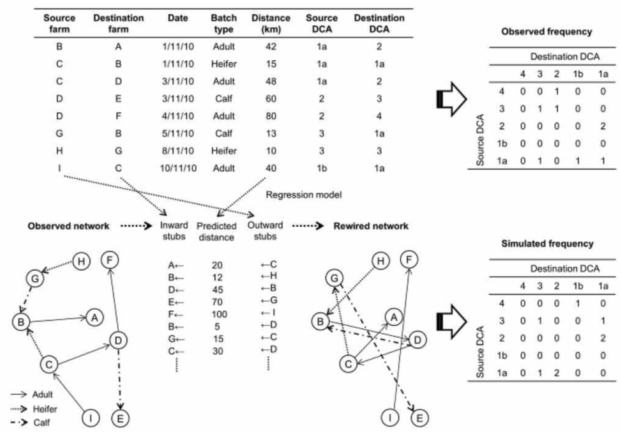



In this analysis, we developed a novel network re-wiring algorithm that allows us to explore the range of possible movement patterns that could emerge under three different trading behaviour scenarios: (1) the 'safe' scenario where farms in low-risk regions preferentially source cattle from the lowest 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.

## Materials and methods

In this analysis, we used dairy cattle movement data recorded between 1st July 2010 and 30th June 2011. A total of 23,443 batch movements were eligible for analysis. Each batch was classified as calves, heifers, or adults according to the age group of cattle that were dominant in the batch. A modified configuration wiring algorithm was used for network simulation to preserve key temporal, spatial, and demographic attributes of cattle movement patterns. In the simplest configuration wiring model, each node is assigned a set of virtual objects - stubs - corresponding to the number of connections it has in the original network. In our model, each farm was assigned a fixed number of inward stubs corresponding to the number of batches received and a fixed number of outward stubs corresponding to the number of batches sent. Connections of inward and outward stubs were performed by working through the list of inward stubs sequentially from top to bottom until no more stubs remained. For each inward stub, we searched through the list of remaining outward stubs to identify ones that met the following criteria: (1) outward and inward stubs had the same age class, (2) the movement date for outward stub was the same as or within 7 days of that of a given inward stub, (3) the source and destination farms were different, and (4) geographical distance produced by inward and outward stubs was the closest possible match to the distance that was predicted by hurdle regression models we developed based on farm-level and batch-level characteristics. Schematic representation of the rewiring process is summarised in Figure 2.

**Figure 2**. Schematic representation of rewiring process.




To capture stochastic variation in the possible networks, we repeated the re-wiring process 1,000 times for each of the three scenarios, cited above.

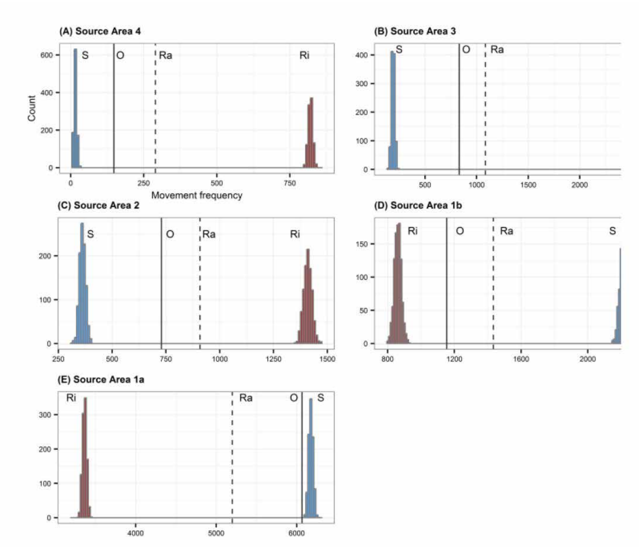
## Results and discussion

For movements into Area 1a from Areas 2, 3, and 4, the observed frequencies were smaller than the 2.5th percentile of simulated distributions from the network rewiring model under the random selection scenario, whereas the observed frequency exceeded the 97.5th percentile of a distribution for movements within Area 1a.

Figure 3 shows where the observed frequencies of movement towards Area 1a lie in the spectrum of the lower and upper limits of movement frequencies that were reproduced in the safe and risky scenarios, respectively. Figure 3 (A) – (C), and (E) show that the observed frequencies were between those simulated under the random and safe scenarios and farther away from that simulated under the risky scenario. In contrast, the observed movement frequency from Area 1b to Area 1a was between simulated frequencies under the risky and random scenarios (Figure 3 (D)).

In conclusion, we 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.

**Figure 3.** Comparison of the observed and simulated frequencies of movement towards Area 1a.




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.

We provided evidence of human behavioural change in response to disease control strategies. Future studies focus on understanding physical constraints and socio-psychological factors that determine herd managers' livestock trading behaviour. This will allow us to evaluate the efficacy of disease control strategy explicitly accounting for the effect of human behavioural feedback on disease spread, which in turn will facilitate the development of effective disease control policies.

## References

1. **Vernon *et al.*** Prev Vet Med. 105, 110–117, 2012
2. **Christley *et al.*** Prev Vet Med. 100, 126–133, 2011
3. **Valeeva *et al.*** Prev Vet Med. 102, 284–295, 2011
4. **Gates *et al.*** Prev Vet Med. 108, 125–136, 2013