Factors Associated with the Transmission Dynamics of Bovine Tuberculosis in New Zealand

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— Abstract —

This thesis presents the results of a series of studies on the epidemiology of TB in brushtail possum and domestic cattle populations in New Zealand.

The first set of studies provides an analysis of the results of routine TB testing carried out in the Featherston area from July 1980 to June 2004. The median annual incidence rate of TB reduced from 4.7 cases per 1000 cattle-years at risk for the period 1986 to 1991 to 1.8 cases per 1000 cattle-years at risk for the period 1992 to 2003, coincident with the use of poisoning to control possums in the surrounding forest park (a major possum habitat area). We identified clusters of cattle TB cases adjacent to the forest park and found no evidence of spatio-temporal interaction of TB risk among farms. Our findings support the hypothesis that possums living in the forest park are a source of bovine TB in this area and that farm-to-farm transmission was not an important mechanism of infection spread. A mixed-effects Poisson regression model was developed to investigate the influence of farm-level covariates on the number of cattle confirmed with TB. The model showed that, despite intensification of possum control activities, proximity to forest parks remained a significant predictor of the number of confirmed TB cases per farm per year. Our analyses identified a significant, 3-fold increase in TB risk in dairy cattle relative to beef conditional on the size of local possum habitat, and confirmed the positive influence of cattle population size and the presence of previous infection status as a determinant of the number of confirmed TB cases per farm per year.

The second set of studies investigates details of capture events recorded during a longitudinal, capture-mark-recapture study of possums in a 22-hectare study site near Castlepoint, from April 1989 to August 1994. Social network analyses were used to identify contact patterns and to estimate the influence of contact on R_0 for bovine TB. The average number of contacts per possum ranged from 20 to 26 per year. We estimated that TB would spread if an average of between 1.94 and 1.97 infective contacts occured per year per infected possum. We evaluated the effect of sex, habitat and contact behaviour of 26 *post-mortem* confirmed TB cases in possums with those of 104 matched controls. Unit increases in the number of infected contacts increased the odds of TB infection by 2.61 (95% CI 1.29 – 5.29, P $<$0.01). Our results show that individual contact behaviour is a determinant of the presence of TB foci within this population and challenge the hypothesis that contact with many individuals increases the probability of infection.

A model to predict spatial variation in possum abundance was developed using a Geographic Information System. Details of possum capture events were obtained from 157 10-trap lines distributed within 42 randomly located transects at Molesworth Station. Two GIS-based models were developed to predict the number of possums caught per line using Poisson regression techniques. The first model used remotely sensed environmental data; the second used a combination of remotely sensed and fine-scale data. Both models provided adequate predictive ability with Pearson correlation coefficients greater than 60%. We conclude that the prediction maps produced from this model provide a useful decision support tool for possum control managers. These results have implications for the management of TB in this area of New Zealand, providing the information that will allow effective control activities to be applied at significantly lower cost.

A Tony et Lila.
To my past and my future,
Always remembered and loved.

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Nomenclature

AHB	Animal Health Board
AR	Activity range
AIC	Akaike information criterion
BCG	Bacillus Calmette-Guérin
BFT	Between-farm transmission
CAR	Conditional autoregressive model
CC	Clustering coefficient
CCC	Cophenical correlation coefficient
cELISA	Competitive enzyme linked immunosorbent assay
CFT	Caudal fold test
CI	Confidence interval
CSF	Classical swine fever
CSR	Complete spatial randomness
CV	Coefficient of variation
DEM	Digital elevation model
FB	Flow-betweenness
FPM	Forest-pasture margin
GAM	Generalised additive model
GD	Geodesic distance — Path length
GIS	Geographic information system
GPS	Global positioning system
HVF	Height above valley floor

IR	Incidence rate — Incidence density
IRR	Incidence rate ratio
LCDB2	Land cover database
LENZ	Land environments of New Zealand
LISA	Local indicators of spatial autocorrelation
LME4	Linear mixed-effects models using S4 classes
LRT	Likelihood ratio test
MCMC	Markov chain Monte Carlo
NDVI	Normalized difference vegetation index
NLDB	National livestock database
NPCA	National Pest Control Agency
NPMS	National pest management strategy
NSIHC	Northern South Island high country
OIE	Office International des Epizooties — World Organisation for Animal Health
OR	Odds ratio
PPV	Positive predictive value
Q1 – Q4	First to fourth quartiles
P	P-value
R_0	Basic reproduction ratio
R^2	Coefficient of determination
REA	Restriction endonuclease analyses
RHDV	Rabbit haemorrhagic disease virus
ROC	Receiver operating characteristic
RR	Risk ratio
RTCI	Residual trap-catch index

RVF	Rift valley fever
SAR	Simultaneous autoregressive model
SD	Standard deviation
SE	Standard error
SI	Susceptible-Infectious
SIR	Susceptible-Infectious-Recovered
SNA	Social network analysis
SPB	Short path betweenness
SPLANCS	Spatial and space-time point pattern analysis
SWN	Small-world network
TB	Bovine tuberculosis
TCI	Trap-catch index
TSS	True skill statistics
UPGMA	Unweighted pair group method with arithmetic mean
VRA	Vector risk area
WCT	Wildlife-to-cattle transmission
WFT	Within-farm transmission
WNV	West Nile virus

List of Publications

Peer-reviewed articles:

Porphyre T, Stevenson M & McKenzie J (2008) 'Risk factors for bovine tuberculosis in New Zealand cattle farms and their relationship with possum control strategies'. *Preventive Veterinary Medicine* **86**, 93 – 106.

Porphyre T, Stevenson M, Jackson R & McKenzie J (2008) 'Influence of contact heterogeneity on TB reproduction ratio R_0 in a freeliving brushtail possum *Trichosurus vulpecula* population'. *Veterinary Research* **39**:31.

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Porphyre T, Titus S, Jackson R & Stevenson MA (2007) 'Heterogeneity of contacts between wild possums : How the tuberculosis R_0 can be affected?' *Proceedings of the Epidemiology & Animal Health Management Branch of the NZVA*, Palmerston North, New Zealand. FCE Publication No. 259, 147, 2007.

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Contents

List of Figures

List of Tables

'Lorsque des éléments, des détails, même anodins, reviennent régulièrement dans une enquête, il faut toujours les retenir, parce qu'ils dissimulent à coup sûr une signification profonde.'
When some elements, some details, even nothing, come back regularly in an investigation, we need to remember them, because they are hiding, for sure, a deep signification.

Jean-Christophe Grangé
Extract from *Les rivières pourpres*.