

USE OF SOCIAL NETWORK ANALYSIS TO STUDY *MYCOBACTERIUM BOVIS* INFECTION OF CAPTIVE BRUSHTAIL POSSUMS

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In New Zealand, tuberculosis (TB) caused by *M. bovis* is endemic in feral brushtail possums (*Trichosurus vulpecula*) which are a source of infection of domestic cattle and deer.¹ Because natural transmission of TB in possums is principally by aerosol, social interactions are important in its spread. In captive possum colonies, transmission is most likely to occur between possums that share common air spaces of 'dens'. Social network analysis (SNA) provides standardised methods for describing social relationships. SNA is based on the relationship of interacting units defined by linkages between individuals, such that the unit of interest is not individuals, but the ties between two or more individuals.^{2,3} We wanted to conduct a trial of BCG vaccine efficacy in possums using challenge by natural transmission from experimentally infected possums. We hypothesized that social interactions would influence the risk of TB exposure. The aim of this study was to describe the social structure of captive possum colonies and apply this information in a study of vaccine efficacy.

Materials & Methods

Social hierarchies within colonies were determined by observing denning locations and den-sharing partners for each individual possum. SNA methods were used to analyse the structure of the social networks, examine the interactions, and explore the effects of alterations to the environment and population membership. Adult male brushtail possums were kept in outdoor pens. Observations on 4 groups (20 to 29 possums per colony) were made on consecutive days during 11 periods of between 7 and 27 days. Colonies were disturbed either by moving them to new pens, varying the possum:den ratio, or introducing new members to an established colony. Quantitative estimates of den use and possum interactions were made. UCINET 5 for Windows Ver 5.1.1.1 (Analytic Technologies, Harvard, Massachusetts, USA) was employed to calculate the structural parameters of Closeness, Closeness Centralisation index, Betweenness and Betweenness Centralisation index. The relations within the networks were visualised using the social network graphing software Krackplot 3.2⁵

TB was introduced into 2 colonies of 24 possums by experimental infection with *M.bovis* of the four most socially active individuals.⁴ In each colony, a list ranking possums based on social behaviour was used to allocate the remaining 20 possums

alternately to BCG vaccinated (10) or unvaccinated control (10) groups. After 22 weeks, infection with TB was assessed by post mortem examination.

Results

In undisturbed groups, mean Closeness and Closeness Centralisation indices decreased significantly over time and after the possums were moved to a new enclosure. Both measures increased when the possum:den ratio was increased and decreased when the ratio was decreased. Mean Betweenness and Betweenness Centralisation indices decreased significantly with time. For the disturbed groups, these measures did not vary except when a large number of possums were socially isolated. The frequency of den sharing declined noticeably over time. The proportion of all possums that each possum shared a den with varied between groups. A decrease in the possum:den ratio did not affect the number of partners but an increase in the ratio was followed by a marked decrease in sharing dens. The effect of moving a group to a new enclosure was a small decrease in interactions.

An individual possum's rank in the network of disturbed groups was very stable. Undisturbed groups showed instability in Closeness but stability in Betweenness. When 3 new possums were introduced into an established colony, the number of partners and the frequency of interactions decreased. The relative social ranking, as determined by Closeness, was substantially altered, but not the Betweenness ranking. The new possums interposed themselves into the existing structure, disrupting the cohesion but not the "information" pathways within the group.

In the TB transmission study, 6 possums in one group (4 vaccinates and 2 controls) and 12 possum in the other (6 vaccinated and 6 control) contracted TB. There was a significant difference in all four measures of social structure between the possums that became infected and those that remained free of disease (Table 1). The possums in the three treatment groups and their position in the social network in one TB transmission study is shown in Figure 1.

Discussion

In these colonies, the social distance between possums increased over time, the network became less dense, more homogeneous and individuals became less differentiated. The effect of time was stronger than the effect of disturbance. The rank of an individual in the social network was reasonably stable and was not affected by time or by changes in the possum's environment. The introduction of strangers to an established group did not reverse the effect of time.

Social network analysis is a quantitative tool for evaluating the relationship structure of populations. The measures we found most useful were those for centrality (Closeness) and information flow (Betweenness) through the network. In the TB transmission study,

both measures indicated that we had correctly identified individual possums that were most likely to spread the disease. Possums that became infected were more sociable than those that remained disease-free.

In the design of experiments where infected animals are the source of contagion for groups receiving different treatments (e.g. vaccinated or not), it is important that each treatment group has an equal risk of exposure to infection. In the case of social animals, social network analysis is a useful tool for achieving more uniform exposure.

Table 1. Natural transmission Study: Mean Closeness and Betweenness scores and mean ranking for the experimentally infected possums and those that became infected or remained disease-free

Disease Status ^a	Closeness ^b		Betweenness ^c	
	Mean (±sd)	Mean rank	Mean (±sd)	Mean rank
Exp Inf	17 (± 5.9)		96 (± 40.5)	16.0
Nat Inf	18 (± 5.1)	18.7	114 (± 54.2)	17.2
Dis Free	13 (± 7.4)	9.9	50 (± 62.8)	9.5

a Disease Status: Experimentally infected, Naturally infected and Disease Free

b Kruskal-Wallis test, p=0.05

c Kruskal-Wallis test, p=0.06

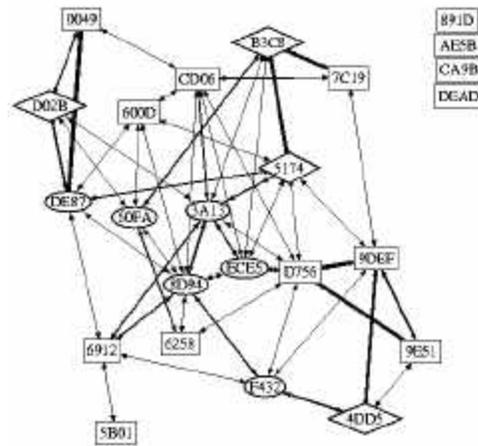


Fig. 1. The social network of a colony of possums after the introduction of TB: Diamond - experimentally infected, Oval - acquired TB by natural transmission and Rectangle - remained disease free. The four possums on the left of the network were socially isolated (did not share a den) during the period. The width of the line between nodes denotes the frequency of the interaction.

References

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