

Tuberculosis Breakdown in Cattle Herds in New Zealand A Case-Control Study

D.U. Pfeiffer and R.S. Morris

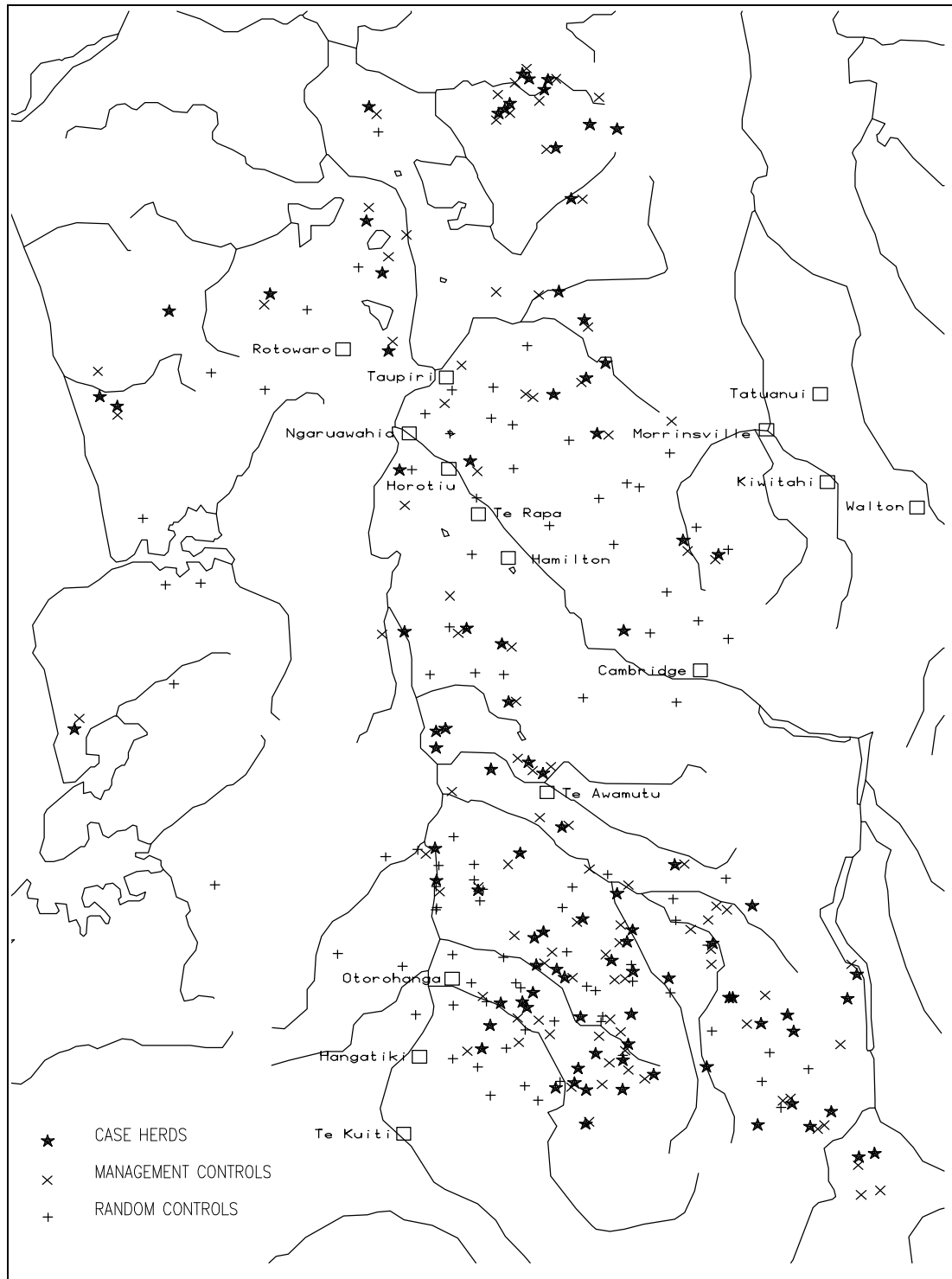
Introduction

In New Zealand tuberculosis infection in the common brushtail possum (*Trichosurus vulpecula*) has been identified as a major wildlife reservoir of infection in cattle. King Country has been declared as an area which has endemic with tuberculosis infection in the possum population. In order to protect the Waikato area a buffer zone of low possum population density had been established in the Rangitoto ranges. After the buffer had been put in place a number of breakdowns of cattle herds to tuberculosis infection occurred north of the buffer zone. In most cases detailed epidemiological investigations did not reveal any obvious sources of infection. In 1989/90 a case-control study was conducted in cooperation between the Ministry of Agriculture and Fisheries (Quality Management) and Massey University. The objective was to identify risk factors which are associated with the establishment of infection in herds (breakdowns).

Materials and Methods

The study covered 285 farms - 95 cases (C), 95 random (RC) and 95 matched (MC) controls. A case was defined as a herd (previously free of infection) which was placed under movement control in the period 1986-89, due to the identification of tuberculosis-infected cattle through routine surveillance and testing procedures. A random control was a farm of any enterprise type chosen at random from the same county. A management control was a farm of the same enterprise type as the case and located in its immediate vicinity. The farms are located in the Waikato region of the central North Island, New Zealand (see figure 1). A questionnaire was developed which comprised 134 items, of which 118 were to be answered by the person in charge of cattle management on the farm. Interviews were conducted by field personnel of the Ministry of Agriculture and Fisheries between 1/12/88 and 30/5/1990. The questionnaire included farm specific data, general information on the interviewee, general stock information, stock management information, tuberculosis data and a section which required the interviewee to describe his assessment of himself with regard to farm management style.

Figure 1: Map of farm locations



The data was analysed in three steps. The outcome variable was the case-control status of a herd. Separate analyses were conducted for the combination of cases with matched or random controls. First, a univariate analysis using logistic regression was conducted to screen the data statistically for variables which were significantly associated with the case-control status of a herd based on the score test at a significance level $p < 0.10$. Then, in a multivariate analysis a sub-group found to be most important among the initial factors was selected using a stepwise logistic regression

approach. Conditional logistic regression was used for matched controls.¹ Finally, path analysis was used to statistically describe the causal web of relationships between factors and the outcome variable. The technique used has been described in more detail in Chesterton et al.² A null hypothesis model was developed based on prior biological and epidemiological understanding of the situation. It incorporated the factors found to be significant in the final logistic regression models plus other factors which were considered to be of sufficient biological importance to be further tested in this final stage. Clusters of factors which shared common features were grouped into component models and analysed separately. Stepwise logistic and least squares regression techniques were used to test relationships between a factor and all the factors with arrows leading to it for statistical significance. Paths not statistically significant were dropped from the diagram. The strength of the relationship between factors, adjusted for the effect of other parameters included in the model, is expressed by the sign and size of the regression coefficient. In the case of categorical risk factors the coefficient was interpreted as an odds ratio. The final path diagrams describe the direct and indirect effects of a putative 'causal web' for tuberculosis breakdown in cattle herds. Table 1 lists descriptions of codes for variables which have been used in the analysis. The direction of risk factor effects is indicated by (+) for increase and (-) for decrease. In the path diagrams, significance levels of regression coefficients for individual paths are indicated as * for $p < 0.1$, ** for $p < 0.05$ and *** for $p < 0.01$. The abbreviation "n.s." stands for a non-significant statistical relationship, "s" for standard deviation, "OR" for odds ratio and LSU for livestock units.

¹ Breslow, N.E. and Day, N.E. 1980: Statistical Methods in Cancer Research. Vol. 1 - The analysis of case-control studies. IARC Scientific Publications No.32, Lyon, pp350.

² Chesterton, R.N. et al 1990: Environmental and behavioural factors affecting prevalence of foot lameness in New Zealand dairy herds - a case-control study. N.Z. vet. J. 37, 135 - 142.

Table 1: Codes and descriptions of variables used in the multivariate analysis

VARIABLE	LABEL
ADULTCAT	PROPORTION OF COWS AND BULLS IN TOTAL CATTLE
BEEFCATT	PROPORTION BEEF IN TOTAL CATTLE
BEEFLSU	NO. BEEF CATTLE IN LIVESTOCK UNITS
BUSHACCE	CATTLE ACCESS TO BUSH
BUYLIVES	PREFERENCE TO PURCHASE MACHINE / LIVESTOCK
BUYREPLA	BUYS REPLACEMENTS?
CATTDENS	CATTLE DENSITY ON PASTURE
CATLLSU	TOTAL CATTLE IN LIVESTOCK UNITS
CATTPURC	TOTAL LSU CATTLE PURCHASED
CCSPREAD	SCORE KNOWLEDGE ABOUT CATTLE-CATTLE SPREAD
CHSPREAD	SCORE KNOWLEDGE ABOUT CATTLE-HUMAN SPREAD
CONTEFFE	OPINION ABOUT EFFICIENCY OF MAF DISEASE CONTROL
DAIRYLSU	TOTAL NUMBER DAIRY CATTLE IN LSU
DIFFHER	PURCHASE FROM 0, <= 3 OR >3 HERDS
EPIDEMIO	SCORE EPIDEMIOLOGICAL UNDERSTANDING
FARMSIZE	FARM SIZE IN HECTARES
FOREST	AREA FOREST IN HECTARES
FORFARM	AREA FOREST PER TOTAL FARM SIZE
GIVINGIN	SEES HIMSELF AS FORCEFUL/GIVING IN EASILY
GIVINGUP	SEES HIMSELF AS PERSEVERING/GIVING UP EASILY
HARDWORK	PREFERS NO HARD WORK/LIKES HARD WORK
HEISTCAT	HEIFERS AND STEERS PER CATTLE LSU
INTRODUC	KNOWLEDGE ABOUT PATHS FOR DISEASE INTRODUCTION
LIVEPREF	PREFERS MACHINERY / LIVESTOCK
LIVESDEN	LIVESTOCK DENSITY ON PASTURE
MAFCOMET	SCORE KNOWLEDGE ABOUT MAF CONTROL METHODS
MAINGRAZ	MAIN GRAZING ON OR OFF FARM
MAINOP	MAIN TYPE OF CATTLE OPERATION (DAIRY OR BEEF)
MODEST	SEES HIMSELF AS NOT MODEST / MODEST
NEWIDEAS	SEES HIMSELF AS TRADITIONAL / LIKES NEW IDEAS
NOTALKAT	CONSIDERS HIMSELF TALKATIVE / NOT TALKATIVE
OTHEMPL	OTHER EMPLOYMENT COMMITMENTS?
OTHERCAT	OTHER FARMERS CATTLE GRAZED?
PASTURE	AREA PASTURE IN HECTARES
PERLABCA	PERMANENT LABOUR UNITS PER TOTAL CATTLE LSU
PERLABFA	PERMANENT LABOUR UNITS PER HECTARE FARM SIZE
PERLABLI	PERMANENT LABOUR UNITS PER LIVESTOCK UNIT
PERMLABO	PERMANENT LABOUR UNITS
PERTOTLA	PERMANENT LABOUR UNITS PER TOTAL LABOUR UNIT
PURCATT	TOTAL PURCHASE CATTLE LSU PER CATTLE LSU PRESENT
RECORDS	DISLIKES / LIKES KEEPING RECORDS
SOCIABLE	SEES HIMSELF AS UNSOCIABLE / SOCIABLE
SPECIES	SCORE KNOWLEDGE ABOUT RESERVOIR SPECIES FOR TB
TOTALLSU	TOTAL LIVESTOCK UNITS
TOTLABCA	TOTAL LABOUR UNITS PER CATTLE UNIT
TOTLABFA	TOTAL LABOUR UNITS PER HECTARE FARM SIZE
TOTLABLI	TOTAL LABOUR UNITS PER LIVESTOCK UNIT
TOTLABOU	TOTAL LABOUR UNITS
WEATOTPU	WEANERS PER TOTAL CATTLE PURCHASE LSU
WEAYEACA	LSU WEANERS, YEARLINGS PER CATTLE LSU
WHSTOTPU	LSU WEANERS, HEIFERS, STEERS / PURCHASE LSU

Results

The majority of case farms were located in "non-endemic" (21%) and "surveillance" (53%) tuberculosis control areas, as classified according to the MAF disease management plan for the Waikato region. 84% of study herds were mainly cattle operations and 62% were involved mainly into dairy production. The average farm size was 152.6 hectares (s = 161). On average, cattle herds comprised 1721 livestock units (s = 1165). 70% of interviewees owned the farm and 19% were share milkers.

Univariate analysis of the questionnaire data reduced the number of potential risk factors to 15 and 20 for matched and random controls respectively (see tables 1a and 1b). Factors which were not statistically significant included for example farming experience, the interviewee's relationship to the property, the water source for livestock, the amount of contact with neighbouring farms and the possibility of bush access.

Table 1a: Some results of univariate analysis for random controls using logistic regression

PARAMETER	BETA COEFFICIENT	SCORETEST	DF	P-VALUE
ADULTCAT	0.3065	0.6513	1	0.420
BEEFCATT	0.5844	4.205	1	0.040
BEEFLSU	0.3884E-03	9.916	1	0.002
BUSHACCE='yes'	0.3111	1.089	1	0.297
BUYLIVES	0.5185E-01	1.089	1	0.297
BUYREPLA	-0.1333	0.6667E-01	1	0.796
CATTDENS	0.9008E-02	1.302	1	0.254
CATLLSU	0.1754E-03	4.919	1	0.027
CATTPURC	0.4741E-03	9.205	1	0.002
CCSPREAD	0.1134	1.417	1	0.234
CHSPREAD	0.1615	2.099	1	0.147
CONTEFFE='yes'	-0.9524E-01	0.2381	1	0.626
DAIRYLSU	0.2989E-04	0.7517E-01	1	0.784
DIFFHER='0'		7.073	2	0.029
DIFFHER='<=3'	-0.1176	0.1765	1	0.674
DIFFHER='>3'	0.6897	6.897	1	0.009
EPIDEMIO	0.1412E-01	0.7835	1	0.376
FARMSIZE	0.1074E-02	4.593	1	0.032
FOREST	0.1496E-01	1.482	1	0.224
FORFARM	5.305	1.009	1	0.315
GIVINGIN	0.8040E-01	1.286	1	0.257
GIVINGUP	0.2429E-01	0.7287E-01	1	0.787
HARDWORK	0.5682E-01	1.989	1	0.158
HEISTCAT	1.173	6.063	1	0.014
INTRODUC	0.1213	2.123	1	0.145
LIVEPREF	0.5027E-01	1.282	1	0.258
LIVESDEN	0.7940E-02	1.203	1	0.273
MAFCOMET	0.9658E-01	2.318	1	0.128
MAINGRAZ='off'	0.5455	0.8182	1	0.366
MODEST	0.3070E-01	0.4298	1	0.512
NEWIDEAS	0.1642E-01	0.1232	1	0.726
NOTALKAT	0.6678E-01	1.269	1	0.260
OTHEMPL='yes'	-0.4242	1.485	1	0.223
OTHERCAT='yes'	0.2500	0.5000	1	0.480
PASTURE	0.1284E-02	3.898	1	0.048
PERLABCA	-85.71	1.286	1	0.257
PERLABFA	2.899	0.1594	1	0.690
PERLABLI	0.0000	0.0000	1	10.000
PERMLABO	0.2011	4.102	1	0.043
PERTOTLA	0.1786	0.8484	1	0.357
PURCATT	0.2981	1.326	1	0.249
RECORDS	0.1242E-01	0.7453E-01	1	0.785
SOCIABLE	0.2105E-01	0.2737	1	0.601
SPECIES	0.6061E-01	1.030	1	0.310
TOTALLSU	0.8810E-04	3.815	1	0.051
TOTLABCA	-40.00	0.4000	1	0.527
TOTLABFA	2.491	0.1744	1	0.676
TOTLABLI	40.00	0.2000	1	0.655
TOTLABOU	0.1512	3.863	1	0.049
WEATOTPU	1.373	3.343	1	0.067
WEAYEACA	-1.598	4.834	1	0.028
WHSTOTPU	0.7632	4.400	1	0.036

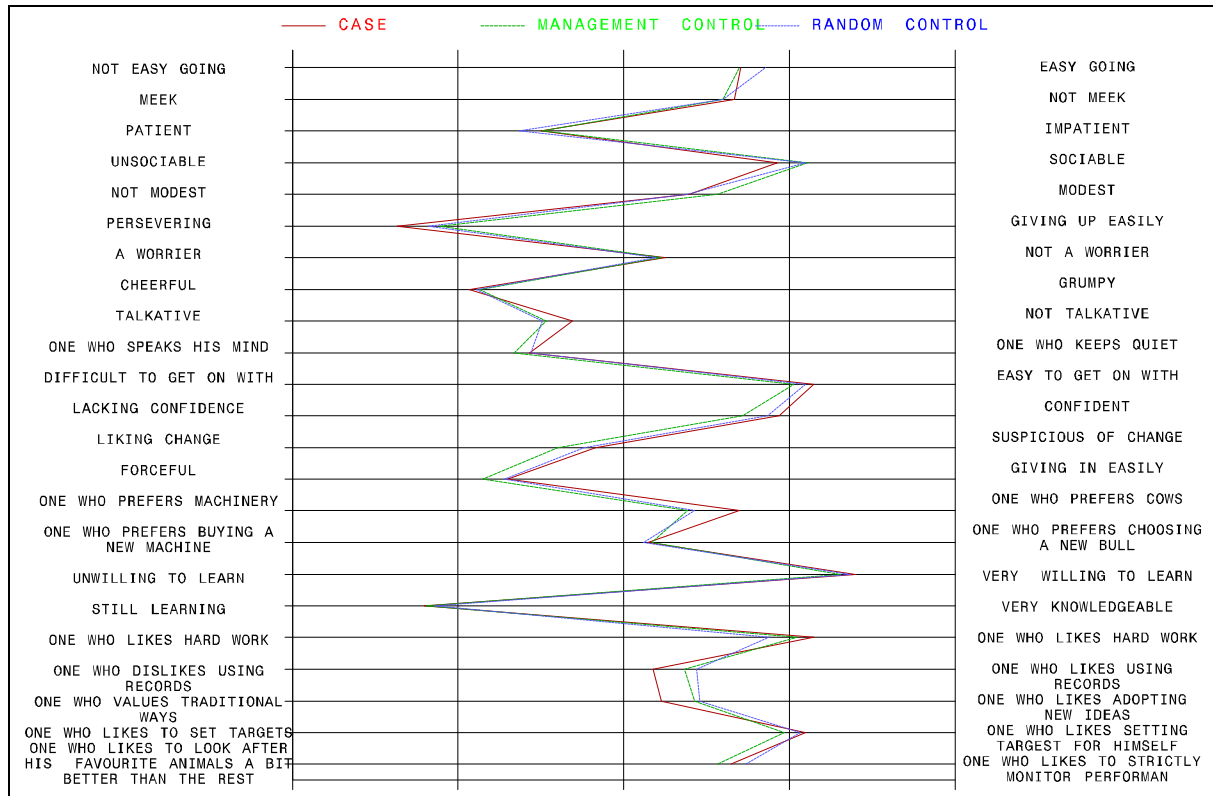
Table 1b: Some results of univariate analysis for matched controls using logistic regression

PARAMETER	BETA COEFFICIENT	SCORE TEST	DF	P-VALUE
ADULTCAT	1.154	3.088	1	0.079
BEEFCATT	0.8830	1.246	1	0.264
BEEFLSU	0.4843E-03	7.603	1	0.006
BUSHACCE='yes'	-0.3158	0.4737	1	0.491
BUYLIVES	-0.1081	0.4324	1	0.511
BUYREPLA	0.4000	0.4000	1	0.527
CATTDENS	-0.9682E-02	0.1597	1	0.689
CATTLISU	0.2772E-03	3.198	1	0.074
CATTPURC	0.4249E-03	4.586	1	0.032
CCSPREAD	0.2745	1.922	1	0.166
CHSPREAD	0.4167	4.167	1	0.041
CONTEFFE='yes'	-0.6207	2.793	1	0.095
DAIRYLSU	-0.2036E-03	0.8474	1	0.357
DIFFHER='0'		7.679	2	0.022
DIFFHER='<=3'	-0.7586	4.172	1	0.041
DIFFHER='>3'	1.130	7.348	1	0.007
EPIDEMIO	0.4029E-01	0.9468	1	0.331
FARMSIZE	0.2459E-02	9.207	1	0.002
FOREST	0.2386E-01	2.755	1	0.097
FORFARM	3.890	0.4603	1	0.497
GIVINGIN	0.1277	0.3830	1	0.536
GIVINGUP	-0.2963	2.370	1	0.124
HARDWORK	0.3467	2.253	1	0.133
INTRODUC	0.1500	0.4500	1	0.502
LIVEPREF	0.4040E-01	0.8081E-01	1	0.776
LIVESDEN	-0.1055E-01	0.1688	1	0.681
MAFCOMET	0.4688	7.031	1	0.008
MAINGRAZ='off'	-0.2857	0.1429	1	0.705
MODEST	-0.2951	2.656	1	0.103
NEWIDEAS	0.0000	0.0000	1	10.000
NOTALKAT	0.2182	1.309	1	0.253
OTHEMPL='yes'	-0.1538	0.7692E-01	1	0.782
OTHERCAT='yes'	0.5000	1.000	1	0.317
PASTURE	0.3337E-02	8.034	1	0.005
PERLABCA	-66.67	0.6667	1	0.414
PERLABFA	18.18	1.000	1	0.317
PERMLABO	0.6411	8.398	1	0.004
PERTOTLA	0.7837	1.242	1	0.265
PURCATT	0.4228	0.9957	1	0.318
RECORDS	-0.5660E-01	0.1698	1	0.680
SOCIABLE	-0.1527E-01	0.7634E-02	1	0.930
SPECIES	0.3185	3.981	1	0.046
TOTALLSU	0.1674E-03	4.379	1	0.036
TOTLABCA	-66.67	0.6667	1	0.414
TOTLABFA	-0.1134E-05	0.7391E-14	1	0.000
TOTLABOU	0.3937	4.173	1	0.041
WEASTCAT	1.743	7.217	1	0.007
WEATOTPU	0.9885	1.310	1	0.252
WEAYEACA	-2.793	4.049	1	0.044
WHSTOTPU	1.500	7.837	1	0.005

Analysis of the interviewee's self concept using arithmetic means suggests that case farmers were less sociable, less talkative, more persevering, more livestock orientated, less likely to use herd

records and were more traditional (see figure 2). These differences were not statistically significant, when tested using a nonparametric statistical test.

Figure 2: Personality traits of interviewees averaged for case-control status



The final logistic regression model comparing cases and matched controls included farm size (+), understanding about transmission between cattle and humans (+), perseverance (+), proportion of young stock in total number of animals purchased (+), purchase from more than 3 different herds compared with no purchases (OR=3.6), and total number of permanent labour units (+). For random controls the model included proportion of young stock in herd (+), knowledge about MAF disease control methods (+), total number of labour units (+), total number of beef livestock units (+), main grazing areas off instead of on main farm (OR=3.1), total number of livestock units (-) and other employment commitments (OR=0.5).

For path analysis potential risk factors were grouped into parameters describing physical farm characteristics, operational characteristics, herd characteristics, purchase behaviour, self concept, problem understanding and other factors. Figures 3a and 3b show the final path diagrams for comparison of cases with matched and random controls. Final path models for matched and random controls had the factors "purchase from more than 3 herds", "proportion of young stock in total purchase", "proportion of young stock in herd" and "confidence in the efficiency of current MAF control measures".

Figure 3a: Final path diagram for comparison of cases with matched controls

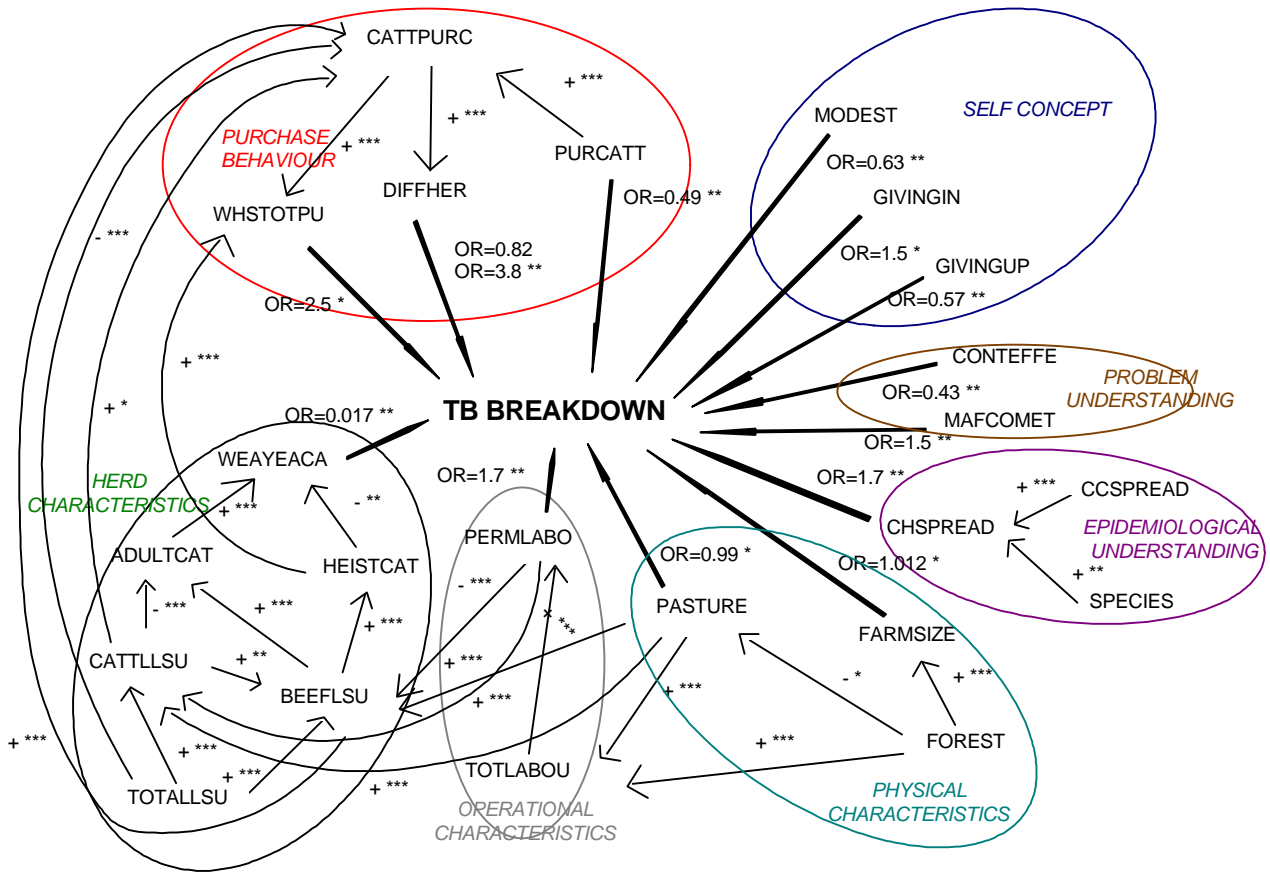
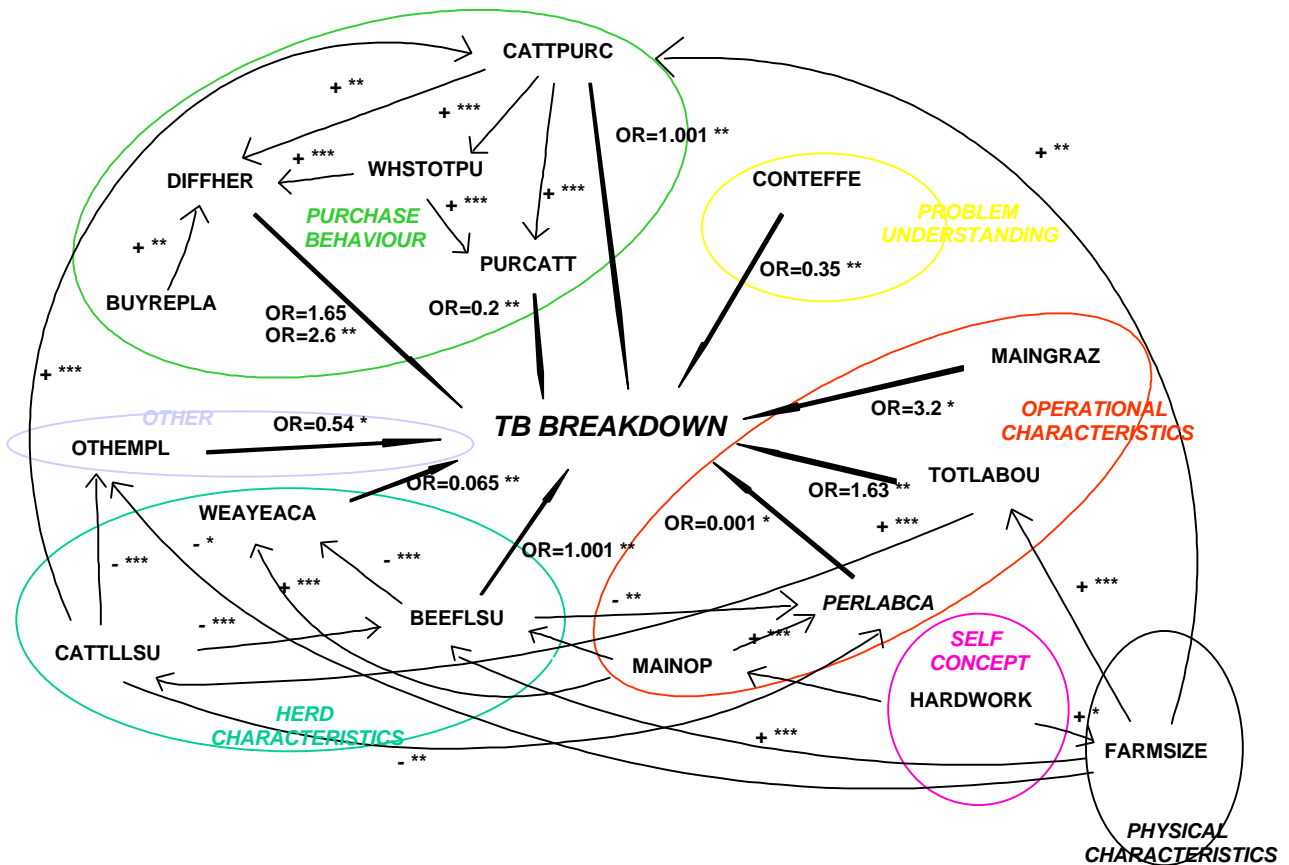


Figure 3b: Final path diagram for comparison of cases with random controls



The most important component models for matched controls were purchase behaviour and epidemiological understanding, for random controls herd characteristics and purchase behaviour (see figure 4).

Figure 4: Goodness of fit of component models

Cluster of Risk Factors	Random Controls					Matched Controls
	Percent Change in Deviance	Sensitivity	Specificity	Percent Correct	Percent Change in Akaike's Information Criterion	Percent Change in Deviance
Epidemiological Understanding	n.s.	n.s.	n.s.	n.s.	n.s.	0.14
Herd Characteristics	0.12	47.5	80.0	63.7	0.10	0.06
Operational Characteristics	0.07	64.2	58.9	61.6	0.05	0.05
Other	0.01	83.2	27.4	55.3	0.01	n.s.
Physical Farm Characteristics	n.s.	n.s.	n.s.	n.s.	n.s.	0.07
Problem Understanding	0.03	34.5	84.3	56.7	0.02	0.09
Purchase Behaviour	0.08	45.3	71.6	58.4	0.05	0.14
Self Concept	n.s.	n.s.	n.s.	n.s.	n.s.	0.11
Stepwise Logistic Regression Model	0.20	64.2	68.4	66.3	0.14	0.30

Discussion

Interpretation and comparison of the results of the analyses for matched and random controls has to take into account that both control groups represent samples with quite different characteristics. In the case of random controls, factors which appear to be statistically significantly associated with case-control status could well be confounded with differences in operational characteristics. Matching is used to control for such effects. Potential exposure to tuberculosis infection from wildlife reservoir species cannot be excluded as an extraneous variable, because the infection status of local possum populations was for study herds. Matching cases with controls from the vicinity does not completely control for such extraneous effects, as tuberculosis infection in possum populations appears to occur patchy in space.³ The presence of tuberculous possums is more likely in the southern part of the study area as it is closest to the endemic area in King Country.

The images a farmer holds about himself/herself affect behaviour and decisions regarding farm management. The main dimensions of the self-concept in farming practice, which can be used for differentiation between individual farmers, include degrees of experience, intensiveness, progressiveness, efficiency and livestock orientation.⁴ Higgins, C.B.R. and Seabrook, M.F.⁵ consider the dimensions 'livestock orientation', 'efficiency' and 'progressiveness' as having a major influence on the acceptance of innovations in the dairy sector. A strong cognisant self on a particular dimension is indicated when the interviewee identifies himself/herself with the extreme left or right of the

³ Pfeiffer, D.U. et al (in preparation): The epidemiology of bovine tuberculosis infection in possums in the Taupungaroa ranges, New Zealand.

⁴ Seabrook, M.F. and Higgins, C.B.R. 1988: The role of the Farmer's Self-Concept in Determining Farmer Behaviour. *Agric. Admin. & Extension* 30, 99-108.

⁵ Higgins, C.B.R. and Seabrook, M.F. 1986: The self concept as a factor influencing flexibility in farming practice. *Agri. Manpower Soc.* 1 (12), 14-25.

alternatives on the semantic scale used in the questionnaire. 21% of case farmers, 13% of management and 16% of random controls perceived themselves strongly as livestock orientated. In a small survey in England, 40% of dairy farmers considered themselves strongly as livestock orientated.⁵ This difference suggests that this sample of New Zealand farmers has quite a different attitude towards management of a livestock enterprise than English farmers do. 64% of cases, 51% of management and 57% of random controls saw themselves strongly as still learning rather than very knowledgeable. 55% of case farmers, 47% of management and 53% of random controls were very willing to learn. Hence, the majority of farmers saw themselves as less than efficient, but were willing to learn. Both dimensions of the self-concept, 'experience' and 'livestock orientation', would affect a farmer's willingness to take up innovations and recommendations. For any extension work to be successful, it has to be recognised that farmers might reject anything which they see as conflicting with their image of themselves.

Both models selected by a stepwise multivariate logistic regression approach included factors related to replacement strategies of farms. The proportion of weaners and heifers in total herd size was higher in cases compared with random controls and the proportion of weaners, heifers and steers in total cattle purchase was higher in cases compared with management controls.

For path analysis, factors were grouped into clusters representing major structural components of the causal web of relationships. Statistical analysis was conducted separately for each component model. This approach allows to evaluate the importance of biologically relevant relationships, which if analysed purely on statistical grounds would disappear in the presence of multicollinearity in the data.

The effects represented by the component models "Epidemiological Understanding" and "Problem Understanding" are both likely to be a result of the case-control status of the farm. Managers of case herds were more likely to know about MAF disease control measures and the epidemiology of tuberculosis, because they had to deal with tuberculosis in their cattle herd. But it also suggests that general awareness of the disease problem is poor if a manager has not yet been confronted with the problem.

The component model describing herd characteristics was most important when comparing cases with random controls and appeared to be of minor importance in the case of matched controls. This is a reflection of the situation that matching was conducted based on the type of enterprise, which has some influence on herd characteristics. For both control groups the proportion of weaners and yearlings in the total cattle herd (in LSU) was lower in case herds. Case farms were more likely to have a larger beef component than random controls. For random controls, there was a statistically significant negative interaction between "LSU WEANERS, YEARLINGS PER CATTLE LSU" AND "NO. BEEF CATTLE IN LSU". This means that the strength of the relationship between the proportion of weaners and yearlings in the herd and case-control status herd appeared to decrease with an increasing beef component.

The operational characteristics of the farms were of minor importance in both path diagrams. In both models case herds appeared to have more labour units available. Farm size and herd size, both are indirectly associated with case-control status in this component model through labour units.

Physical farm characteristics did appear to be unimportant for random controls and of minor importance for matched controls. There is some indication that case-farms were more likely to have a larger forest component than matched controls. This could represent potential exposure to a tuberculosis infected possum population.

The farmer's self concept was important only in the comparison of cases and matched controls. Case farmers perceived themselves as less modest than controls did. They were less forceful in pursuing their own ideas, and less likely to give in when interacting socially than matched controls.

Both final path diagrams include purchase behaviour as one of the most important component models. The only difference is that for random controls "TOTAL LSU CATTLE PURCHASED" was directly associated with case-control status and "LSU WEANERS, HEIFERS, STEERS / PURCHASE LSU" only indirectly. For matched controls, "TOTAL LSU CATTLE PURCHASED" was indirectly associated with case-control status and "LSU WEANERS, HEIFERS, STEERS / PURCHASE LSU" had a direct association with disease status of the herd. This difference is related to the fact that comparison between cases and matched controls allows a more specific definition of the problem factors. Both models indicate that case farms were more likely to buy from more than 3 herds while the proportion of animals replaced was actually lower in cases compared with controls. Hence, it is more the total number of animals especially young stock which is related to increased risk of tuberculosis breakdown than the proportion of the total herd which is replaced each year.

The results of both path analyses suggest that factors other than just exposure to infection in a local possum population may be of some importance with regard to the risk of tuberculosis herd breakdown in the Waikato region. One such factor could be the purchase of infected young stock in the endemic area of the King Country. It is notable that in non-affected farmers the knowledge and understanding about the disease is poor.