

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

The effectiveness of on-farm control programmes against wildlife-derived bovine tuberculosis in New Zealand

A thesis presented in partial fulfilment
of the requirements for the degree of
Doctor of Philosophy at Massey University

Carola Sauter-Louis

2001

Printed by Massey University Printery, 2001

To obtain a copy of this thesis write to:

EpiCentre

Wool Building

Massey University

Palmerston North

New Zealand

Ph: +64 (0)6 350 5270

Fx: +64 (0)6 350 5716

E-mail: carola@sauter-louis.de

Abstract

In New Zealand the Australian brushtail possum (*Trichosurus vulpecula*), introduced in the middle of the 19th century, is the main wildlife reservoir for *Mycobacterium bovis* infection for farmed livestock and other wildlife species. Thus, control of tuberculosis (TB) has to involve both livestock and vector animals. Areas with endemic wildlife infection constitute 23% of New Zealand's land area. Vector control is mainly performed by large scale poisoning operations, by both aerial and on-ground baiting, conducted by official agencies, such as Regional Councils. The costs of vector control rose from NZ\$18 million in 1995 to NZ\$28 million in 1998/99, and finances are not available to cover all areas with endemic wildlife infection. There is a need for farmers to be involved and participate in TB control to complement the official control efforts. This thesis comprises a number of studies that looked in detail at on-farm control measures that could be applied at farm level, their efficiency and cost-effectiveness, in order to determine if and how farmers could take on-farm measures which would complement the official TB control programme.

In an initial survey of 27 Wairarapa herd managers, whose cattle herds were TB infected, 'grounded theory' was used to identify factors related to farm management and TB infection in cattle. Most farmers had knowledge or suspicion about potential high risk areas on their farm, where cattle were more likely to become infected with TB. Farms that grazed cattle in paddocks with TB hot-spot areas had a greater herd TB incidence than farms that excluded cattle from such areas, and used adjacent paddocks. Grazing management was found to be flexible, more so on beef farms than on dairy farms. These results formed the basis for designing on-farm control measures.

A subsequent intervention study used 67 Wairarapa farms. On-farm control measures were implemented for three years on 34 randomly selected 'focused control' farms. On-farm control measures included targeted vector control in spring and autumn, and adoption of grazing management in summer and winter that excluded cattle from TB hot-spots during these times. These measures were implemented by the research team during the first two years and farmers continued the control work in the third year. At the end of three years the effect of the interventions was evaluated. Focused control farms achieved more effective TB control than standard control farms. They were significantly less likely to have multiple TB animals per year, a higher proportion of focused control farms came off Movement Control, and the two-year cumulative TB incidence was reduced more on focused control farms than on standard control farms.

Part of the project was also to compare the Wairarapa project with a contemporary intervention study. The study was conducted on a national scale in four separate areas of New Zealand by a

national organisation, using 35 focused control and 70 standard control cattle/deer farms. Farmers were advised by a multi-disciplinary team on possible management changes and vector control for two years. The implementation of these measures was the responsibility of the individual farmers. Three and a half year after the start of the project the effectiveness was evaluated as part of this thesis. Focused control farms reduced the two-year cumulative TB incidence more than standard control farms. Comparison with the Wairarapa project indicated that the hands-on operational approach of the Wairarapa project had advantages over the 'advice only' approach in the national project.

All farmers involved in the two intervention studies were surveyed at the end of the intervention studies using a questionnaire, asking about farm management and TB related issues. Only the Wairarapa focused control farmers were interviewed during the project period. Only slight differences existed in these variables between focused and standard control farms in each of the projects, indicating that the allocation of farms to the two farm groups was adequate. Questions were also asked about attitudes towards TB and its control. Overall farmers rated the importance of TB eradication as very high. However, the majority of farmers were not in favour of stricter Movement Control regulations, removal of compensation or having to pay TB testing costs directly. Many farmers saw organisations, such as Government and Regional Council, as being responsible for eradicating TB and did not see any need to conduct control programmes themselves.

An economic analysis of the adoption of on-farm control measures was conducted using deterministic, stochastic and decision analysis. Under the current compensation level of 65% for TB test positive animals, the adoption of on-farm control measures generally was beneficial to dairy farms, but for beef farms only if they achieved TB free herd status. Reducing the compensation level to zero did not alter the situation significantly. The net gain in dairy farms increased, the situation in the beef breeding farms changed minimally and on beef finishing farms the adoption of control programmes became beneficial if the number of TB animals was reduced at least by two, without achieving TB free status.

The final stage of the project described in this thesis was the development and use of FarmORACLE, a whole-farm simulation model, that allows the user to combine knowledge about TB and its occurrence on farms with farm-specific grazing strategies. The model was used to compare traditional grazing strategies with alternative strategies, that excluded cattle and deer from grazing TB hot-spot paddocks during high-risk times. Four farms were described in detail. In all four farms an alternative grazing strategy was found that resulted in higher production or greater economic returns, while protecting the herd against exposure to tuberculous possums.

Acknowledgements

I came to New Zealand for the first time in 1993 and thanks to the encouragement and support I received during that time I decided to start a PhD. It was due to the vision of Roger Morris, my chief supervisor, that the project was developed and continued. Often I would think the problems are too big, the benefits too low, but Roger re-assured me and his enthusiasm would lift my spirits. I am especially grateful to Roger for providing the opportunity for me to do a PhD and for his personal and professional support. To Peter Wilson, my second supervisor, I am particularly grateful for the time and guidance I received during all these years. Especially in the last year, trying to teach me how to write not only correct English, but academic English. Thanks also to Dirk Pfeiffer, my third supervisor. For his guidance in many analytical matters and for his and Susanne's friendship I am especially grateful. The combination of these three supervisors was the best I could have wished for, both on a personal and on a professional level.

I would like to express a special thanks to the late Ron Goile and to his wife, Donna. Ron conducted most of the fieldwork for me; he and Donna autopsied many possums and enabled me to go back and see my family in Germany. Without their help and input this project would never have been completed. Ron and Donna were like a second family to me here in New Zealand. Through their help and even more through their friendship I was able to grow with the project and not only learn about project related issues, but also about life and the importance of other things. I am extremely sad that Ron is not able to see this thesis finished, but I know that he will be with me in all the years and all the projects to come. Ron had a wonderful personality and I will never forget the talks we had about life, work, and personal things, sitting on the motorbike, having lunch under a tree, or when doing autopsies of smelly possums on the back of his truck.

The project involved three years of intensive fieldwork on 35 farms in the Wairarapa. Thank you to all these farmers and their families who made us feel so welcome and part of their families. Without their commitment this project would never have been completed and without their friendship it would not have been as enjoyable. Thank you also to all the farmers who participated in the various questionnaires.

This PhD would never have been completed without the support and friendship from all the people at the EpiCentre. Thanks to Ron Jackson, who encouraged me many times, to Fiona, whose help in writing English and publishing was often required; to Deb, who had to spend many hours of 'counselling' when things didn't go the way I expected them to go; thanks also to Leigh and Laurie for their support and encouragement. A special thanks to Joanna, without her encouragement, reassurance and proof-reading, I probably would not have finished this PhD. Thanks to Nigel and Mark for their support. Thanks to Jörg, Sonja, Klim and Kathrein for the 'German' evenings and

the great company. And a special thanks to my office colleagues over the last few years – Joanna, Naomi, Rene and Nina, who supplied encouragement when times were difficult and a constant flow of chocolate at the end of the writing-up stage to keep my (and probably their own) sanity.

I would also like to acknowledge the tremendous help and friendship I have received from members of AgriQuality NZ based in Masterton, who provided me with data and field information, in particular Gillian Atkinson, Garth Pannett, and Alan Cornelius and all the livestock officers. I received also considerable help from staff in the Wellington Regional Council, based in Masterton. Thanks also to Chris Carter of AgriQuality and Tony Rhodes of Agriculture New Zealand for the help in obtaining the data from the national project, so that I could conduct the analysis.

I also would like to acknowledge the support of the AHB who funded this project and were helpful and patient many times during this PhD.

Finally, the greatest and deepest thanks goes to Tommi, my husband. We met one year into my PhD, got married, and lived for most of the time half a world apart, he in Germany, me in New Zealand. It was hard for both of us at times, having a marriage by e-mail, but he was supportive all the years, although he really wished nothing more than that I would be at home with him. He built databases, entered data totally unfamiliar to him ('shoot them down' instead of 'down the chute' a colloquial term for condemned carcasses), created queries and analytical outputs. He would encourage, support, give me confidence, and edge me on many times over the phone. I am unable to adequately express my gratitude to him and I am looking forward to enjoy 'real' married life with him. Thanks also to his family for supporting him while I was away.

I am particularly grateful to my parents, my sister and my brother. Without their encouragement, help and support, I would never have come to New Zealand in the first place and I would not have stayed that long. My father once was asked what I would be, once I have finished my PhD in New Zealand. He only smiled and said 'Forty'. I managed to finish it before then, but sometimes it made me feel even older than that. Their support and love, even when separated by 20,000 km helped me to continue and conquer this challenge.

Thanks to all these people, and to all the students and staff from the EpiCentre for helping me to grow in myself, grow in personality, grow in character and grow professionally.

Carola Sauter-Louis
EpiCentre, Institute of Veterinary, Animal and Biomedical Sciences,
Massey University, Palmerston North, New Zealand

February 2001

Table of Contents

ABSTRACT.....	I
ACKNOWLEDGEMENTS	III
TABLE OF CONTENTS	V
LIST OF FIGURES	XI
LIST OF TABLES	XV
INTRODUCTION A GUIDE TO THE METHODOLOGIES AND RATIONALE FOR RESEARCH PRESENTED IN THIS THESIS	1
BIBLIOGRAPHY	6
CHAPTER 1 CHANGING BEHAVIOUR: A LITERATURE REVIEW	9
INTRODUCTION	11
BEHAVIOUR CHANGE.....	11
COGNITIVE PROCESS.....	11
INFORMATION CHANNELS AND SOURCES	13
BRIEF OVERVIEW OF ADULT EDUCATION	14
INNOVATION DIFFUSION MODEL	15
INNOVATION PROCESS	15
CHARACTERISTICS AND ADOPTION OF INNOVATIONS	16
CHANGE AGENT.....	18
CONSEQUENCES OF INNOVATIONS	19
DECENTRALISED DIFFUSION SYSTEMS	19
HUMAN BEHAVIOUR CHANGE: THE SMOKING EXAMPLE.....	20
EXAMPLE FROM AGRICULTURAL EXTENSION	23
DEFINITION OF EXTENSION.....	24
ADOPTION PROCESS AND EFFICIENCY OF TECHNOLOGY TRANSFER.....	25
RECENT TECHNIQUES IN AGRICULTURAL EXTENSION	27
<i>'Farmer first' model</i>	27
<i>Communication</i>	28
<i>Farmers' and consumers' goals</i>	29
<i>Motivation</i>	30
<i>Computer aided programs</i>	30
AGRICULTURAL EXTENSION IN NEW ZEALAND	31
<i>History of extension</i>	31
<i>Communication channels</i>	34
<i>Factors influencing change in farm practices</i>	36
<i>Commercialisation of advisory services</i>	38
RELEVANCE TO THE HYPOTHESIS RESEARCHED IN THIS THESIS	39
CONCLUSION.....	39
BIBLIOGRAPHY	40

CHAPTER 2 ANALYSIS OF WAIRARAPA FARMER PERCEPTIONS OF TUBERCULOSIS AND MANAGEMENT OPTIONS FOR CONTROL	57
ABSTRACT	59
INTRODUCTION	59
MATERIALS AND METHODS	60
GROUNDED THEORY	60
ANALYSIS OF QUALITATIVE DATA	61
SELECTION OF FARMS	62
INTERVIEW PROCESS	63
CONTENT ANALYSIS	63
RESULTS	65
DESCRIPTIVE ANALYSIS OF STUDY FARMS	65
<i>General farm characteristics</i>	65
<i>TB history from existing records kept by AgriQuality</i>	66
BUILDING THEORIES USING THE INTERVIEWS	68
<i>Tuberculosis related observations by farmers</i>	68
<i>General farm management</i>	75
<i>Grazing management</i>	76
DISCUSSION	79
DESCRIPTIVE ANALYSIS OF STUDY FARMS	79
METHODOLOGY	80
INTERVIEW CONTENT ANALYSIS	81
BIBLIOGRAPHY	87
CHAPTER 3 EFFECTIVENESS OF ON-FARM TUBERCULOSIS CONTROL PROGRAMMES: FARMS LOCATED IN THE WAIRARAPA	93
ABSTRACT	95
INTRODUCTION	95
MATERIALS AND METHODS	97
STUDY AREA	97
POSSUM CONTROL EFFORTS BY THE REGIONAL COUNCIL	98
FARM SELECTION PROCESS	99
CATTLE TB DATA	101
CONFIRMATION OF TB STATUS	101
FARM VISITS	102
TB CONTROL MEASURES EMPLOYED IN THIS STUDY	103
<i>Basis of the hypothesis</i>	103
<i>Targeted localised possum control</i>	105
<i>Livestock grazing management practices</i>	107
ANALYSIS OF DATA	107
RESULTS	108
POWER ANALYSIS	108
VECTOR CONTROL CONDUCTED ON FOCUSED CONTROL FARMS BY THE RESEARCH TEAM	110
VECTOR CONTROL BY REGIONAL COUNCILS	113
ANALYSIS OF TUBERCULOSIS TESTING RECORDS	114
<i>Time spent on Movement Control and Herd TB status at the end of the project</i>	114
<i>Number of TB cattle</i>	116
<i>Cumulative incidence and its reduction over three years</i>	117
DISCUSSION	121

CONCLUSIONS	127
BIBLIOGRAPHY	127
CHAPTER 4 EFFECTIVENESS OF ON-FARM TUBERCULOSIS CONTROL PROGRAMMES: COMPARISON OF WAIRARAPA STUDY WITH A CONTEMPORARY NATIONAL STUDY	133
ABSTRACT	135
INTRODUCTION	135
MATERIALS AND METHODS	136
STUDY AREAS	136
FARM SELECTION PROCESS	137
METHODS EMPLOYED	138
CATTLE AND DEER TB DATA AND CONFIRMATION OF TB STATUS.....	139
ANALYSIS OF DATA	139
RESULTS	140
VECTOR CONTROL CONDUCTED ON THE PROJECT FARMS BY THE REGIONAL COUNCIL	140
ANALYSIS OF TUBERCULOSIS TESTING RECORDS	141
<i>Time spent on Movement Control and herd TB status at the end of the project.....</i>	<i>141</i>
<i>Number of TB animals.....</i>	<i>142</i>
<i>Cumulative TB incidence and its reduction over three years.....</i>	<i>143</i>
COMPARISON OF THE NATIONAL PROJECT WITH THE WAIRARAPA PROJECT	147
<i>Comparing only cattle farms.....</i>	<i>147</i>
<i>Comparing all farms</i>	<i>149</i>
DISCUSSION	151
EVALUATION OF THE NATIONAL ONE-ON-ONE PROJECT	151
COMPARISON BETWEEN NATIONAL AND WAIRARAPA PROJECT	154
BIBLIOGRAPHY	154
CHAPTER 5 ATTITUDES OF FARMERS TO BOVINE TUBERCULOSIS CONTROL IN NEW ZEALAND	159
ABSTRACT	161
INTRODUCTION	161
MATERIALS AND METHODS	162
SURVEYS	162
<i>Wairarapa project farms.....</i>	<i>162</i>
<i>National project farms.....</i>	<i>163</i>
DEFINITION OF TERMS USED	165
ANALYSIS OF DATA	165
RESULTS	166
WAIRARAPA FARMS.....	166
<i>General farm characteristics.....</i>	<i>166</i>
<i>Herd manager</i>	<i>171</i>
<i>Stock management.....</i>	<i>172</i>
<i>TB risk assessment.....</i>	<i>173</i>
<i>Vectors and vector control on farms</i>	<i>175</i>
<i>Attitudes towards TB and its control.....</i>	<i>179</i>
<i>Perceived cost of TB and its control by farmers.....</i>	<i>186</i>
<i>Multivariate analysis between Wairarapa focused and standard control farms</i>	<i>187</i>
NATIONAL STUDY FARMS	187
<i>General farm characteristics.....</i>	<i>187</i>

<i>Herd manager</i>	190
<i>Stock management</i>	192
<i>TB risk assessment</i>	193
<i>Vectors and vector control on farms</i>	195
<i>Attitudes towards TB and its control</i>	197
<i>Perceived cost of TB and its control by farmers</i>	202
<i>Multivariate analysis between national focused and standard control farms</i>	202
DISCUSSION	203
COMPARING FOCUSED CONTROL FARMS WITH STANDARD CONTROL FARMS	203
ATTITUDES TOWARDS TB AND ITS CONTROL	204
CONCLUSIONS	206
BIBLIOGRAPHY	207
CHAPTER 6 ECONOMIC EVALUATION OF TB CONTROL PROGRAMMES AND POTENTIAL BENEFITS OF USING INCENTIVES OR AN INSURANCE SCHEME FOR DIFFERENT FARM TYPES	209
ABSTRACT	211
DEFINITIONS	211
INTRODUCTION	212
NEED FOR ECONOMIC ANALYSIS	213
TECHNIQUES AVAILABLE FOR ANALYSIS	214
AIM OF THIS STUDY	214
INSURANCE	214
MATERIALS AND METHODS	216
REPRESENTATIVE FARMS INCLUDED IN THE STUDY	216
TUBERCULOUS ANIMALS	217
DETAILS OF COSTS AND REVENUES USED IN THE PARTIAL BUDGETING	218
<i>Additional returns resulting from the implementation of control measures</i>	218
<i>Reduced costs resulting from the implementation of control measures</i>	219
<i>Additional costs resulting from the implementation of control measures</i>	219
<i>Returns foregone as a result of the introduction of control measures</i>	221
PARAMETERS USED IN THE ECONOMIC ANALYSIS	221
<i>Deterministic model</i>	221
<i>Stochastic model</i>	222
<i>Decision analysis</i>	225
RESULTS	226
DETERMINISTIC MODEL	226
<i>Current situation (65% compensation)</i>	226
<i>Alternative situations with reduced or no compensation for reactor animals</i>	228
<i>Alternative situation with subsidies on control costs</i>	230
<i>Break-even points</i>	232
STOCHASTIC MODEL (@RISK)	233
<i>Stochastic model on dairy farms</i>	233
<i>Stochastic model on beef breeding and beef finishing farms</i>	236
<i>Comparing 65% compensation level for reactors with zero compensation</i>	239
DECISION ANALYSIS	241
<i>Decision analysis on dairy farms</i>	241
<i>Decision analysis on beef breeding farms</i>	242
<i>Decision analysis on beef finishing farms</i>	246
PROVISION OF VOUCHER FOR CONTROL AND OFF-MC-PAYMENT FOR THE WAIRARAPA REGION.....	249
DISCUSSION	251
FACTORS CONSIDERED AND OMITTED IN THE PARTIAL BUDGET	251

FARMS USED IN THE STUDY AND TB REACTOR SCENARIOS ANALYSED.....	253
RESULTS FROM THE DETERMINISTIC AND STOCHASTIC MODELS	254
<i>Farm types</i>	255
<i>Compensation level and subsidies</i>	255
RESULTS FROM THE DECISION ANALYSIS	256
INSURANCE AS AN ADDITIONAL METHOD.....	257
EFFECTS FOR FUTURE CONTROL OF TB	258
<i>TB and its effect in the wider economy</i>	262
CONCLUSIONS	263
BIBLIOGRAPHY	264
CHAPTER 7 FARMORACLE, A FARM SIMULATION MODEL	271
ABSTRACT.....	273
INTRODUCTION	273
OVERVIEW OF FARMORACLE	275
SETTING UP PADDOCKS AND ANIMAL CLASSES/MOBS	277
GRAZING PLANS IN FARMORACLE	280
OUTPUT OF FARMORACLE.....	282
USE OF FARMORACLE ON SOME OF THE WAIRARAPA FOCUSED CONTROL FARMS	285
COMPARING GRAZING PLANS ON DAIRY FARMS.....	285
<i>Dairy farm A</i>	285
<i>Dairy farm B</i>	288
COMPARING GRAZING PLANS ON BEEF FARMS	291
<i>Beef breeding farm</i>	291
<i>Beef finishing farm</i>	296
DISCUSSION	301
POTENTIAL FURTHER DEVELOPMENT OF FARMORACLE.....	305
CONCLUSIONS	305
BIBLIOGRAPHY	306
CHAPTER 8 GENERAL DISCUSSION	313
INTRODUCTION	315
ARE THERE ANY CONTROL MEASURES AVAILABLE FOR FARMERS?.....	316
ARE THESE ON-FARM METHODS PRACTICAL AND EASILY IMPLEMENTED?.....	316
ARE THESE ON-FARM CONTROL MEASURES EFFECTIVE?	317
ARE THESE ON-FARM CONTROL MEASURES FINANCIALLY WORTHWHILE?	317
ATTITUDES OF FARMERS TOWARDS TB CONTROL.....	318
WHAT UNDERSTANDING OF BEHAVIOUR IS IMPORTANT FOR ACHIEVING CHANGE?	319
OPPORTUNITIES FOR ENHANCEMENT OF ON-FARM PROGRAMMES.....	320
FUTURE RESEARCH PROPOSALS EMANATING FROM THIS STUDY	320
ADOPTION OF CONTROL METHODS STUDIED	320
FARMORACLE.....	321
IMPLICATIONS OF THE METHODS STUDIED FOR TB CONTROL.....	321

CONCLUSION 322

BIBLIOGRAPHY 322

APPENDIX..... 325

APPENDIX I: QUESTIONNAIRE USED FOR THE INTERVIEWS (CHAPTER 2) 327

APPENDIX II: LIST OF CATEGORIES AND CODES USED IN WINMAX98 331

APPENDIX III: REGULATIONS REGARDING TB CONTROL AND TESTING 334

APPENDIX IV: QUESTIONNAIRE USED ON WAIRARAPA AND NATIONAL PROJECT FARMS.. 339

APPENDIX V: SPREADSHEETS USED FOR ECONOMIC ANALYSES..... 351

List of Figures

Figure 1: Text coding windows for TB history of one sample farm using the qualitative software programme WinMAX98.....	64
Figure 2: Example of a Mind Map with categories and events used in describing the TB situation and TB perception of one farmer in the sample.....	65
Figure 3. Box-plot of five-year cumulative TB incidence rates (lesioned animals 1990-1994) for the three main farm types (excluding one extreme outlier in the beef breeding group with an incidence of 0.87).	67
Figure 4. Location of study farms in the Wairarapa in the North Island of New Zealand.	98
Figure 5. Average monthly point prevalence of TB in possums (data obtained from the longitudinal study in Castlepoint).	104
Figure 6. Proportion of possums dying from tuberculosis per month of population at risk.	105
Figure 7. Relationship between power and sample size at four different proportions of focused control farms and 30% of standard control farms remaining on Movement Control.....	109
Figure 8. Relationship between sample size and power to detect a difference in cumulative incidence of TB of 0.01 and 0.02 between focused and standard control farms with a common standard deviation of 0.045.	110
Figure 9. Percentage of farms under RC vector control, assuming that a control operation lasts for four years.	113
Figure 10. Percent of focused and standard control farms that had equal or more than one, two, or three reactors in any one of the two years.....	117
Figure 11. Frequency histogram of pre-study cumulative incidence of TB animals in 1995/96 for focused and standard control farms.	118
Figure 12. Frequency histogram of cumulative incidence of TB animals 1998/99 for focused and standard control farms.	119
Figure 13. Distribution of 2yr cumulative incidence (skin test reactors plus lesioned culls) for 1995/96, stratified by farm group and herd type.	120
Figure 14. Distribution of 2yr cumulative incidence (skin test reactors plus lesioned culls) for 1998/99, stratified by farm group and herd type.	120
Figure 15. Study farm locations within four areas of New Zealand.....	137
Figure 16. Percent of farms under RC vector control, assuming that a control operation lasts for four years.	140
Figure 17. Time (in months) spent on Movement control by focused and standard control farms between 1996 and 1998.....	141
Figure 18. Proportion of farms with one, two, three or more TB animals in the years 1993/94; 95/96 and 98/99 for focused control and standard control farms.	143
Figure 19. Reduction in cumulative TB incidence between 1993/94 and 1997/98 for focused and standard control farms.	144
Figure 20. Cumulative TB incidence in different herd types of focused and standard control farms for 1993/94 and 1997/98.	145
Figure 21. Comparison of reduction in cumulative TB incidence in cattle farms of Wairarapa and national focused and standard control farms.	149
Figure 22. Effective farm size distribution of all farms included in the Wairarapa study.....	167
Figure 23. Violin plots for effective farmed area of Wairarapa focused control, standard control and non-TB farms.	168
Figure 24. Cattle herd size distribution of farms included in the study in livestock units.	169
Figure 25. Violin plots for the cattle proportion of total livestock units for focused control, standard control, and non-TB farms.....	170
Figure 26. Violin plots for cattle density on focused control, standard control, and non-TB farms.....	170

Figure 27. Distribution of age groups of herd managers on focused control, standard control, and non-TB farms.....	171
Figure 28. Personality trait means for focused control, standard control, and non-TB farmers (adapted from Seabrook, 1984)	172
Figure 29. Time spent per year on vector control by focused control, standard control, and non-TB farmers.	178
Figure 30. Box and Whisker plot of the proportion of farm area controlled by focused control, standard control, and non-TB farmers.	179
Figure 31. Importance of TB eradication as considered by Wairarapa focused control, standard control and non-TB farmers.	180
Figure 32. Attitudes of farmers towards Movement Control restrictions, if they should be stricter or less strict, stratified by Wairarapa focused control, standard control, and non-TB farmers.....	181
Figure 33. Farmers' belief regarding the effect of removing compensation for TB reactor cattle, stratified by Wairarapa focused control, standard control, and non-TB farmers.....	182
Figure 34. Organisations/institutions perceived as being responsible for TB eradication.	184
Figure 35. Effective farm size distribution of all farms included in the national study.	188
Figure 36. Violin plots for effective farmed area of national focused and standard control farms.....	189
Figure 37. Distribution of age groups for herd managers of national focused and standard control farms.....	190
Figure 38. Personality trait means for national focused and standard control farms (adapted from Seabrook, 1984).....	192
Figure 39. Days spent per year on vector control by national focused control and standard control farmers.....	196
Figure 40. Importance of TB eradication as considered by national focused and standard control farmers.....	197
Figure 41. Percent of national focused and standard control farmers who believed Movement Control restrictions should be more or less strict.	198
Figure 42. Organisations/institutions perceived as being responsible for TB eradication.	200
Figure 43. Expected net returns on dairy farms for different reductions in reactor numbers using different compensation levels for reactor animals.	228
Figure 44. Expected net returns on beef breeding farms for different reductions in reactor numbers using different compensation levels for reactor animals.	229
Figure 45. Expected net returns on beef finishing farms for different reductions in reactor numbers using different compensation levels for reactor animals.	229
Figure 46. Additional revenues per animal reduction in reactor numbers and if the herd came off Movement Control.	233
Figure 47. Economic outcome distributions from @Risk stochastic partial budgeting model for returns minus costs for six scenarios of reductions in reactor numbers for a dairy farm.....	234
Figure 48. Tornado graph with results of sensitivity analysis showing the importance of influence of different input variables for the situation where a dairy farm had 5 reactors and reduced it to 2/yr due to the implementation of on-farm control programmes.....	235
Figure 49. Comparison of the range of expected returns minus costs from the stochastic @Risk partial budgeting model for the six scenarios of reducing reactor numbers in a dairy farm.	236
Figure 50. Economic outcome distributions from @Risk stochastic partial budgeting model for returns minus costs for six scenarios of reductions in reactor numbers for a beef finishing farm (ordered from worst case scenario to best).	237
Figure 51. Tornado graph with results of sensitivity analysis showing the importance of influence of different input variables for the situation where a beef finishing farm had 2 reactors and reduced it to one every 2 nd year due to the implementation of on-farm control programmes.....	238

Figure 52. Tornado graph with results of sensitivity analysis showing the importance of influence of different input variables for the situation where a beef breeding farm had 5 reactors per year and reduced it to zero due to the implementation of on-farm control programmes.....	238
Figure 53. Expected revenues minus costs from stochastic partial budgeting (@RISK) for all three farm types and all six scenarios of reducing reactor numbers with 65% and zero compensation.....	240
Figure 54. Decision tree for expected financial outcomes for adoption or non-adoption of on-farm control measures on a dairy farm with five reactors.	242
Figure 55. Decision tree for expected financial outcomes for adoption or non-adoption of on-farm control measures on a beef breeding farm with five reactors.	243
Figure 56. Decision tree for beef breeding farm starting with two reactors and changed probabilities of reducing reactor numbers after implementing on-farm control programmes.....	245
Figure 57. Subsidies and off-MC-payments for beef breeding farms in order to make adoption of on-farm control programmes the preferred option in the decision analysis for the five-, two, and one-reactor starting situation.	246
Figure 58. Subsidies and off-MC-payments for beef finishing farms in order to make adoption of on-farm control programmes the preferred option in the decision analysis for the five-, two, and one-reactor starting situation.	248
Figure 59. Graphical display of FarmORACLE.....	277
Figure 60. Creating a paddock map in FarmTracker.....	278
Figure 61. Setting up grazing plans in FarmORACLE.	281
Figure 62. Location of animal groups on the farm map in FarmORACLE.....	282
Figure 63. FarmORACLE output of animal intake and farm cover for dairy cows.....	283
Figure 64. FarmORACLE output of animal liveweight plus supply and demand for dairy cows.....	284
Figure 65. Paddock map of dairy farm A, with TB hot-spot area in grey.....	286
Figure 66. Grazing routines during summer and winter on dairy farm A, using traditional grazing plans.....	287
Figure 67. Alternative grazing routines during summer and winter on dairy farm A, excluding TB hot-spots from grazing at these times.....	287
Figure 68. Paddock map and TB hot-spot (in grey) on dairy farm B.....	289
Figure 69. Aerial photograph of beef breeding farm.....	292
Figure 70. Aerial photograph of beef breeding farm with paddock layout.	293
Figure 71. Paddock map on beef breeding farm (TB hot-spot in grey, pine plantation in dark green).....	294
Figure 72. Grazing locations of cattle and sheep, using traditional grazing plans, for August 1998 on the beef breeding farm.....	295
Figure 73. Paddock map and TB hot-spot (in grey) of the beef finishing farm.....	297
Figure 74. August grazing plans under the traditional grazing scheme for cattle and sheep on the beef finishing farm.....	298
Figure 75. December grazing plans under the traditional grazing scheme for cattle and sheep on the beef finishing farm.....	298
Figure 76. Alternative grazing plans for cattle during high risk times (winter and summer).	299

List of Tables

Table 1. Mean [and range] of some characteristics of study farms in the Wairarapa.	66
Table 2. Distribution of focused and standard control farms by herd type and Regional Council vector control area (December 1996).	100
Table 3. Details of possum trapping and poisoning on the focused control farms, together with their effective farmed area.	112
Table 4. Number of focused and standard control farms by TB status at the end of the intervention programme (December 1999).	115
Table 5. Transitions of TB status of focused and standard control farms during the project period 1997-1999. (I= infected, C= clear status, D= disbanded).	116
Table 6. Number of focused and standard control farms with one, two or more reactors in any one of the two years.	117
Table 7. Average two-year cumulative incidence (cum inc.) of TB animals in focused and standard control farms and the reduction versus the 1995/96 cumulative incidence.	118
Table 8. Within group average of two-year cumulative incidence of TB animals in focused and standard control farms, stratified for herd type; and reduction in cumulative incidence achieved. (The number of farms in each category is shown in brackets.).....	119
Table 9. Two-year cumulative TB incidence for 1995/96 and 1998/99 for focused and standard control farms, stratified by Regional Council control received prior to June 1996.	121
Table 10. Number of focused control and standard control farms by TB status at the end of 1998 – in brackets the percentage of total farms	142
Table 11. comparing TB status at end of 1998 within herd type, in brackets percentage of farms in that herd type group.	142
Table 12. Number of focused and standard control farms with one, two or more TB animals in any one of the two years.	143
Table 13. Average two-year cumulative TB incidence (Cum inc.) for national focused and standard control farms	144
Table 14. Average two-year cumulative incidence (Cum inc.) of TB in focused control and standard control farms, stratified for herd type and reduction in cumulative incidence achieved.	145
Table 15. Comparison of two-year cumulative TB incidence (Cum inc.) and reduction between focused and standard control farms stratified by regions (the number of farms is shown in brackets).	146
Table 16. Two-year cumulative TB incidence (Cum inc.) on focused and standard control farms stratified on whether they had received vector control prior to the start of the project mid 1995 (the number of farms is given in brackets).	146
Table 17. TB status of Wairarapa and national cattle study farms at the end of the projects.	147
Table 18. Number of Wairarapa and national study cattle farms with one, two, three or more TB animals in the final study year.	147
Table 19. Comparison of two-year cumulative TB incidences in the years prior to the commencement of the intervention studies and the last two years of the projects of Wairarapa and national study farms (cattle farms only).	148
Table 20. TB status of Wairarapa and national study farms at the end of the projects.	150
Table 21. Number of Wairarapa and national study farms with at least one, two or three TB animals in the final study year.	150
Table 22. Comparison of two-year cumulative TB incidences (Cum inc.) in the years prior to the commencement of the intervention studies and the last two years of the projects of Wairarapa and national study farms (all farms).	151
Table 23. Number of farmers responding to the questionnaire in the Wairarapa and National project.	164

Table 24. General characteristics of focused control, standard control, and non-TB farms.....	167
Table 25. Average farmed area stratified by herd type and Wairarapa farm group (with range in brackets).	168
Table 26. Information on stock movements on and off farms for focused control, standard control, and non-TB farms.....	173
Table 27. Information on the TB situation and perception of focused control, standard control, and non-TB farms.	175
Table 28. Assumed likelihood of contact between possums/ferrets and livestock, as indicated by focused control, standard control, and non-TB farmers.	176
Table 29. Vector control by Regional Council and farmers as stated by focused control, standard control, and non-TB farmers.	177
Table 30. Attitudes towards TB control by Wairarapa focused control, standard control, and non-TB farmers (percentages of farm group in brackets).....	181
Table 31. Importance of farmer conducted vector control as seen by the three farm groups – focused control, standard control, and non-TB farmers.	183
Table 32. Organisations considered by Wairarapa herd managers to be responsible for eradicating TB (in brackets the number of farms that ranked these organisations with the highest priority). The last column gives the percentages of all farmers that nominated this organisation.	184
Table 33. Organisations considered by Wairarapa herd managers to be responsible for doing the actual work to eradicate TB (in brackets the number of farms that ranked these organisations with the highest priority). The last column gives the percentages of all farmers that nominated this organisation.....	185
Table 34. Estimated costs of TB and its control to Wairarapa focused and standard control farms.	186
Table 35. General farm characteristics of National focused and standard control farms.	188
Table 36. Average farmed area stratified by herd type and national farm group (with range in brackets).	189
Table 37. Livestock units and stock densities of cattle and deer on national focused and standard control farms.	190
Table 38. Information on herd managers for national focused and standard control farms.	191
Table 39. Information on stock movements on and off farms for national focused and standard control farms.....	193
Table 40. Information on the TB situation and perception of national focused and standard control farms.....	194
Table 41. Assumed likelihood of contact between possums/ferrets and livestock, as indicated by national focused and standard control farmers.	195
Table 42. Vector control by Regional Council and farmers as stated by national focused and standard control farmers.	196
Table 43. Attitudes towards TB control by national focused and standard control farmers (percentages of farm group in brackets).	198
Table 44. Importance of farmer conducted vector control as seen by focused and standard control farmers.....	199
Table 45. Organisations considered by national herd managers to be responsible for eradicating TB (in brackets the number of farms that ranked these organisations with the highest priority). The last column gives the percentages of all farmers that nominated this organisation.	200
Table 46. Organisations considered by national herd managers to be responsible for doing the actual work to eradicate TB (in brackets the number of farms that ranked these organisations with the highest priority). The last column gives the percentages of all farmers that nominated this organisation.....	201
Table 47. Estimated costs of TB and its control to national focused control and standard control farms.....	202
Table 48. Some characteristics of farms in the Hawke's Bay-Wairarapa District (from Ministry of Agriculture and Forestry, 1998).	217

Table 49. Summary of data and assumptions used in partial budgeting of implementing on-farm control programme on the three farm types in the Wairarapa.	221
Table 50. The six scenarios analysed in the study.....	222
Table 51. Distribution parameters for input variables for costs and returns used in the stochastic @ RISK partial budgeting model for the three farm types in the Wairarapa.	224
Table 52. Assumed probabilities of reducing reactor numbers per farm if conducting on-farm TB control or not.	226
Table 53. Expected economic outcomes of the partial budgeting for reducing the number of reactors in three different farm types (using current compensation of 65%).	227
Table 54. Expected economic outcomes in partial budgeting of reducing the number of reactors in the three different farm types with zero compensation.....	230
Table 55. Expected net returns with subsidy to cover costs of poison and bait stations for beef breeding farms and additional subsidies necessary to achieve net gain in all and all except one scenarios.	231
Table 56. Expected net returns with subsidy to cover costs of poison and bait stations for beef finishing farms and additional subsidies necessary to achieve net gain in all and all except one scenarios.	231
Table 57. Expected net returns with subsidy to cover costs of poison and bait stations for dairy farms and additional subsidies necessary to achieve net gain in all and all except one scenarios.	232
Table 58. Descriptive statistics for the probability distributions of the difference between returns and costs resulting from simulation modelling of the six different scenarios for dairy farms.....	234
Table 59. Expected financial values of adoption and non-adoption of on-farm control measures on dairy farms under different levels of compensation and slaughter levies with different starting numbers of reactors.....	241
Table 60. Expected financial values of adoption and non-adoption of on-farm control measures on beef breeding farms under different levels of compensation and slaughter levies with different starting numbers of reactors.	244
Table 61. Yearly off-MC-payments and subsidies for material and labour necessary to make 'adoption' of on-farm control programmes the preferred option on beef breeding farms under 65% and zero compensation for reactor animals, stratified for reactor starting situations with five, two and one reactors.	246
Table 62. Expected financial values of adoption and non-adoption of on-farm control measures on beef finishing farms under different levels of compensation and slaughter levies with different starting numbers of reactors.	247
Table 63. Yearly off-MC-payments and subsidies for material and labour necessary to make 'adoption' of on-farm control programmes the preferred option on beef finishing farms under 65% and zero compensation for reactor animals, stratified for reactor starting situations with five, two and one reactors.	248
Table 64. Subsidies used for the three farm types under two different amounts of off-MC-payments, stratified for starting reactor numbers under 40% and 65% reactor compensation.....	249
Table 65. Regional cost for providing vouchers for control work and two different off-MC-payments under two different compensation levels for reactor animals.	250
Table 66. Expected financial outcome of adopting on-farm control measures for the three herd types and the different reactor scenarios.	259
Table 67. Economic outcomes of deterministic and stochastic partial budgeting on adopting on-farm control methods for TB, stratified by farm types, compensation level and reduction of TB reactor numbers.....	263
Table 68. Outcomes of decision analysis whether to adopt on-farm control programmes or not, stratified by farm types, reactor compensation level and number of reactors to start with. ...	264
Table 69. Liveweight targets for dairy cows and heifers (in kg), used in FarmORACLE.	279
Table 70. Liveweight targets for beef cattle and sheep (in kg), used in FarmORACLE.....	280

Table 71. Production outcomes in modelling traditional (base) and alternative grazing plans on Dairy farm A..... 288

Table 72. Production outcomes in modelling traditional ('Base List' and 'Base High') and alternative grazing plans on Dairy farm B..... 290

Table 73. Economic comparison between grazing plans used on Dairy farm B. 291

Table 74. Summary of cattle and sheep liveweights for sale using different grazing plans..... 296

Table 75. End liveweights of cattle and sale ewes for three different grazing plans..... 299

Table 76. Difference in carcass weights and economic outcome comparing different grazing plans on the beef finishing farm. 300

Table 77. Comparison of grazing regimes using 800 versus 1600 kg DM/ha residual. 301