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

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# Abstract

In New Zealand the Australian brushtail possum (*Trichosurus vulpecula*), introduced in the middle of the $19^{th}$ 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 questionnaires, 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.

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# Introduction

# A guide to the methodologies and rationale for research presented in this thesis

Bovine tuberculosis (TB) is a disease of farmed cattle globally, which has been eradicated from many countries within the last century. The eradication is complicated in some countries by the existence of wild animal reservoirs for tuberculosis, that are able to transmit the disease back to domestic animals. Such reservoirs of TB have been found in badgers in England and Ireland (O'Reilly and Daborn, 1995; Hughes *et al.*, 1996), in Cape buffalo in South Africa (O'Reilly and Daborn, 1995), in cervids in North America (Schmitt *et al.*, 1997) and in several wildlife species in New Zealand such as farmed and feral deer (Nugent, 1994), sheep (Cordes *et al.*, 1981), feral pigs (Wakelin and Churchman, 1991), feral cats (Lugton, 1997), ferrets (Walker *et al.*, 1993), possums (de Lisle *et al.*, 1993; Jackson *et al.*, 1995a; Jackson *et al.*, 1995b). Amongst the wildlife species, the Australian brushtail possum (*Trichosurus vulpecula*) is considered the main vector for tuberculosis in New Zealand (Morris *et al.*, 1994; Jackson, 1995).

Tuberculosis control therefore not only has to include the management and control of TB in livestock (cattle and deer), but also in the main vector species, possums. Areas where possums are known to be infected with tuberculosis are termed Vector Risk Areas (VRA) while those, where no tuberculosis has been found in vector species are termed Vector Free Areas (VFA). The Vector Risk Areas receive the majority of vector control efforts with the main control method being to reduce the possum population.

The Animal Health Board (AHB), the national organisation for the control and eradication of bovine tuberculosis, produced a national pest management strategy (PMS) for the five-year period from 1995 in accordance with provisions of the Biosecurity Act 1993 (Animal Health Board, 1995). In the following, some of the issues covered by the PMS are summarised:

Impacts on human health, on the health and productivity of farmed cattle and deer and the impact on New Zealand's export trade in beef, dairy and venison products were cited as the actual or potential negative impacts of tuberculosis. The impact on human health is considered low due to an overall low incidence of TB, sound slaughterhouse inspection and pasteurisation of milk. If the disease was not controlled, negative effects on the farm productivity could also occur due to TB being a chronic, usually fatal disease. Under current practice the disease generally is detected early and the animals removed from the herd. Therefore, the impact on farm productivity under current practice is associated principally with control measures - by disrupting farming practices and compulsory slaughtering of infected or suspected tuberculous animals. The impact on New Zealand's export trade of beef, dairy and venison products, which is worth approximately $5 billion per year, is considered as the most serious aspect of tuberculosis. The incidence of bovine tuberculosis in New Zealand is higher than in many other countries, therefore potentially creating a disadvantage for New Zealand in the current international trading environment.

Therefore, the long-term goal of the AHB is "to eradicate bovine tuberculosis from New Zealand". However, the report stated that "eradication is not a realistic possibility within the term of the strategy with current technology. Therefore the primary focus of the five year strategy is on the reduction, and where technically feasible, elimination of the transmission of *M. bovis* to and within domestic livestock, specifically cattle and farmed deer" (Animal Health Board, 1995).

The presented thesis addressed a national requirement and aimed to assist the AHB by assembling information required to further succeed in the control and eradication of TB. The following key points of the AHB strategy provided the framework for the studies presented in this thesis.

Four objectives were stated for the five-year period:

- to reduce the number of infected herds in TB Vector Free Areas from 0.7 percent to 0.2 percent of the total herds in those areas,

- to prevent the establishment of new TB Vector Risk Areas and/or the expansion of existing TB Vector Risk Areas into farmland free of TB vectors,

- to decrease the number of infected herds in TB Vector Risk Areas from 17 percent to 11 percent of the total numbers of herds in those areas,

- to encourage individuals to take action against TB on their properties and in their herds.

Disease control and vector control are proposed as two main areas for achieving these objectives. The strategy states that "managing and eliminating <u>disease risk</u> from wild animals through increased vector control operations is critical to the success of the strategy" (Animal Health Board, 1995). At the time of publishing the strategy, an increase in vector control expenditure from $18 million in 1995/96 to $31 million in 1999/2000 was expected. Following priorities were listed for vector control (Animal Health Board, 1995):

- Establishment of protection zones to prevent leakage of infected vectors from infected areas.

- Encouragement and assistance to farmers in infected areas to improve their disease status through:

    - Assistance with development and implementation of regional and locally initiated vector control programmes.

    - Reclassification of areas as vector risks are reduced.

    - Assistance to farmers with high risk herds.

- Self-help programmes.
- One-on-one programmes.

- Commitment to control of infected wild animals on Crown land adjacent to farmland.

This thesis presented addresses the priority 'encouragement and assistance to farmers to improve their TB status'. The general objective of the thesis was to test whether intensive management advice and its adoption could accelerate the control and eradication of TB from individual farms, particularly those with persistent TB problems.

- Chapter one: Literature review of the field of human behaviour change and agricultural extension, to examine how change can be achieved and what factors limit the scope for change in practice.
- Chapter two: Interview survey to establish management, practices and attitudes of farmers who own or manage TB-infected farms, in order to establish baseline data which would be incorporated into the intervention study.
- Chapter three: Intervention study of using on-farm TB control programmes on farms in the Wairarapa region, in order to evaluate the effectiveness of on-farm TB control programmes under field conditions.
- Chapter four: An evaluation of the national one-on-one TB programme, undertaken by AgriQuality, the state veterinary service, and Agriculture New Zealand, an agricultural advisory company, and comparison with the Wairarapa programme.
- Chapter five: Questionnaire analysis, comparison of focused control farms (receiving interventions) and standard control farms (receiving no interventions) for both projects analysed separately; farmers' attitudes towards TB and its control.
- Chapter six: Economic analysis of TB and on-farm TB control programmes on farms in the Wairarapa, in order to assess the cost effectiveness of such programmes and propose potential motivational incentives.
- Chapter seven: FarmORACLE, a computer model that allows modelling of each specific farm situation and compares different farm management policies (such as different grazing strategies), in order to facilitate and assist decision making in relation to TB control.

A final discussion of the results of all studies presented in this thesis and a discussion on the application of findings in future TB control programmes is presented in the General Discussion.

This thesis has been written in the form of a series of papers. The papers will be submitted in adjusted form following the submission of this thesis.

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**Australian Brushtail Possum**

**Farm in the Wairarapa**

# Chapter 1

# Changing Behaviour: a literature review

# Introduction

In order to get farmers to take more responsibility in disease control programs, such as programmes for tuberculosis (TB) control in New Zealand, two main factors are necessary: First that farmers have the required tools (knowledge, understanding and methods) available to them; and second that they then adopt and implement these tools and methods.

Ashby wrote in 1926:

> "If we want to know how or why a farmer acts in a certain way or how to induce him to act in a certain way, we have to enquire why men act, and especially why men act as they do when they live in the sort of social environment and general circumstances in which farmers live."

Therefore it was necessary to look into the field of behaviour change and methods applied, especially in agriculture, to understand this change. This chapter reviews the published literature on the process of change, and the behaviour involved. Two examples are reviewed in more detail of how these behaviour changes have been applied in real live situations: one example in the human health field of smoking cessation, and the second example in agricultural extension. Extension is a term commonly used in agriculture for the process of transferring information from scientists/industries and others to the end users of the information (Morris *et al.*, 1995).

# Behaviour Change

Any behaviour change involves processes at the cognitive level, which can be stimulated by information channels and sources. Through the diffusion of new ideas or innovations eventually a behaviour change can be achieved on a broad basis throughout the populations or social system.

## *Cognitive process*

Behaviour is guided by the physical, social and economic environment of the individual. Each individual's personal characteristics (such as beliefs, values, opinions, norms, objectives, expectations, attitudes, habits, and intellectual and physical capabilities) play a role in that individual's behaviour. These characteristics lead to the way an individual views the world, which can be considered to be the individual's mode of cognition. Cognition and environment provide opportunities and restrictions to activity (Triandis, 1971). Each individual has a tendency towards consistency. If there is inconsistency, cognitive and behavioural processes start with the aim of reducing this inconsistency and re-establishing consistency. The reduction of inconsistency can either be obtained through manipulating cognition, by suppressing, rejecting or rationalising information and not changing the behaviour, or through a change of behaviour.

The process of behaviour change is a complex cognitive process including four stages: need recognition ➔ search for information ➔ evaluation ➔ choice (Fairgray, 1979; Rogers, 1995; Steenkamp, 1997).

Fairgray (1979) and Rogers (1995) provide a review on the literature of this process, which in the following is elaborated. The initiating factor in behaviour change is a challenge to the existing state of satisfaction with current behaviour. This can occur when events or information suggest a disadvantage of the present practice or the non-use of an alternative one. Generally, the first reaction to such information and the challenge is to ignore it, reject it as being irrelevant or inaccurate, or change the information in a way that it will be consistent with current behaviour/attitudes. However, if the information is accepted, it creates a dissonance between the existing attitude and the new knowledge, an inconsistency between the old belief(s) and the new belief(s), that the alternative practice should be used. Mostly the acceptance of the information comes from close evidence or from a trusted source.

Once the individuals have recognised the challenge, they will assess alternatives that are available. This step involves drawing from the person's own experience and ideas, as well as seeking additional information. The objectives and capabilities determine the viable alternatives, whereas the importance of the challenged behaviour determines the extent of the search for new information. The potential gains and losses of each alternative are compared with those of the others and mainly with those of the existing practice. Main determinants in this process of evaluation are the perceived risks and uncertainties. The existing practice/behaviour has advantages in terms of being established and having less risk of failure than a new practice. Therefore it requires more effort to make a decision to change than to decide to keep the existing practice. For each situation the costs being saved and/or risks avoided by not changing are compared against the anticipated advantages to be gained by changing. The level where the first outweighs the latter one is called the threshold level, which depends on factors such as the risks and costs of the alternative option involved, the scale of change and the satisfaction with the existing practice (Fairgray, 1979).

At the end of this stage of persuasion or evaluation the individual makes a tentative decision to adopt or reject the new alternative and tries to confirm this decision. If the decision was made to change the individual seeks information that supports this and ignores, if possible, information that contradicts the decision. The last stage of the decision-making process towards change is the adherence to the decision, where the behaviour is confirmed and the challenge resolved or suppressed. Therefore decision making can result in a behaviour change, a reinforcement of the existing practice, or a situation where the challenge is accommodated and accepted, but no behaviour change occurs because no decision is being made (Rogers, 1995).

For an 'extension agent', anybody conveying information to others, there are two critical points in the decision-making process: the challenge to existing practices and the evaluation stage. The agent has to challenge the existing practice by challenging the existing attitudes and providing new information in favour of the new practice/innovation. The individual's objectives are most important. Often the individual has to be made dissatisfied with the existing practice by pointing out alternatives that better achieve the individual's goals or that achieve higher or alternative objectives. The resulting dissonance has to be strong enough to be too uncomfortable to be ignored or suppressed, which occurs when the perceived advantages outweigh the cost of the adoption (Fairgray, 1979).

### *Information channels and sources*

In order to change behaviour, information on the innovation must be available, understood, accepted, retained and acted on. The acceptance of information however depends very much on the source of it.

Three types of information channels are available: personal direct, personal indirect and impersonal indirect. The personal direct information channels are the five senses (sight, sound, taste, touch, smell), whereby the information is sifted before, during and after the receipt of the message. The information is also prone to distortion through selective attention, limited capacity of the nervous system to receive information and further alteration after it has been received and understood (Fairgray, 1979).

If the information comes through another person, such as by face-to-face contact or by telephone, it is termed personal indirect information channel. Impersonal indirect channels include letters, books, journals, newspapers, radio, television and more recently the Internet. These three information channels related strongly to the source of information: intrapersonal, interpersonal and media (Schramm, 1973).

Six characteristics were identified by Schramm (Schramm, 1973) as affecting the utility of information channels: a message is more likely to be received

- the more senses it affects,

- the more control the receiver has over the speed of the delivery,
- if the message is in permanent form,
- if it is easily understood,
- the higher the multiplicative power of the channel (determines the number of people reached and the area covered), and
- the greater the opportunity for immediate feedback between source and receiver.

Interpersonal communication is generally more effective in obtaining acceptance of a message than mediated communication, as interpersonal communication has the additional power of persuasion. There are three processes, whereby information can be accepted (Kelman, 1967): through compliance, if the change agent has authority over the recipient; through identification, where the agent has attractiveness, such as prestige, experience, whereby the content of the information may be irrelevant; or through internalisation, if the contents of the message seem logically correct and rewarding and therefore warrant acceptance. For the third one, the agent needs credibility, such as expertise, objectivity, success and proof. In many extension services the first process, compliance, is unimportant.

### *Brief overview of adult education*

The rate of learning is a major factor in the adoption of innovations and achieving change. Only if an individual's conceptual framework is changed, new ideas can be applied. Thus, in order to achieve change, it is not enough to provide purely information and knowledge, but also opportunities for learning (Stantiall, 2000). Learning, the continued updating with new information, is an essential element of today's knowledge (Barr, 2000). Information and knowledge are two distinct concepts. Information can be shared, stored, communicated, while knowledge is within the minds of each individual (Stantiall, 2000).

The process of adopting innovations depends on learning, and an individual's ability to learn is enhanced by strategies that conform with the learning style preferred by this individual (Kolb, 1984). There are two main parts to learning, first to grasp the information, either through conceptualising or through experience and the second part is the transformation of the information into knowledge, either through reflection or through experimentation (Kolb, 1984). Individuals can be grouped into four distinct theoretical learning styles, depending on how they grasp information and transform it into knowledge: Accomodator who learns by experience; diverger who learns by weighing up different perspectives; converger, who learns by putting theories into practice; and assimilator, who learns by sorting information into concise logic (Kolb, 1984). In practice, learning styles are influenced by past and present experiences.

Lewin, a psychologist in the first half of the twentieth century did a lot of work on experiential learning. It will result in altered cognitive structures, modified attitudes and expanded range of behavioural skills. Within experimental learning there are several principals: people will believe more in knowledge they have discovered themselves than in knowledge presented by others; the more supportive the social environment is, the more likely a person is to experiment with new behaviours/attitudes; and learning is more effective when it is active than passive. (Jackson and Caffarella, 1994; Ballantyne and Packer, 1996; Botha, 2000). In participatory learning the learner is involved throughout the learning process, even at the design stage. Participatory learning empowers the individual, resulting in 'education for change' rather than 'education for adaptation' (Peet and Peet, 1995).

As individuals may have different conceptions when dealing with a learning task, they will learn different things from the same event and apply their understanding differently (Ballantyne and Packer, 1996).

## Innovation diffusion model

In order to achieve behaviour change on a broad basis, the concepts have to be disseminated throughout the population. The main model used to describe this process is the innovation diffusion model, as described by Rogers (1995). It is the process whereby an innovation is diffused or communicated to populations or social systems over time. Spontaneous diffusion is distinguished from directed or managed diffusion (Rogers, 1995). If the spread of information is unplanned it is called a spontaneous diffusion, while directed or managed diffusion describes the deliberate attempt to spread the innovation or new idea. Because of the directed diffusion this theory has found wide interest and application. The theory involves the innovation process, innovations themselves and their characteristics, the adoption of innovations and the communication channels or change agents.

### *Innovation process*

The entire innovation process can be divided into two main parts: Firstly, the innovation-development process comprises all decisions and activities and their impacts that result from recognition of a need. Included are research (basic as well as applied), development and commercialisation of the innovation through diffusion and adoption by the users and finally its consequences.

The second part is the innovation-decision process an individual goes through: Knowledge ➜ Persuasion ➜ Decision ➜ Implementation ➜ Confirmation (Rogers, 1995). In the beginning the individuals gain a first knowledge of the innovation, then they form an attitude towards this innovation and decide then to adopt it or to reject it. If they adopt it, they will implement the innovation and confirm the decision (Rogers, 1995).

A similar model of stages was proposed by Prochaska *et al.* (1992), cancer prevention researchers, who investigated how individuals change an addictive behaviour. Their 'transtheoretical' five-stage model was first proposed in 1983 and is now widely used in the human public health field to explain the adoption of preventive health innovations, such as dietary measures (Ni Mhurchu *et al.*, 1997; Sporny and Contento, 1995), quitting cocaine, smoking, adolescent delinquent behaviour, safe sex, contraception, use of sunscreen and others (Prochaska *et al.*, 1994). The first stage is precontemplation, where the individual is aware of the problem and starts thinking about overcoming it. The second stage is contemplation, where the individual is seriously thinking about overcoming the existing problem, but they have not made a commitment yet. In the third stage, the preparation stage, the individual intends to make a commitment in the near future, but has not done so. The fourth stage is the action stage, where the individual actually changes the behaviour or the circumstances in order to overcome the problem. The fifth stage is maintenance, at which the individual consolidates and continues the behaviour change. Individuals generally cycle through these five stages several times before overcoming the addiction (Prochaska *et al.*, 1992). It is important to assess the stage of an individual's readiness for change and to tailor interventions accordingly. If the majority of individuals are not yet in the action stage, then action-oriented programmes will only serve a minority of the population (Prochaska *et al.*, 1992).

All these stages have to be passed in sequence by the individual, and the communication channels have to be aligned with the stages in the innovation-decision process (Rogers, 1995). More recent modifications of the linear model account for the recycling through the stages in order to account for relapses (Brownell *et al.*, 1986).

### Characteristics and adoption of innovations

There are five main characteristics of innovations which are critical to their adoption (Rogers, 1995; Greer and Greer, 1996): relative advantage, compatibility, complexity, trialability and observability.

The relative advantage as it is perceived by the user, can be expressed in economic terms, social prestige or other benefits. Economics might be the most important predictor for the rate of adoption, but Rogers regards it as unlikely that it is the sole predictor (Rogers, 1995). For certain innovations like clothing fashion, social prestige is almost the only benefit for the adopter. Economics were found to be less important to peasant farmers in the Third World, where the farmers attached greater importance to social approval than to financial return (Fliegel *et al.*, 1968).

Preventive innovations have particularly slow rates of adoption because individuals have difficulties perceiving the advantage, partly because the consequence is somewhere in the distant future. The rewards of adoption are not only delayed but also uncertain and therefore also rely on the scale of risk perceived by the individual. Someone practising safe sex in order to prevent infection with HIV/AIDS might not have contracted it even without adopting safe sex (Rogers, 1995).

Incentives are often used to accelerate the rate of adoption of innovations by increasing the degree of relative advantage. They have been used in many fields, such as agriculture, human health and family planning. A wide range of different types of incentives exists (Rogers, 1973 quoted in Rogers, 1995): incentives that are paid to adopters directly, incentives that are paid to individuals that persuade others to adopt, positive and negative incentives, monetary and non-monetary incentives, immediate and delayed incentives. Rogers (1995) drew the following conclusions: incentives increase the rate of adoption of innovations, incentives can change the group of individuals that adopt the innovations (individuals who would not have adopted otherwise). Incentives also increase the number of adopters. However, the quality of adoption might be lower than desired, thus limiting the intended consequences, because if individuals only adopt in order to get the incentive, there is less motivation to continue to use it. Rogers (1995) proposes that the effectiveness of incentive policies can be improved if empirical studies evaluate the effects first.

At a national level, if incentives are not taken up at a rate which Government desires, it can use legislation and enforce certain changes, such as the People's Republic of China having mandated the one-child family.

Compatibility is the degree to which individuals see the innovation as consistent with existing socio-cultural values and beliefs, with past experiences (previously introduced ideas) and/or client needs for the innovation. The latter is especially important in Third World Countries. Often the indigenous knowledge systems are not recognised or are considered inferior by change agents that come from developed countries. Ignoring these knowledge systems can not only miss important local knowledge, but also lead to a decreased rate of adoption (Rogers, 1995). The more compatible an innovation is, the greater its adoption.

The perception of individuals on the degree of difficulty to understand and use innovations falls under the category 'complexity'. Generally, the more complex an innovation, the slower its rate of adoption (Rogers, 1995).

Trialability is personal experimentation with an innovation to find out how it works under the individual's own circumstances. The easier it is to trial the innovation, the greater the adoption, especially for the early adopter category (Rogers, 1995).

Observability is the degree to which the results of the innovation are visible to others; it is positively related to its rate of adoption (Rogers, 1995).

### *Change agent*

A change agent is an individual that influences clients' innovation-decision process towards a direction desired by the change agency. A change agent usually tries to ensure adoption of innovations. However, they might also attempt to prevent the adoption of certain innovations with undesirable effects (Rogers, 1995). They intend to be a communication link between the resource system and the client system. This communication has to be two-way. Feedback from the client system has to go through the change agent back to the change agency, so that latter one can adjust their programmes in order to meet the needs of their clients. Rogers (1995) defines seven roles for the change agent in the process of introducing innovations: (1) To help develop a need for change by pointing out alternatives to existing problems and convince the individual that they are capable of confronting the problem; (2) To establish an information-exchange relationship, which can be enhanced by being perceived as credible, competent, trustworthy, and by empathising with clients' needs and problems. Before clients will accept the innovation, they must accept the change agent who promotes it; (3) To diagnose problems, where the change agent has to analyse the client's problems to find out why existing alternatives do not meet their needs; (4) To create an intent in the client to change. In this phase the change agent tries to motivate clients' interest in the innovation; (5) To translate an intent to action. Peer-networks are the most important influence in this stage, and the change agent can only operate indirectly by working with opinion leaders; (6) To stabilise adoption and prevent discontinuance, through giving reinforcing messages while the clients are at the implementation or confirmation stage of the innovation-decision process; (7) To achieve a terminal relationship, where the change agent tries to develop the clients' ability to be their own change agents (Rogers, 1995).

The success of a change agent increases with the amount of effort spent in communicating with clients, but the timing of the client contact has to depend on the stage of diffusion the clients are in. Another positive relationship was found between agent's success and the client orientation (versus a change-agency orientation). Such change agents are regarded as having higher credibility and obtain a higher feedback. The probability of success is also positively related to the compatibility with clients' needs, the change agent's empathy with the clients' needs, the credibility in the clients' eyes and the similarity between the change agent and the client. From the latter relationship Roberts concludes that change agents have most contact with clients who are most like themselves and therefore change agent contact is positively related to a higher social status, higher education and cosmopoliteness amongst clients. This means there is a more effective communication between the two parties the more similar they are. However, this leads to a circle of relationships where the change agents help those people most that least need their help (Rogers, 1995).

In order to encourage the less-educated clients, aides are necessary. These people are not fully professionals, but help to bridge the gap between the professionals and the clients. They have less credibility regarding their competence, but greater credibility as being trustworthy (Rogers, 1995).

### Consequences of innovations

The consequences of innovations are often inadequately investigated, firstly because often the change agencies assumed the consequences to be positive, secondly because they are difficult to measure and the usual survey research methods may be unsuitable. The consequences can be desirable or undesirable. However, the consequences often have both outcomes. Consequences can also be direct or indirect, anticipated or unanticipated. The consequences of diffusion of innovation usually widens the gap in socio-economic status between the early and the late adopters, and often the gap between rich and poor in the system (Rogers, 1995). However, this can be avoided by specifically targeting certain groups within the system (Rogers, 1995).

### Decentralised diffusion systems

In the classical diffusion model, Government officials or technical experts decided on what innovations had to be diffused, what channels to be used and to whom the innovation was diffused (Fairgray, 1979). The diffusion is from top to bottom, with the individual adopter of the innovation being a passive acceptor. In recent decades decentralised diffusion systems were being recognised, where innovations originated from the operational levels of a system (Rogers, 1986). These innovations were then spread horizontally through peer network with modifications along the line, in order to suit their particular circumstances. These decentralised diffusion systems are generally not run by technical experts, but are client controlled, where the adopters often serve as their own change agents (Rogers, 1986; Rogers, 1995). These systems are designed to stimulate innovation because it enhances the diversity of approaches (Sherman and Schultz, 1998). However, decentralisation also can lead to decreased efficiency in resource usage. The innovation is divided into smaller parts, possibly overlapping, and thus resources might be spent on overlapping projects (Banks and Harley, 2000).

## Human behaviour change: the smoking example

Smoking is strongly related to the occurrence of lung cancer (Stellman and Garfinkel, 1989), increased respiratory illness among children whose mothers smoke (Stoddard and Gray, 1997). It is also a major risk factor for heart diseases and stroke and affects foetuses. In smoking there are four stages – initiation, maintenance, cessation and resumption or relapse (Lichtenstein, 1982). Psychosocial factors are important in all four stages, while the pharmacological effects of nicotine only start to appear in the second stage.

Because of the negative effects of smoking, many health professionals encourage the cessation of smoking. Most smokers know that smoking is harmful and many try to overcome the addiction (Leshner, 2000). Individuals overcome the addiction with and/or without the help of professional treatment programs. Early investigations of smoking assumed a linear model of behaviour change stages, where the individuals pass through the different stages of precontemplation, contemplation, action and maintenance (DiClemente and Prochaska, 1982). However, most people who actually take action to overcome the addiction, do not maintain it, and therefore have several action attempts before they become long-term smoke-free (Norcross and Vangarelli, 1989; Cohen *et al.*, 1989). Prochaska *et al.* (1992) concluded that the linear progression through the stages of the model of change is possible, but relatively rare with addictive behaviour. Often the individuals relapse and regress to an earlier stage in the model, but not necessarily back to where they started, which led to the development of the spiral model, whereby the success of quitting was not related to the number of previous attempts (Cohen *et al.*, 1989; Prochaska *et al.*, 1992). In an earlier study they found that 85% of smokers return to the contemplation or preparation stages (Prochaska and DiClemente, 1984). However, some individuals feel like failures and refuse to think about behaviour change, therefore returning to the precontemplation stage. This transtheoretical model of stages has been subject to several critiques, especially as any change is a continuum rather than a process through discrete stages (Sutton, 1996; Davidson, 1998). Nevertheless, the model is still considered extremely valuable within the addiction field, as it is practical, intuitive appealing to several theoretical orientations and as it includes motivation (Davidson, 1998).

Quitting smoking is not a single event, but a process and there are many ways to cessation. There is much debate about the superiority of self-quitting versus professional treatment programmes for smokers. Schachter (1982) suggested that individuals attempting to quit smoking by themselves had a higher success rate than individuals who attended formal programs. However, evaluations of professional programmes only look at a single attempt to quit smoking, whereas retrospective studies on self-quitting look at the result of mostly multiple attempts to quit (Cohen *et al.*, 1989). In a study looking at 10 long-term prospective studies on self-quitting it was found that self-quitting had a similar or lower success rate than formal programs.

Excellent action-oriented treatment and self-help programmes were designed and available, but professionals are disappointed with the percentage of smokers taking these programmes up. Schmid *et al.* (1989) reported on four different recruitment strategies for home-based smoking control intervention programs, but found that only 0.1 to 5% of smokers enrolled, indicating that the vast majority of smokers are not at the action stage yet. Di Clemente and Prochaska (1998) estimated from a range of studies on smoking behaviour, that 20 percent of smokers are prepared for action, 40 percent are only in the contemplation stage, and 40 percent in the precontemplation stage. From these percentages the authors concluded that action-oriented control programmes would only target a small percentage. The success of smoking cessation programmes is directly related to the stage the smokers were in at the beginning of the intervention, indicating that traditional ways of treating all individuals as if they were the same is not achieving maximum success (Prochaska *et al.*, 1992). Thus they suggested that interventions should be stage-matched in order to achieve maximum success in terms of people entering therapy, continuing therapy, progressing in therapy and progressing after therapy (DiClemente and Prochaska, 1998).

There is a wide range of programmes available to help individuals overcome their addiction or to prevent addiction. Smoking prevention programmes that were intended to prevent adolescents from becoming cigarette smokers have tried several approaches: providing information on the consequences of smoking; concentrating on social influences and resistance skills to withstand the temptation of smoking; and general life/social skills (Durell and Buoski, 1984). The latter two approaches seemed to be more successful than the first one (Silvestri and Flay, 1989). These skills are also incorporated into cessation programs. Programmes available for individuals being addicted to smoking range from no-cost self-change programs, to self-help books, media, community programs, self-help groups, advice from health professionals, and to expensive commercial or clinical programmes (Thompson, 1978; Brownell *et al.*, 1986). Nicotine replacement treatment by patch is one form of commercial program, which was shown to be effective when comparing with a placebo group (Hays *et al.*, 1999), while nicotine gum was only effective on short-term assessment (Haaga and Kirk, 1998). Such programmes are mostly combined with consultation and follow-up and relapse prevention consultations (Fiore *et al.*, 1994; Hurt *et al.*, 1994; Silagy *et al.*, 1994). The effect of such combined therapies might be higher than either alone (Klesges *et al.*, 1996). Although the training for professional consultants is stressed, some studies did not find any differences in the effect of self-trained versus workshop-trained professionals (Cameron *et al.*, 1999). For most individuals certain programmes work better than others and screening individuals prior to the commencement of a programme might help to match individuals for their optimum strategy and would allow professionals to focus on these individuals with the greatest chance of success (Brownell *et al.*, 1986).

In order to facilitate long-term maintenance of non-smoking three main methods were traditionally available: The first method was the provision of 'booster' sessions, which have been found to be ineffective (Lichtenstein, 1982). The second method was the addition of relaxation, contingency management and assertion training to the ordinary treatment methods. However, these additions cause complexity, and thus less compliance and less effectiveness (Marlatt and Gordon, 1985). Lifelong treatment was the third method, an approach taken by Alcoholics Anonymous or by Weight Watchers offering lifetime membership. An evaluation of these programmes is difficult because of their long-term duration and the problems associated with research on commercial groups (Brownell *et al.*, 1986).

Apart from education, anti-smoking policies also include regulation and taxation. It seems that taxation regulations are effective, while advertising bans are less effective. Several studies across different countries found a decrease in cigarette consumption after increasing taxes, whereby the larger the tax, the higher the reduction in tobacco consumption (Peterson *et al.*, 1992; Godfrey and Maynard, 1995; Stephens *et al.*, 1997; Jha and Chaloupka, 2000), however none of these studies investigated if the reduced consumption was sustained. A decrease in tobacco consumption can also be achieved with extensive bans on tobacco advertising. Partial advertising bans had little or no effect (Horgen and Brownell, 1998; Jha and Chaloupka, 2000), mainly because of other forms of advertisement. Advertising as posters or in magazines proved to be more cost-effective than for example television advertisement (Horgen and Brownell, 1998). One example of a removal of advertisement that had no effect on consumption, was when the tobacco industry 'voluntarily' removed all advertising from television in the United States. However, this happened after legislation was put into place, that required an equal amount of time being spent on anti-smoking advertisements. The tobacco industry feared the effect of these anti-smoking messages and removed all advertisement from television, but instead concentrated on other media (Horgen and Brownell, 1998).

More recent methods of preventing relapse and cessation programmes include motivation enhancement, even involving monetary incentives. In different studies it was found that addiction to smoking or other drugs did not seem to be due to lack of suffering, knowledge, education and insight. Thus more focus is now put on motivation (Miller, 1998). Motivation is often brought in context with the analogy of a carrot and a stick, whereby many people misunderstand the stick as some sort of punishment. Yet in the original image the carrot is tied to a stick and therefore dangling in front of the donkey, who cannot reach it, but in trying to get to it, the donkey will move forward and pull the cart. Thus the carrot and the stick is not a punishment, but an alternative to it (Miller, 1998). Motivation does not try to trick people into doing something they do not want to do, but it tries to bring people to understand that their addiction is counterproductive to main goals/objectives the individual has (Miller, 1998). A motivator for most behaviours is positive reinforcement, as people will do what causes a positive feeling (Miller, 1998). This positive reinforcement is most effective if it comes frequently and from individuals close to the addicted person (Miller, 1998).

Another form of motivation is often the personalised realisation of pros and cons of smoking and its related diseases. It is often postulated that the general knowledge of these pros and cons is insufficient unless the smoker experiences them in his/her own situation. A study of post-coronary patients resulted in a high cessation rate (Burling *et al.*, 1984; Ockene and Zapka, 1997). In contrast a study by Silagy *et al.* (1994), who performed a meta-analysis on nicotine replacement therapies, found only limited success. In their study the combined results of using nicotine gum in hospital-based patients only showed a cessation rate of 15% versus 11% in the no-treatment group, which the authors considered 'disappointing', as the patients often had coexisting smoking-related diseases that might have been an added incentive to quit.

Motivation not only includes the perception that quitting smoking is a better/healthier way, but also that the smoker sees him-/herself capable of quitting smoking (Haaga and Kirk, 1998). It is concluded that research and investigation still have to continue in the field of motivation.

## Example from Agricultural Extension

Behaviour change is needed when there is a gap between where an organisation/individual/ community is at present and where the individual/policy makers/market forces/quality assurance schemes and others want it to be. These forces encourage behaviour change by three means: economic means (penalties, subsidies), legislation (rules, regulations) and by participatory processes, such as extension, where people change because they perceive it to be for their own best (Greer and Greer, 1996).

### *Definition of Extension*

Extension can be defined as a linear process transferring information and knowledge about new technology from scientists/industry/other organisations to educators and then to users (Morris *et al.*, 1995). Technology transfer is only one element of extension. Extension is defined differently across countries and organisations, causing inherent conflicts (Röling, 1988). There are two main elements to extension: providing information so that the individual can clarify and achieve their own goals and empowering the poor and thereby achieve structural changes (Röling, 1988, p.37). Often human resource development principles are used in both elements, teaching people how to learn, organise, manage, analyse their environment and others. Röling (1988, p.39) notes that despite the varying definitions extension comprises following common features:

- it is an intervention
- it uses communication to induce change
- it is only effective through voluntary change
- it focuses on several different processes and outcomes
- it is arranged by an institution.

Extension is expensive, a reason why it was usually carried out by institutions rather than individuals (Röling, 1988, p.48). All over the world, Governments use extension as a policy instrument in order to achieve goals such as export goals, national food security, efficient use of national resources. To the Government these goals may be more important than the welfare of the individual farmer (Röling, 1988, p.38).

In the second half of the nineteenth century an increase of agricultural innovations occurred and as a consequence the linear model of extension became popular. Scientists defined which aspects of farming should be investigated and passed the solutions to farmers through extension by specialist educators. This linear model was accepted very rapidly and universally, as the development of the 'diffusion of innovation' concept showed. Rogers (1995) defines this concept as 'the process by which an innovation is communicated through certain channels over time among the members of a social system'. A slight variation of this linear model is the multiplier diffusion model, where the information diffuses in a secondary diffusion process through the informal farmer to farmer network (Fairgray, 1979).

Pretty and Chambers (1993; reviewed in Haug, 1999) categorised extension theory according to the approach taken and the influence of different disciplines into four stages:

- Classical top-down, one-way transfer of technology (1900-1975)

  Farmers were seen as recipients of technology. Pioneering work in crop and animal breeding.

- Two-way transfer of technology (1975-1985)

Farmers were seen as sources of information and technology design. Pioneering work by economists and agronomists.

- Ecological stage (1985-1995)

  Farmers were seen as causes and victims of environmentally unsustainable development. Main disciplinary influences from anthropology, agroecology and geography.

- Institutional stage (1995-onwards)

  Farmers are seen as full collaborators in research and extension. Disciplinary influences from psychologists, sociologists, political scientists, training specialists and educators.

### *Adoption process and efficiency of technology transfer*

In order to be successful a desired change or new innovation has to address farmers' needs or create awareness for these needs. Efficiency of technology transfer from scientists to farmers varies with the nature of the technology (Röling, 1998). Easy to use, cost-effective methods will quickly be adopted by the majority of farmers often after only creating awareness. In contrast, other technologies need more intervention, such as face to face consultation, in order to get them adopted. The 'trickle down' or diffusion model assumes that once some individuals have adopted the new technology, its use will 'trickle down' or diffuse through the whole target population. The model therefore assumes that the better the communication in the first place, the better and the more effective the diffusion process will be (Röling, 1998, p.53). However, Rogers (1995) adds that most innovations diffuse at a 'disappointingly slow rate'. Anderson (1981) cautions on overemphasising the 'early adopter' group, as the network of these farmers often contain a high proportion of other 'early adopters'. Therefore any information entering this circle is likely to remain there, rather than diffuse down to the general farming community.

In the 1920's studies started looking at the adoption of innovations and a vast number of studies supported this 'trickle down' strategy (Weber, 1974; Kung, 1984; Ghosh, 1993; Timmons Roberts, 1995 just to mention a few). Rogers (1995) provided a summary of the literature on the technology transfer, in which he divides the adoption process into five distinct stages: knowledge, persuasion, decision, implementation, and confirmation. The knowledge stage can occur even before a farmer feels the need to change. Once the need is there, the change is made and the outcome classified as favourable or unfavourable (persuasion stage). However, a favourable outcome does not necessarily mean adoption. The decision to adopt the change depends on its relative advantage, its compatibility with existing systems, its ease to use, its risk of implementing, and its observability.

These five characteristics were found to be the most important factors in explaining the rate of adoption of innovations (Rogers, 1995).

Rogers (1995) stated that most innovations had an S-shaped rate of adoption and he divided the individuals into five groups: innovators, early adopters, early majority, late majority, and laggards. He also mentions that the most innovative members of a social system are often perceived as a 'deviant from the social system' and the average members of the system assign them low credibility. Other members of the social system will act as opinion leader or 'knowledge influentials', which is an informal leadership that does not depend on the individual's formal position or status in the social system, but which is earned through the person's technical competence, social accessibility, and conformity to the system (Anderson, 1981; Rogers, 1995). It was also found that these opinion leaders and early adopters were usually more educated, had higher social status, got exposed to greater mass media communication, showed greater social participation and more cosmopoliteness, and were generally more progressive thinking than individuals adopting innovations later (Wassell and Esslemont, 1992; Rogers, 1995). Anderson (1981) observed that the early adopters were mainly belonging into the 'upper' and 'lower middle' rather than into the 'upper middle' economic rank.

Innovations can be adopted or rejected by individuals independent of the decision of others (optional innovation-decision), but the social system as a whole can also decide to adopt an innovation, either by collective or by authority decision. Collective innovation-decisions are made by consensus among the members of the system. Once the decision is made, all units of the system have to comply with it. Authority innovation-decisions are made by relatively few individuals, who have the power, status or technical expertise. The individual members of the system are then required to implement the decision (Rogers, 1995).

A major role of researches has been the identification of barriers to adoption. When Rogers and Shoemaker (1971, cited in Rogers, 1995) produced their first review of the diffusion literature they were emphasising motivation in the decision to adopt changes, whereas in the later versions they increasingly put more emphasis on the role of economic factors (Rogers, 1995). Anderson (1981) found that there is a resistance to change, in that farmers have accumulated practical knowledge and by resisting change they did safeguard them against mistakes made by advisors over-enthusiastic for change. Since then other constraints have been identified: if innovations are difficult to understand, farmers' motivation, their belief and opinion towards the innovation, their perception of the relevance of the innovation and farmers' attitudes towards risk and change (Guerin and Guerin, 1994).

Research into diffusion of innovations contributed importantly to the understanding of human behaviour change. However, there is also criticism about the method, such as ignoring or under-emphasising rejection or discontinuation of innovations, which results in a lower understanding of innovation failures than innovation successes (Rogers, 1995). One has to acknowledge that the rejection or discontinuance might be rational and appropriate from the individual's point of view (Reid *et al.*, 1996). Late adopters and laggards are mostly individually blamed for not adopting the innovation, but it could be that the innovation was not as advantageous for them as it was for the early adopters. Additionally, farmers do not all have the same or even similar goals and needs, but extension programmes are often designed as if they had. Therefore Hannibal and Sriskandarajah (1996) proposed that extension programmes should be designed at the individual farm level, allowing the farmer to use those elements and techniques that suit his situation and mix it with existing practices. Nearly forty years ago McMeekan (1963) advocated that extension had to focus more on the needs of the industry in order to stay as useful for the industry as it was in the past. However, until recently, scientists and some groups in agriculture decided the research priorities, whose results were handed to farmers (Chambers and Jiggins, 1987), rather than priorities being determined by the individual or the industry itself.

Another criticism is that diffusion researchers for a long time did not pay sufficient attention to the consequences of innovations, especially how the socio-economic benefits of innovations are distributed within the social system (Rogers, 1995). Much analysis of the linear technology transfer model was done in developing countries and fed back to the developed countries (Röling, 1988). These analyses showed that they mostly benefited the most productive and richest farmers, thereby increasing the socio-economic gap between the rich and the poor (Hightower, 1973; Rogers, 1995).

## ***Recent techniques in agricultural extension***

### 'Farmer first' model

Out of the increasing criticism of the linear diffusion model, new models of technology transfer were developed, where farmers were regarded as co-researchers in a two-way exchange of knowledge between farmers and researchers (Morris *et al.*, 1995). Often it was the case that farmers rejected innovations for practical reasons rather than conservatism. Farmer had detailed local knowledge of their environment for their farming system and should be seen as knowledge producers not only knowledge receivers (Kloppenburg, 1991). Some more recent extension systems try to incorporate local resources and match local needs ('Farmer first' models) (Chambers and Jiggins, 1987; Chambers *et al.*, 1989). These programmes formally investigate farmers' circumstances, their goals, and constraints to change. Then they try to involve farmers in the research process when designing and evaluating strategies intended to improve farmer well-being (McRae *et al.*, 1993). Instead of starting at the scientists' end, these programmes start at the farmers' end. A similar approach is used in the human health field, for achieving changes in nutrition behaviour, when using social marketing to find out the consumer's perspective (Griffiths, 1994).

'Farmer first' programmes are also called 'participatory' or 'bottom-up' approaches, where farmers participate in research and extension processes. Thus they are also described as 'Agricultural Knowledge Information Systems' (AKIS) (Röling and Engel, 1991). They were originally intended to be complementary to the conventional transfer of technology (Chambers *et al.*, 1989), while others see them as self-sufficient alternatives. Yet, these programmes also have been criticised for various reasons, such as new problems for farmers might not be recognised within the local knowledge of farmers, little dissemination beyond the group itself and others, little self-development of the individual group members and others (for details see Black, 2000)).

Another more recent development is using marketing approaches, whereby new knowledge is seen as a product, which is developed and then actively promoted. One such programme was the 'Prime Pasture program' in Australia, which aimed to increase the success of pasture establishment (Keys and Orchard, 2000). The programme combined different companies (seed, fertiliser, herbicide, machinery) to promote an integrated message, using financial incentives, on farm demonstrations, high quality brochures and other mass media. These different marketing strategies provided continuous reinforcement of the project's message (Keys and Orchard, 2000).

### Communication

Extension becomes increasingly multidisciplinary, with more emphasis not only on farmers' knowledge, but also on their personal goals, circumstances, and their individual learning styles (Paine, 1993; McRae *et al.*, 1993; Fairweather and Keating, 1994). Paine (1993) suggested that extension agents can achieve better adoption of innovations by their clients by using communication methods that are compatible with their clients' preferred learning strategy, or by establishing relationships between farmers with opposite learning styles.

There are three main types of extension techniques available: mass media channels (radio, TV, articles in newspaper, journals, booklets, newsletters), personal contact on a one-to-many basis, such as in discussion groups, field days, seminars, workshops, conferences; and there is personal contact on a one-to-one basis, such as farm visits. Anderson (1982) found that these farm visits mostly involved the 'progressive' farmers, which had better education and larger and wealthier farms. He also found that reading as an information source became less important with the age of the farmer (Anderson, 1981). The one-to-one relationships can also be used to potentially increase the adoption of innovations by using such 'focus' farmers as an integral part of the delivery process to help 'sell' innovations (Pearson *et al.*, 2000).

A potential fourth type of communication could be e-mail and the World Wide Web, which might have positive effects, in that the language chosen is more informal and personal, closer to one-on-one contact than the traditional written information (Fell, 2000).

## Farmers' and consumers' goals

Farmers' goals are main determinants of their motivation for adoption or rejection of innovations, thus making them an important factor in extension. Without the knowledge of the goals and circumstances of farmers it is impossible for extension agencies to define what problems have to be solved (McRae, 1993). The goals themselves depend amongst many other factors on the country and other social factors. Gasson (1973) found that farmers in Britain often mentioned 'independence' and 'way of life' as personal goals and 'producing good livestock/crop' as business goals. For small farmers in New Mexico the 'quality of life' was more important than 'income' (Harper and Eastman, 1980), and farmers in Australia (Queensland) found 'safeguarding income for the future' more important than 'maximising income' (Cary and Holmes, 1982). However, these studies were done in 1973, 1980 and 1982 respectively. As farmers' goals are dynamic (McRae, 1993) it is questionable if these goals are still the same 20 to 30 years later.

A recent example of involving farmers in the complete process of research and technology transfer, is the work of the Foundation for Arable Research (FAR). This foundation was set up by arable farmers to manage farmers' investment in research and information transfer. The involvement of farmers was described by Pyke and Johnston (2000) at a recent conference on achieving change.

Another more recent development is the involvement of consumers' values and goals into the agricultural process. Most industrialised economies have an oversupply of agricultural products and therefore market growth is determined by quality not quantity (Grunert *et al.*, 1997). Thus agriculture has moved from a producer-dominated market to a consumer-dominated market. This also means that agriculture has to move away from being product-oriented to being consumer-oriented, by meeting the needs of consumers. Therefore not only the goals of farmers are important but also the goals and values of customers (Frazer, 2000). These values and their application in the beef-industry were recently investigated in marketing research using the method 'means-end chain theory' (Audenaert and Steenkamp, 1997). A means-end chain intends to explain how a product allows the achievement of a desired end state, such as consumers buying products with certain attributes (e.g. beef without hormones), that can achieve a desired consequence (e.g. feeling healthy) which is of value to the consumer (Gutman, 1982). In consumer behaviour three types of factors are generally distinguished – properties of the food, person-related factors and environmental factors (Steenkamp, 1997). The aim of marketing research is to identify growing production systems and thus indicating research areas for improved technologies (Janssen and Tilburg, 1997).

## Motivation

More recently the term technology transfer has been redefined as technological learning and knowledge application (Foundation for Research Science and Technolgy, 1998). Within the theory of learning, five factors are important: motivation, relevance, interest, environment, and satisfaction (Dryden and Vos, 1993). One of these factors on which much emphasis is put in recent years, is motivation (Alderman, 1990).

Motivation of the farming community is one of the main roles in agricultural extension (Allison, 1981). However, it is very difficult to investigate motivations for adoption of innovations, as some people might not be able to clearly state these, others might not be willing to do so. Economic motivation is often important for certain innovations, especially if these involve high expenses. Another motivation is the prestige, which people might gain in adopting new technologies before their peers (Becker, 1997). However, for private organisations, such as farming, economics might be more important than for public organisations, where prestige reasons might prevail (Rogers, 1995). Farm profitability and production are often found to be main motivators for practical decisions (Carr and Tait, 1991).

In some cases, such as conservation issues, legislation and regulation may be the only effective way to ensure long-term change, if the dominant beliefs and values of the majority of farmers disagree with the change required (Carr and Tait, 1991).

## Computer aided programs

The more complex farm problems get, the more complex the methods for analysing and solving these problems, especially when it comes to such long term problems, for example like land degradation problems. In these situations the use of microcomputer-based decision-support systems could be efficient and effective in analysing the complex situations, especially when the solutions become economically prohibitive (Ludwig and Marsden, 1993).

In Australia it was claimed that so far there has been little adoption of intelligent support systems, which they attributed in part to the incompatibility with current farming practices, or with attitudes of farmers towards computers (Lynch *et al.*, 2000). Yet, in New Zealand a relatively high proportion of dairy and pig farmers in comparison to such farmers in other countries use computer recording and evaluation programs (17% of dairy farmers use DairyWin and they manage 25-30% of cows, M.Stevenson, pers. comm. 2000).

Another form of using computers is by providing internet based two-way communication between extension workers and farmers as done in a study group of sheep farmers in the South Island of New Zealand (Mulcock *et al.*, 2000).

## *Agricultural extension in New Zealand*

### History of extension

In New Zealand, extension prior to 1985, has been carried out by national non-commercial Ministry of Agriculture and Fisheries (MAF), and co-operatives of farmers but rarely by voluntary agencies (Morris *et al.*, 1995). Most literature on extension is concerned with the adoption of individual technologies, the speed of diffusion and the characteristics of adopters and non-adopters.

New Zealand implemented the diffusion of innovation model with some adaptations for local conditions and experienced the same weaknesses as other countries, such as expectations that technology provides solutions for all problems, and assumptions that increasing levels of technology is beneficial (Morris *et al.*, 1995). The linear model of extension focused on a small number of farmers and leaves it up to communication amongst farmers to diffuse new innovations. New technologies that required minimal extension activities were aerial topdressing, farm bikes and some animal health remedies; whereas rotational grazing for example required much more intervention.

From World War II to the mid 1980s production was the main focus of farm management and extension, and the key criterion for judging success (Fairweather and Keating, 1994). During this phase, the industry concentrated on increasing the volume of production as a result of Government incentives, increased processor capacity, agricultural research and extension (Parminter *et al.*, 1993).

Attitudes towards extension in New Zealand were strongly influenced by the nature of its agriculture, with major exports of agricultural products, such as dairy products, wool and sheep meat. Government was involved in agriculture since the time of early settlement, first by controlling the sale of land, later by controlling pests and some diseases, by importing animals, providing credits for farmers, instituting research and providing agricultural regulations. In the twentieth century Government established producer boards, quality controls, export regulations and sometimes price support (Morris *et al.*, 1995). The Department of Agriculture, established in 1892, employed instructors in farming techniques (Nightingale, 1992). Their number increased very rapidly, especially after the introduction of mass production of dairy products and refrigeration. By 1920 face-to-face consultations with farmers, pamphlets and reports were available (Nightingale, 1992). The department used the diffusion model. It decided what changes should be promoted, it trained extension officers in technical and financial management, but also in adult education skills, and encouraged farmers to make their own decisions and monitor their own progress. Especially during the time when agricultural production was rapidly increasing these programmes seemed to be highly successful (Parminter *et al.*, 1993; Morris *et al.*, 1995).

With Great Britain joining the EEC, the guaranteed access to British markets was lost and farmers were subsidised for finance, fertiliser and transport until 35% of farmers' income (40% of sheep and beef farmers' income) was paid by Government in 1983 (OECD, 1988; Tyler and Lattimore, 1990; Walker and Bell, 1994) By the early 1980s it was apparent that these financial compensations to farmers did not achieve the intended social or economic results, but only contributed to unsustainable national debt (Hawke, 1987; Rayner, 1990). Additionally New Zealand's farming community had decreased to only about 2% of the population at that time (New Zealand Department of Statistics, 1940-1995) causing decreased justification for large Governmental expenditure on agriculture. In 1984 a new elected Labour Government rapidly removed subsidisation, progressively introduced cost-recovery for consultancy, and restructured Government's research and development agencies, in order to make them more efficient (Rayner, 1990; Walker and Bell, 1994).

In the 1990s profitability became more important than production, with economic efficiency being the key criterion of success (Fairweather and Keating, 1994). In addition the agricultural extension service, previously owned by Government, was commercialised (transition to user-paid consultancy) and privatised (transition to privately owned services). Many articles and books address the changes to the extension service during the privatisation process (Rayner, 1990; Fairweather, 1992; Ritchie, 1995). Shortly after the change of Government MAF began to charge for selected extension services, after legislation for this was put in place (Tyler and Lattimore, 1990). In 1987 MAF was restructured and in 1991 the research group within MAF Technology unit was transferred to the Department of Scientific and Industrial Research (DSIR), from which time full cost recovery was employed for all extension services. In 1992 the DSIR was commercialised as well and restructured into Crown Research Institutes (CRI), which are state owned but operate as for-profit business that pay dividends to their shareholders and taxes to Government (Coddington, 1993). MAF Technology itself was renamed to Agriculture New Zealand to indicate its commercial nature, and was fully commercialised in 1994 as a stand-alone agency within MAF and one year later privatised to Wrightson Pty Ltd, a national agriculture supply/service company (Hall and Kuiper, 1998).

Many farmers had to come to terms with having to pay for services they got free previously but in the process looked to find the best value advisory services. Implementation of innovations was found to be greater if farmers had to pay for them, compared with when they were 'free' (Hall and Kuiper, 1998). After the commercialisation of the public funded extension, farmer co-operatives and commodity boards started to levy their members and in turn provide services to them at low or no cost.

Differences existed and still exist between dairy and sheep and beef farmers in the amount of extension available to them, with more extension available to and used by dairy farmers than sheep/beef farmers. Furthermore the information available to dairy farmers is often less conflicting than that available to sheep/beef farmers, as the latter have a more complex farming system. Extension to dairy farmers is provided by the New Zealand Dairy Board through a levy on farmers, through Agriculture NZ consultants and through The Dairy Research Institute. That institute has three times the number of scientists than the meat industry (Stichbury, 1994). There is no such wide extension range available to sheep farmers (Morris *et al.*, 1995). Rhodes and Aspin (1993) described a similar system whereby the Meat Research and Development Council used the levies by the Meat Board for project support on 24 Focus Farms. These farms are used for education in discussion groups and field days. The difference in the available extension services between the farm types is also related to the way products were marketed. In the dairy industry producer owned co-operatives were acting since the early 20$^{th}$ century, whereas in the meat industry this is more recent (1970s and 1980s) (Morris *et al.*, 1995).

It is estimated that during the period when extension services were free of charge to farmers, approximately 80% of all New Zealand farmers were being served with some form of advisory service. Through the introduction of cost-recovery this number declined to about 10% for beef and sheep farmers until 1990/91. Since then the number has increased again, but it is considered well below the number prior to commercialisation (Hall and Kuiper, 1998).

With commercialisation of the advisory services the focus of the service providers also changed. Whereas the mission and goal statement of the MAF Advisory Services in 1983 was: 'to help farming and horticultural industries to identify and realise potential', it was in 1995-98 'to assist strategic growth in agriculture and horticulture by being New Zealand's foremost provider of rural consultancy services' (Ritchie, 1995). This change in the mission statements reflects the change from leading farmers to independent decision-making to complementing farmers' strengths by advising them in their weak management areas (Hall and Kuiper, 1998).

Recent extension work has not only focused on the 'traditional' crop and livestock farming enterprises, but also on horticulture (Banks and Harley, 2000; Praat *et al.*, 2000), organic production (Kelly *et al.*, 2000), sustainable agriculture (Rush, 2000) and forestry (Bathgate, 2000).

### Communication channels

Extension has to be reviewed regularly in order to ensure that they are meeting the changing needs and goals of farmers (MacClean *et al.*, 1997). Only when these needs and goals are understood the best methods of communication can be established. Prior to commercialisation MAF Advisory Services used mainly discussion groups, field days, meetings and conferences to provide farmers with information. Through commercialisation this was shifted towards one-to-one consultations (Hall and Kuiper, 1998). Currently extension to farmers is provided by education, individual consultations, discussion groups, field days, workshops, conferences, and media (Walker and Bell, 1994; Morris *et al.*, 1995; MacClean *et al.*, 1997).

In educational organisations usually up to date information is used to train students, who then can take out their knowledge into the wider farm population. However, student numbers for agricultural courses have decreased since 1984/85 and less students have contact with farming prior to their studies (Wyllie, 1989). These two facts could have contributed to a lesser introduction of new ideas (Morris *et al.*, 1995). Consultations with farm advisors can help farmers plan for specific goals and provides feedback on new innovations in practice (Garland, 1993; Walker and Bell, 1994). Morris *et al.* (1994) found that farmers using consultants were more production oriented. However, due to the one-on-one contact it is not possible to reach all farmers (Walker and Bell, 1994).

Discussion groups amongst farmers usually involve farmers with similar interests and provide knowledge about new ideas and their implementation to progressive farmers (Rwenyagira, 1985; Walker and Bell, 1994; Greer and Greer, 1996). Their establishment can be very demanding, but they allow the joining of farmers' needs with science information (Tarbotton *et al.*, 1997). In a study of farmers in the North Island of New Zealand they were the most commonly attended events (Gavigan and Parker, 1996). Discussion groups also play a role in providing a social network (Wegener *et al.*, 2000). They also have an indirect influence on non-participating farmers, who observe and copy the improved techniques (Morris *et al.*, 1995). However, often there is help available in setting up groups, but little training or skill development in managing group dynamics and providing on-going support (Oliver *et al.*, 2000). In an Australian study of discussion groups it was found that they are often without specific direction and the extension workers were unsure about the practical implications of the topics discussed (Wegener *et al.*, 2000). Another factor is, that discussion groups may not appeal to all farmers (Morris *et al.*, 1995). The same applies to conferences. However, conferences have the potential of incorporating interactive workshop and seminar sessions that allow extension agents and agricultural researchers to receive feedback from those that will apply the knowledge (MacClean *et al.*, 1997).

Workshops, using small groups, intensive face-to-face contacts, are increasingly used to provide learning opportunities and can achieve that most participants gain the targeted knowledge and skills (Stantiall, 1999; Stantiall, 2000; Frazer, 2000).

Mass media is least linked to changing practices. They principally provide awareness on new methods and innovations and also reasons for change (Walker and Bell, 1994). Nevertheless, publications of this sort are read regularly by farmers (Gavigan and Parker, 1996). As most farmers are not enthusiastic readers, articles written in newsletters and agricultural journals have to be written in a concise readable form, and in a style that is familiar to farmers (Garland, 1993).

One-on-one consultations provide an opportunity for whole-farm analyses, looking at the specific situation of the farm, and establishing professional and personal goals and plans to achieve these. However, they provide fewer opportunities for farmers not using advisory services (Hall and Kuiper, 1998).

Advisors found that extension programmes were most successful if they involved the industry in the planning process, if they gave farmers simple measuring techniques to allow them to measure their own progress on their own farm, if they used the full range of extension techniques, if advisors were trained in adult education and if they assisted farmers in the learning process, rather than telling them what to do (Walker and Bell, 1994). Walker and Bell (1994) quoted the philosophy "tell me what to do and I will remember about 10%, show me what to do and I will remember about 40%, involve me and I will remember most of it". These authors also found that the hardest part of extension programmes was the creation of motivation for change (Walker and Bell, 1994).

## Factors influencing change in farm practices

The effectiveness of extension programmes has been investigated since the 1960s (Allison, 1981; Greer, 1982). Only few farmers resist change, but it is necessary to know the costs and benefits of new innovations on each farmer's own farm in order to understand why adoption or rejection follows (Morris *et al.*, 1995). Factors that are believed to influence adoption of new technologies are age, education, management skills and communication between farmers (Morris *et al.*, 1995).

Higher income and farm size was also positively associated with the adoption of new technologies (Stewart, 1979). The goal of increased farm income, less time having to be spent on farm work, more available time for leisure are some most common motivations for changes (Greer, 1982). Verkerk *et al.* (2000) reduced the number of factors that influenced the acceptance of new technologies to three key performance factors: the success achieved, the financial return and the fit to values and beliefs.

Farmers' goals and underlying values/beliefs are crucial for any change. Although many farmers rank their farm production and profitability as their highest goal, they also have a whole range of other goals (Gavigan and Parker, 1996; Parminter and Perkins, 1997). If this range of goals is accounted for in extension services there is a higher likelihood for voluntary adoption of innovations (Parminter and Perkins, 1997). Not only business goals are important, but also personal goals (McRae, 1993; Fairweather and Keating, 1994), core enterprise beliefs (Parminter *et al.*, 1993) and long-term goals of the farming business, such as expansion and less personal involvement (Valentine *et al.*, 1993). Fairweather and Keating (1994) categorise farmers according to their business and personal goals into three management style groups: dedicated producers, flexible strategists, and environmentalists. These authors suggest that distinctive models could be developed for each of the management styles, taking into account the proportion of each of the types.

Greer (1982) noted that many farmers that had rejected new innovations actually had accepted inaccurate information, on which they based their decision, indicating a flaw in the linear extension model.

Greer (1982) also concluded from reviewing New Zealand literature that because of methodological problems little of the research into motivation of farmers could be linked directly to their adoption behaviour, but that communication between farmers was crucial. This conclusion was also made by several other researchers, such as Fairgray (1979) in his study of farmers adopting rotational grazing, or Parminter *et al.* (1993) in investigating the adoption of new beef breeding cow technologies. Morris *et al.* (1994) also emphasised the farmer network in the spread of new technology. Once farmers considered new technologies they sought information on their performance on farms in the local area and the most convincing proof of an innovation is seeing another farmer successfully using it (Garland, 1993; Morris *et al.*, 1995). This reference to the local area was of major importance (Morris *et al.*, 1995).

'Farmer First' research programmes started in the early nineties that showed that farmers were aware of new technologies, but either considered them unsuitable for their particular situation or were financially not able to adopt them (Reid *et al.*, 1993; Brazendale *et al.*, 1994).

In a study interviewing farmers on their reasons for changing their farm practices several main factors influencing the decision to change farm practices were identified (Morris *et al.*, 1995). The goal for most changes was to increase profitability, either by reducing labour or increasing efficiency. Another factor influencing the adoption of new technology was their trialability. Farmers preferred to try an innovation on part of their farm and then decide to adopt or reject if for the whole farm. Past experiences were especially important for sheep/beef farmers in their decision making. Farmers wanted to farm safely with less associated risks, which also meant that farmers were more likely to adopt changes if they assisted in attaining control over factors which might impact upon production (e.g. soil testing, herbage testing). Sheep/beef farmers were more likely to prepare personally for industry crisis than dairy farmers. Younger farmers were more willing to change and take risks than farmers who farmed at the time of the downturn (1980s) (Morris *et al.*, 1995).

Most farmers were aware of new technology (with more or less detailed knowledge), and non-adoption of new innovations was after a deliberate decision was made not to change (Morris *et al.*, 1995). Some farmers had fewer options to adopt new technologies, due to financial (high debts, small farms) or topographical constraints (Morris *et al.*, 1995).

Morris *et al.* (1995) reported that dairy farmers were more likely to adopt new innovations than sheep/beef farmers, while Journeaux (1990) five years earlier found that sheep and beef farmers, given enough motivation, often relating to financial incentives, were as quick to adopt new technologies as dairy farmers. However both authors state that it was easier for dairy farmers to see the impact of new technologies, as their farming system is simpler and only one outcome (milk) is produced. Furthermore, more extension activities were conducted on dairy farms than on beef farms and farm income for dairy farms has increased even during the time of the rural downturn of the 1980s. Adoption of new technologies in sheep/beef farming systems usually took longer than in dairy farming. Most sheep/beef farmers know of farmers that have lost their farm in the downturn, despite acting on the advice they had been given. The confidence and trust in the industry and in the advice had been undermined for these occurrences (Morris *et al.*, 1995).

### Commercialisation of advisory services

With commercialisation of advisory services an improved adoption rate for innovations was achieved, but on a smaller number of farms, indicating that the farmers who use the service are more likely to adopt it (Hall and Kuiper, 1998). The reasons for this were two-fold: Firstly farmers paid for services and therefore demanded very specific advice, which was immediately applicable to their situation. Secondly, farmers valued service they had to pay for more than the free service (Hall and Kuiper, 1998) It is a characteristic of human nature to perceive something that is received free, as having little or no value (Kerr, 2000). It might be that the farmers willing to pay for advice are also the ones more willing to change and to adopt innovations, therefore the number of farmers adopting innovations might be still the same as before, but the total number of farmers using the service is lower, thus increasing the percentage of farmers receiving and adopting advice (Hall and Kuiper, 1998). Other advantages of commercialisation/ privatisation of extension include a greater responsibility to clients, greater emphasis on benefits and results, rather than purely service activities and the shift from a 'technology push' to a 'demand pull' orientation (Rivera, 2000).

Yet, other authors stress the fact, that there is a need for co-operation between advisors and farmers to develop new ideas and design new systems. This information flow will be cut if all advisory services have to be paid for by farmers (McArthur, 1987; Butcher, 1987). The concept of user-pays depends on the benefits that incur to the farmer and/or to the public (McArthur, 1987; Butcher, 1987). However, in farming it is sometimes difficult to decide who is the main beneficiary. Although additional knowledge is first beneficial to the farmer acquiring it, yet, over time, knowledge becomes a public good, as one person using it does not exclude others using it. On the other hand, the distribution of this knowledge benefits mainly the farmers getting the advice directly, so therefore farmers should pay for this. However, these authors ask the question who is paying whom if the advisor comes on to the farm and a two-way information flow exists between farmers and advisors. Often 'new' technologies are investigated where farmers actually played a creative role in the generation of these new technologies (Chambers *et al.*, 1989). Another disadvantage of commercialisation of extension is that it becomes a service only for producers that can afford to pay for it (Rivera, 2000).

The privatisation of extension services meant also that environmental and sustainable-agriculture education programmes ceased. This necessitated more regulations, fines and legislation to 'encourage' farmers to adopt such practices (Hall *et al.*, 1999).

## Relevance to the hypothesis researched in this thesis

Bovine tuberculosis (TB) is of major importance to New Zealand's agricultural economy with potential trade restrictions, if the level of infected herds cannot be reduced from currently 2% to 0.2% (Oliver *et al.*, 2000). Three main control methods are employed in the control of TB: stock testing, stock movement restrictions, and control of infected wildlife. One of the three key objectives of the 1996-2001 National Pest Management Strategy is to 'encourage individuals to take action against TB on their properties and in their herds' (Animal Health Board, 1995). It is recognised that there is a need to complement official control efforts with farmer effort.

If farmers in New Zealand are expected to assist in the control of tuberculosis more than they have done so far (Animal Health Board, 2000), it is necessary to provide them with new ideas/methods of controlling tuberculosis on the farm level. The insights gained from this literature review were combined with epidemiological knowledge of tuberculosis in livestock and wildlife. Knowledge of habitat factors, TB hot-spots (McKenzie and Morris, 1995) and behavioural studies of interactions between livestock and wildlife (Paterson and Morris, 1995; Sauter and Morris, 1995) led to the development of on-farm control measures (see Chapter 3). These measures had to be implemented and evaluated on study farms. From the literature review it was known that the one-on-one contact provided the best way of transferring knowledge between the farmers and the scientists in a two-way manner. As participation of farmers in the development and implementation of innovations is stressed by several authors as a mean to achieve greater adoption (Chambers *et al.*, 1989; Pyke and Johnstone, 2000; Verkerk *et al.*, 2000), farmers were involved throughout the project and responsibility for vector control handed over to farmers in the third year of the project. The literature also provided evidence that market forces or other external imperatives, such as for example Animal Health Board policies, can have a strong influence on the adoption of new ideas/innovations.

## Conclusion

In this chapter I have briefly described the field of changing human behaviour, the processes involved and some mechanisms that try to achieve this change. Two examples were described in more detail, the field of smoking cessation and the field of agricultural extension with the focus on the New Zealand situation. In both examples the belief is that the change in behaviour will lead to a specific goal, better health in the smoking example and more productivity or achievement of personal goals in the field of agricultural extension.

- The key process for changing human behaviour is:

  need recognition ➜ search for information ➜ evaluation ➜ choice (Rogers, 1995)

  therefore the need to change has to be instigated/accepted, before any of the other steps are following.

- Key factors influencing the adoption of innovations are:

  Farmers' perception of the relevance, compatibility, complexity, trialability and observability of innovations, financial costs, farmers' beliefs and opinions towards the innovation, farmers' attitudes towards risk and change and farmers' motivation (Guerin and Guerin, 1994; Rogers, 1995).

In agricultural extension farmers are not just a passive part in the technology flow, but extension personnel's main purpose is to help farmers help themselves. Therefore, the well-known Chinese proverb can also be applied to agricultural extension:

> "If you give a hungry man a fish, he will be fed for one day.
>
> But if you teach him how to fish, he will be fed for life."

The main emphasis presently is on empowering farmers to take responsibilities themselves. This applies to farm productivity, but also disease control.

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**Beef farm in the Wairarapa**

**Beef farm in summer (photograph courtesy Fiona Dickinson)**

# Chapter 2

# Analysis of Wairarapa farmer perceptions of tuberculosis and management options for control

## Abstract

The Australian brushtail possum is the main vector for bovine tuberculosis in New Zealand. Thus control and eradication of tuberculosis is complicated, both livestock and vector control populations have to be controlled. The main control method to eradicate TB from vector populations is poisoning of possums, which is expensive and cannot be conducted in all areas with infected vector populations. Therefore, more active involvement of farmers in the control of TB is desired and expected.

A survey of 27 farmers in the Wairarapa, whose cattle herd were infected with TB, was conducted using an open-ended questionnaire. Grounded theory was used to identify key factors in the farm management relating to TB and its control. The key theories found were: Farmers knew or had suspicions about potential areas on their farms where their cattle were likely to become infected with TB. Cattle herds that grazed in such areas had a higher TB reactor incidence than farms where cattle were excluded from grazing these areas. A major role in decision making regarding on-farm TB control were economics. On-farm TB control was only sporadic and motivation was lacking or wore off quickly. Information sources were mostly people that visited the farm on animal health business (livestock officers, Regional council staff and veterinary practitioners). Farmers differed in their perception of the TB related knowledge of livestock officers, some farmers found them very knowledgeable, while for others they did not meet the requirements. Grazing management was flexible on beef farms, less on dairy farms. It was influenced by the number of stock and pasture shortage. These findings were used to develop on-farm control methods that exclude cattle from grazing TB hot-spot areas during certain high risk times.

## Introduction

The control and eradication of bovine tuberculosis in New Zealand is complicated by the existence of a wildlife-reservoir, the Australian brushtail possum (*Trichosurus vulpecula*) (Morris and Pfeiffer, 1995). Therefore, tuberculosis control has to comprise disease and vector control (Animal Health Board, 1995). The main control methods for tuberculosis currently are farm animal testing, and reduction of infected possum populations on or near farms, involving trapping, ground poisoning and aerial poisoning operations.

The Animal Health Board, the national organisation responsible for TB control strategies, produced a national pest management strategy (PMS) to operate for the period 1995/96 to 2000/01, which is currently under review. Priority is given to “encouragement and assistance to farmers in infected areas to improve their disease status” (Animal Health Board, 1995). To develop TB control programmes for farmers to improve their disease situation, it is necessary to have detailed knowledge of existing farm management practices and to assess the potential for incorporating TB control methods into these management practices.

It is essential that the initial hypotheses in any study be based on appropriate assumptions, in order to avoid statistically significant but irrelevant results (Boland and Morris, 1988). Especially when human behaviour is involved, assumptions have to be checked for appropriateness. Much scientific research has been based on methodologies in which pre-existing knowledge and theories about the subject matter are the base for formulating hypotheses, which are then tested experimentally. In contrast, the research methodology ‘grounded theory’ investigates the subject of interest without requiring previously formulated hypotheses. It aims to generate theoretical concepts rather than to verify or invalidate them (Glaser and Strauss, 1967).

The present study was the baseline for designing the on-farm TB control programme described in Chapter 3. The first objective was to obtain details of farmers’ observations on TB in both cattle and wildlife on their farm, identify farm grazing strategies, examine relationships between farm management practices and TB infection in cattle, and gain insights into farmers’ attitudes towards TB and its control. The second objective was to identify the sources of information that were used by the majority of farmers. The third objective was to develop hypotheses for using farm and grazing management for TB control purposes. These hypotheses were then tested for effectiveness in on-farm TB control methods (see Chapter 3).

## Materials and Methods

### *Grounded theory*

This section justifies the selection of ‘grounded theory’ as an analytical method for this study. ‘Grounded theory’ was developed by social scientists for behavioural research to reduce the subjectivity of data and the inherent uncertainty of its interpretation. Glaser and Strauss (1967) described two such tools; a specific technique for content analysis of in-depth interview data, and a procedure for constant comparison of interview events. These tools are then used to create a substantive theory *grounded* in the fieldwork data (Boland and Morris, 1988; Strauss and Corbin, 1990). In other words, the researcher does not start with a pre-formed hypothesis to test about behaviour, but rather listens to the responses from subjects and builds an understanding of how and why decisions are made, which is derived directly from the views presented by subjects. These qualitative techniques can be used appropriately in the initial investigation of disease control and management. Boland and Morris (1988) used this technique to study the way in which veterinary practitioners search for information with regard to veterinary innovations.

The 'grounded theory' approach is a style of qualitative analysis that includes its own distinct methods and techniques, such as theoretical sampling and the use of specific coding procedures. It also has methodological guidelines, such as the use of constant comparison and the use of a coding paradigm (Glaser and Strauss 1967, Strauss 1987, Strauss & Corbin 1990). Creativity and insight are vitally important for developing a sensitive interpretation of the data as the number of interview subjects grows (Glaser and Strauss, 1967).

Generating a theory from data means that most hypotheses and concepts are not only derived from the data, but also they are all systematically worked out in relation to the data during the course of analysis by a process of constant comparison, where generation of hypotheses, concepts and categories are continuously 'checked' with the data itself (Glaser and Strauss, 1967).

Interviewing and the use of questionnaires are the primary technique of data collection when using grounded theory methods (Strauss and Corbin, 1990). Data collection, analysis, and interpretation occur simultaneously (also called 'theoretical sampling'). Analysis often involves techniques such as open, axial and selective coding (Strauss and Corbin, 1990; Adams *et al.*, 1999). Categories are developed by finding and comparing code words that describe similar phenomena. Testing is built into every step of the process and negative cases are important, as they contribute to possible variation (Strauss and Corbin, 1990). Generally sampling is continued until 'theoretical saturation' is reached in each category. This occurs when no new data or new concepts relating to the central problem, emerge with additional interviews (Strauss and Corbin, 1990). Emphasis is put on the validity of the data collected in representing the issue of interest, rather than its statistical significance.

### *Analysis of qualitative data*

Qualitative data is often complex, because the goal is to learn new things, and/or to understand the complexity of situations. Efficiency of the researcher can be supported by computers through coding, storing information, counting, and searching text. Creativity, such as data exploration, reflection on data, construction of categories, and theory building are the real challenge for any qualitative analysis, and hence for a software package, which might be used with such data. Flexibility (such as several open windows), quick retrieval of data for iterative processes in theory building and linking of data (e.g. data to categories, data to ideas, memos to theories or text to other interview documents) are all main components of grounded theory facilitated by computers (Richards and Richards, 1994).

Qualitative computing is not only a new way of doing the same things as previously done manually, but the use of computers has also changed the methods, by adding new techniques and offering additional features for old techniques, such as illustrating interpretation of data on the computer screen (Richards, 1997).

Richards (1997) concludes that doing "qualitative research without a computer now would be rather like doing statistical research with an abacus". She compares qualitative software to an innovative cookbook, which should be used as a collection of possibilities, not requirements.

As a first step it was necessary to identify farm management practices, grazing schemes and stock policies, which were apparently associated with TB in cattle, and therefore identify potential risk factors. The study concentrated on the three main farm types: dairy (DH), beef breeding (BB), and beef finishing (beef dry stock, BD) farms in the Wairarapa. As a second step it was important to evaluate if grazing management was flexible enough to be altered for TB control purposes. The Wairarapa region was chosen for its known *M.bovis* infection in wildlife and because the intervention study to evaluate on-farm TB control programmes (Chapter 3) was conducted in this region.

### Selection of farms

No specific sample size or composition was set at the beginning of the investigation. As one of the aims of the study was to evaluate grazing management in relation to TB infection, purposive selection was employed. Two areas in the Wairarapa region were chosen for the study (Featherston and Tinui). In both areas the Regional Council staff were conducting wildlife surveys, either as part of their annual vector control programme or specifically to identify TB hot-spots. As the on-farm control programmes were intended to be employed by farmers having a possum-related TB problem, it was essential to assess the farm situation under circumstances where TB was known to be present in the wildlife. With the help of AgriQuality (formerly MAF Quality Management) veterinary officers, all farmers in these two areas were approached for the study. Only one farmer refused to participate in the study. One additional farm in the Wellington region was chosen, as TB hot-spots were already known on this farm. This purposive sampling approach ensured that all the farms in the study had a high likelihood of their cattle being infected by possums.

### *Interview process*

Between March 1994 and February 1996, 27 farmers were interviewed about their TB herd history and grazing management. The farmers were interviewed with an extensive, open-ended questionnaire (see Appendix I, p. 327), which was tested on two farmers first. Most interviews were organised in an open-ended way around topics such as grazing management, general farm management and tuberculosis. Farmers were thus able to give their views as they wished and refer to several questions at the same time. Mostly the questions were posed by raising key-words, rather than specific questions in order to obtain the farmers' perceptions/opinions in a comprehensive way on these subjects. All interviews were recorded on to audio tapes, to ensure minimal data loss and to preserve detail of responses.

### *Content analysis*

The tapes were transcribed into text documents (using MS Word) and then imported into WinMAX98 (Copyright 1998, Udo Kuckartz, BSS, Berlin, www.winmax.de), a software programme for qualitative data analysis. The study was intended to generate rather than to test or verify theories and therefore the analysis focused on an exploratory and qualitative investigation of the TB situation and grazing management.

The text documents were examined first by the process of 'open coding', where the data was broken into different labelled concepts (e.g. farmer possum control) (Strauss and Corbin, 1990). These concepts were then sorted to establish major themes and categories. The concepts were then grouped into these categories (e.g. TB control) (Phillips and Rempusheski, 1995). The categories were expanded, sub-categories developed and a tree-structure built (see Appendix II, p. 331). Figure 1 shows a screen of the programme WinMAX98 in use, with the open text document on the right window and the codes used for TB history in the left window. The codes were arranged within a tree structure, indicating broad categories and their sub-categories. The lines and boxes in the text window show the coding that was assigned to the different text segments. Each section in the text was analysed for its meaning and assigned to at least one code.

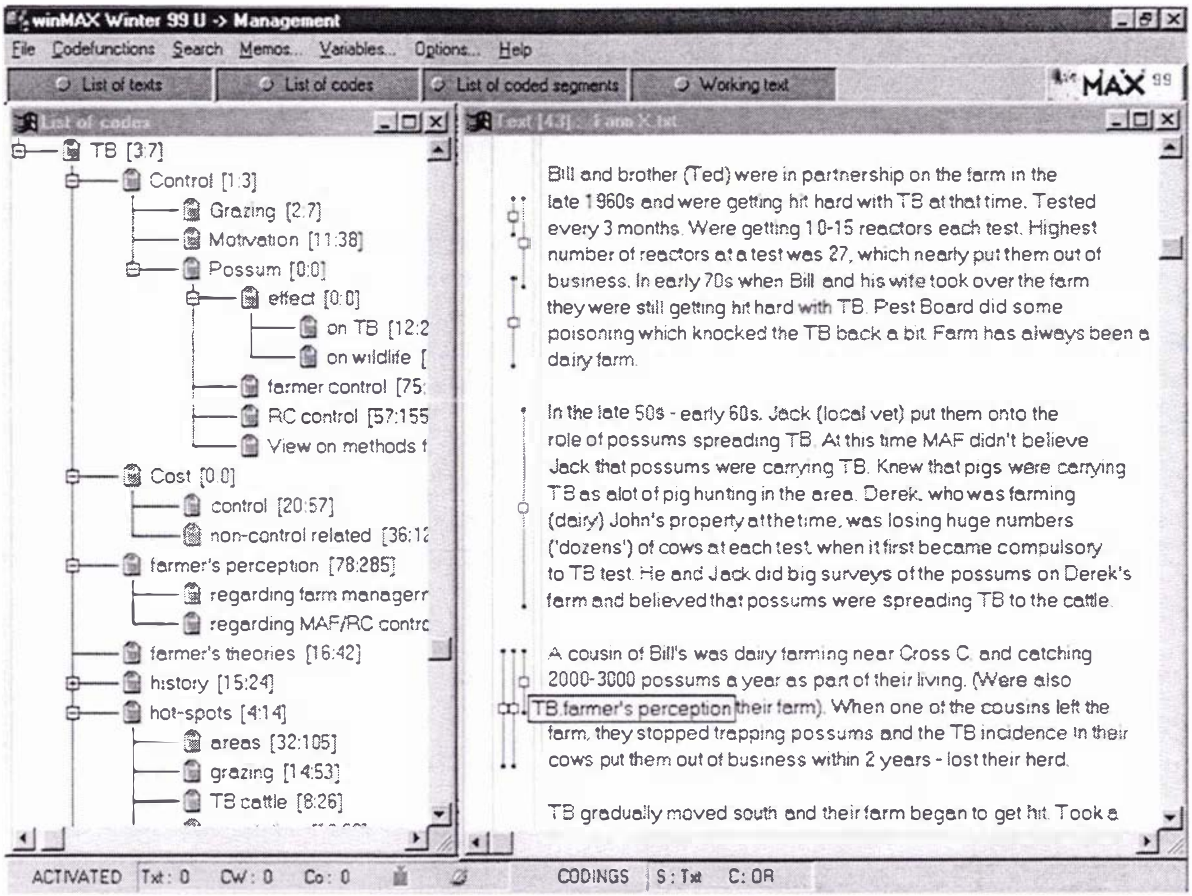


**Figure 1: Text coding windows for TB history of one sample farm using the qualitative software programme WinMAX98.**

With this technique of coding text, similarities in the answers could be found without requiring exact match in terminology as in a method using key word count.

Impressions gained by the researcher and the significance of comments were noted in 'memos',. which were text notes linked to specific comments made by farmers, or loosely linked with the whole text document.

Within WinMAX98 all text segments relating to one or more specific codes, categories and/or memos could be retrieved. For each farm the most significant features were entered into MindManager® (version 3.5.5.; copyright 1999; www.mindmanager.com) for graphical display. Figure 2 presents the codes of the TB situation on a farm as an example of interrelating and displaying the events of the different categories. These Mind Maps together with the retrieved coded segments and memos were used to compare separate interviews.

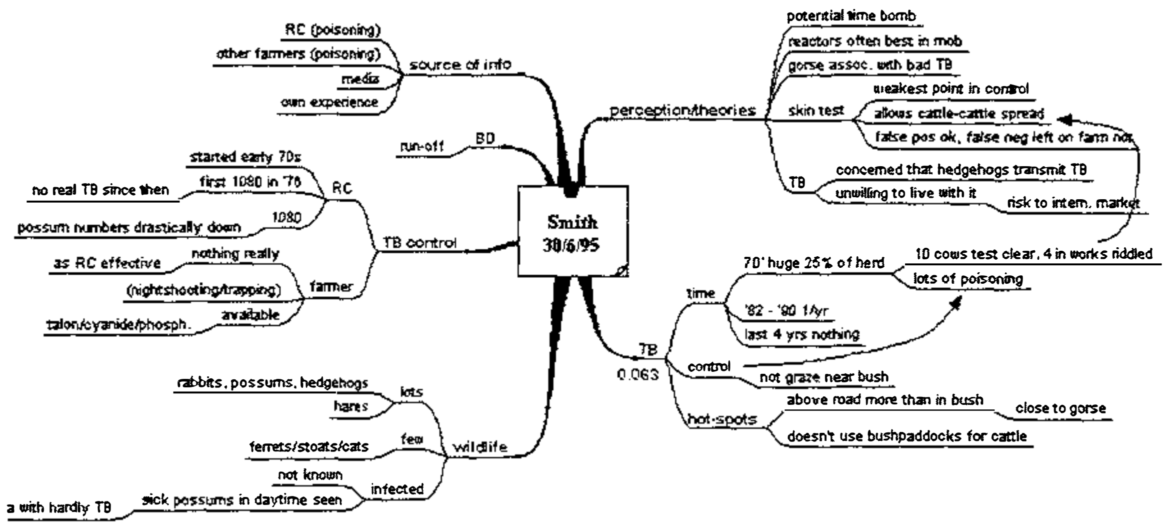


**Figure 2: Example of a Mind Map with categories and events used in describing the TB situation and TB perception of one farmer in the sample.**

Because the data set for this study was already complete at the start of the analysis, several long interviews were analysed first. Then the other interviews were used to challenge or expand the theoretical grasp, a method used by other researchers in the field of grounded theory (Kearney *et al.*, 1995). The final analysis therefore included the full range of variation represented in the study sample.

The TB reactor situation for each of the farms was assessed using the interviews and the official herd testing history as recorded by AgriQuality, the national field veterinary service. More detailed information on regulations regarding TB testing, herd status, and movement of cattle can be found in Appendix III (p. 334).

# Results

## *Descriptive analysis of study farms*

### General farm characteristics

Table 1 presents some characteristics of the study farms. Eleven of the farms were beef breeding farms, three beef finishing farms, 11 dairy farms and two farms had both a dairy and a beef breeding herd. For analysis purposes these latter two farms were included in the beef breeding farms, as their TB problem appeared to be more associated with the beef breeding herd than the dairy herd.

**Table 1. Mean [and range] of some characteristics of study farms in the Wairarapa.**

| | Dairy (n=11) | Beef breeding (n=13) | Beef finishing (n=3) |
|---|---|---|---|
| Size of farm (ha)[a] | 116.82 | 878.85 | 452.00 |
| | [28 – 364] | [48 – 3103] | [247 – 769] |
| Effective area of farm (%)[b] | 86.25 | 79.91 | 83.07 |
| | [55.49 – 100] | [45.54 – 100] | [77.35 – 90.90] |
| Size of run-off (ha)[c] | 30.07 (n=13) | 80.33 (n=3) | 42.00 (n=1) |
| | [7 – 67] | [40 – 146] | |
| Cattle Stock units (CSU) | 1710.59 | 3187.93 | 1298.25 |
| | [1063.5 – 3054.5] | [61.5 – 12808.2] | [1094.5 – 1588.0] |
| Sheep Stock units (SSU) | 562.5 (n=2) | 3380.55 | 2023.33 |
| | [321 – 804] | [52.1 – 6501.0] | [1245.0 – 3025.0] |
| No. cattle ≥ 2yr | 219.45 | 391.08 | 140.00 |
| | [136 - 409] | [11 – 1728] | [98 – 182] |

[a] excludes run-offs or other leased areas
[b] effective size indicates what percentage of the land area is used for grazing, the remainder is bush or unproductive land area; it excludes run-offs or other leased areas
[c] run-offs are areas that generally are located some distance from the main farm. Some farms had multiple run-offs – hence the number is larger than the number of farms.

Stock units were calculated from the number of animals present on the farm at the end of June, using the conversions provided by Fleming (1996). Dairy cows were assumed to weigh an average of 450 kg and produce 165kg milkfat per year (the average value for dairy cows in the Wairarapa).

## TB history from existing records kept by AgriQuality

Records on reactor numbers and lesioned animals were those contained in the National Livestock Database (NLDB), kept by AgriQuality.

The average cumulative incidence for five years (1990-1994) was calculated for each farm type from TB herd history records kept by AgriQuality New Zealand, using the sum of animals with tuberculous lesions at slaughter (lesioned culls and lesioned skin-test positive animals) and the total number of animals tested over the five years. Beef breeding herds had the highest cumulative incidence with an average of 0.026 (range 0.0012 to 0.174), whereas dairy farms had the lowest with an average of 0.008 (range 0.00 to 0.024). Beef finishing herds had on average a cumulative incidence of 0.012 (range 0.0006 to 0.02). However, cumulative incidence was not significantly dependent on farm type. One beef breeding farm with only 11 animals over 2 years of age, but a cumulative incidence of 0.174 and a studentised residual of 4.61 was classified as an extreme outlier – all other BB farms had a cumulative incidence of less than 0.05. After removal of this outlier the ANOVA test of cumulative incidence and farm type yielded an F-statistic of 0.941 with p=0.41. This non-significance is presented in the overlapping ranges in the box-plot of the cumulative incidence for the three farm types (Figure 3). Cumulative incidence was also not dependent on the total effective farm size, nor on the cattle stock units on the farm (p>0.40).

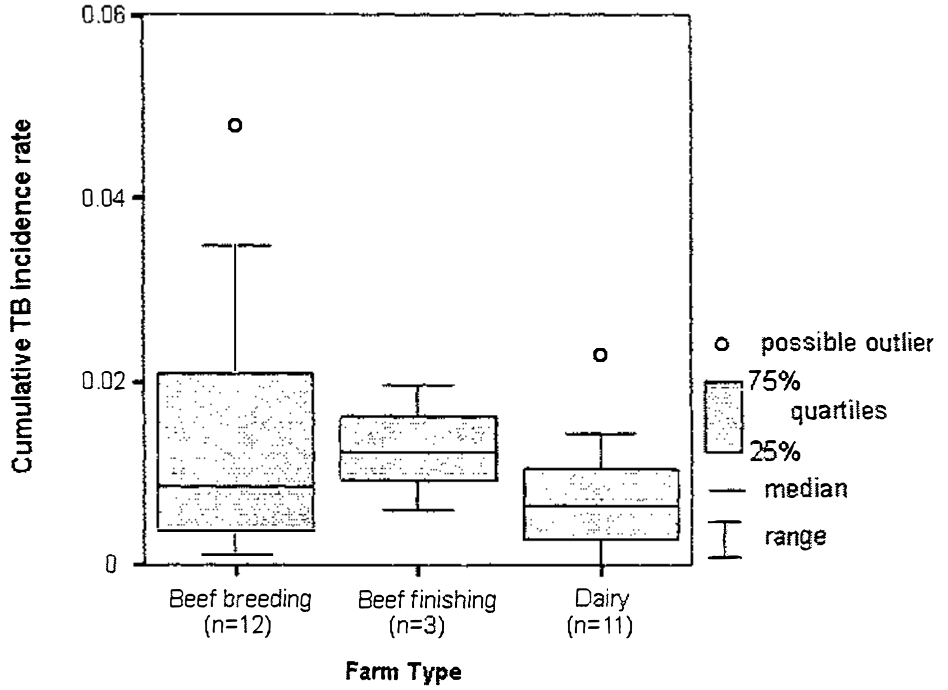


**Figure 3. Box-plot of five-year cumulative TB incidence rates (lesioned animals 1990-1994) for the three main farm types (excluding one extreme outlier in the beef breeding group with an incidence of 0.17).**

The cumulative incidence of TB lesioned animals was positively associated with the total number of whole herd tests conducted within the period 1990 to 1994 (F=2.761, p=0.042, 6 and 19 df, after removal of the extreme outlier). Beef breeding farms had an average of 5.83 whole herd tests during the five-year period, beef finishing farms an average of 1.67 and dairy farms an average of 7.27 (F=12.14, p=0.000, 2 and 23 df).

The beef breeding farms in the study were infected for an average of 4.67 years within the five-year period, the beef finishing farms an average of 3.00 years and dairy farms an average of 3.64 years (F=2.28, p=0.125, 2 and 23 df). The number of years a herd was infected was not associated with the five-year cumulative incidence for TB ($F=0.95$, $p=0.472$, 2 and 23 df), nor with the number of whole herd tests per herd over the five year period ($F=2.63$, $p=0.120$, 2 and 23 df).

## ***Building theories using the interviews***

Many interview questions related to all three aspects of the study: tuberculosis, farm management and grazing management. The division into the three separate groups was more for logistical reasons and many points mentioned are interrelated with each other. Not all farmers commented on each of the points described in the following, explaining the discrepancies in the numbers.

### Tuberculosis related observations by farmers

#### *Cattle affected*

Three farmers mentioned that the reactor animals were mostly amongst the highest producing animals. In dairy herds these were the high producing milk cows and in beef herds or groups of young animals the biggest animals of the group. Nine farmers stated that all age groups of cattle were affected in their herds, whereas 12 farmers stated that confirmed TB infection was mostly in the older animals (cows and rising two-year heifers).

#### *Tuberculosis hot-spots*

In the following the term TB hot-spot is used for localised high tuberculosis risk areas for livestock.

Nineteen farmers (ten BB, three BD, six DH) had either a suspicion or knowledge about certain habitat factors or localities on their farm where their cattle might have become infected with TB from possums. Sometimes no clear habitat factor was mentioned, only that the cattle were presumably infected in certain parts of the farm, such as the run-off. Suspected vegetation included bush, gorse (*Ulex europaeus*), lake edges, willows (*Salix* species), pine (*Pinus radiata*) plantations, dams, and swamp. Dairy farmers mostly suspected their run-off areas, which were often close to rivers and willows. Three farmers mentioned the possibility of having had infected possums in their hayshed, and cattle getting infected either by grazing around the hayshed or being fed with infected hay.

> *"Had two bulls react several years ago when we were fattening cattle, and thought they'd got infected from hay - probably infected possums in the hayshed. Because the cattle had lesions in lymph nodes in the head."*

More beef farmers than dairy farmers (eight BB, one BD, two DH) considered a specific area of their farm as a TB hot-spot area, either because they had reactors out of this area, or because tuberculous possums were found there. Only four farmers (three BB, one DH) stated that many areas of the farm were considered hot-spots. These farms mostly experienced reactor cattle out of one area one year, and out of another area the following year.

A greater proportion of dairy farmers than beef farmers (five DH, three BB) had no idea where their cattle picked up TB. These farmers could only hypothesise that their only areas with bush or trees on the farm could be possible hot-spots. Only one farmer stated that he also might have bought TB infected cattle.

The TB incidence data suggested that farms with hot-spots within paddocks grazed by cattle experienced a higher tuberculosis reactor incidence than farms where there was no clear suspected hot-spot area or where hot-spots were fenced off from grazing areas ($F=2.976$, $p=0.097$, 1 and 24 df). Eight farmers stated that they had a higher number of TB reactors in the group of animals that grazed the hot-spot area, than in other groups of animals.

### *Transmission of tuberculosis to cattle*

Perceptions about transmission of TB not only included possum-to-cattle transmission, but also cattle-to-cattle transmission. Cattle density was mentioned as a possible influencing factor, such as when cattle congregated around water. Cattle-to-cattle transmission was mentioned by five farmers, three of whom had experienced 'anergic' animals in the past. These were mostly older animals that had tested clear several times using the intradermal tuberculin test, but when sent to slaughter showed extensive lesions (mentioned on five of the farms).

> *"Years ago TB was with the herd itself, that means we had one of those cows what they call 'anergic' cow that wouldn't react but would spread it round. A bad problem with dairy farms."*

### *Possum control*

All except four farms had received possum control by the Wellington Regional Council. Most of the 23 farmers who had received control work were pleased with the staff and the work they did, despite six of these farmers stating that the Regional Council should control their farms more often. The farmers that had received possum control by the Regional Council stated that as a consequence the possum population was reduced quite severely and that the TB reactor rate in cattle decreased.

*"Since the Regional Council poisoned the possum in the last three years we have had very little TB, as has next door."*

Eight farmers explicitly stated that they regarded the Regional Council programme as being the best option for possum control, partly as it had experienced staff. Some farmers were even reasoning that they themselves should not have to do any control, as they paid rates to the Regional Council.

*"We are paying the rates to have them do it [possum control]"*

The degree of on-farm possum control conducted by the farmers themselves varied considerably. Ten farmers used to do plenty of possum control themselves or had trappers in to do it, but their efforts had stopped over the years. Only nine farmers had strategic possum-control programmes in place at the time of the interviews. Their reasons were grouped under 'awareness', comprising economical and preventive reasons. Eighteen farmers only controlled possums sporadically, either by setting a few traps or going shooting occasionally. The reasons for their lack of control or for ceasing their control efforts were mostly grouped under the category 'convenience'. Ten farmers stated the good success of the Regional Council control, others mentioned very low possum numbers, not enough time to do control, that it was too difficult, that they would/could not do it over the whole farm, that they could not keep up their motivation if they did not catch any possums, or that they stopped after they knew that the Regional Council will come on to the farm the following year.

*"We didn't trap much any more after the Regional Council was on the place, as we felt the possums were under control."*

*"I've had traps and bait stations out there and haven't caught anything in the traps for ages. One bait station we brought home just the other day and it still had bait in it. So there aren't many possums out there."*

One farmer stated that he stopped because he got frustrated by having conducted possum control and still had TB in his herd.

Eleven farmers pointed out that individual farmer efforts could not be effective, but co-ordinated schemes were necessary, as possums did not recognise farm boundaries. The fact that farmers were not in full control of the situation (wildlife moving around) and the threat that TB posed to the international market and therefore to the whole economy were both mentioned as reasons for the involvement of the Government. Three farmers explicitly mentioned that the scheme as it was in place at the time of the interviews, should remain, and that compensation should not be lowered, as economic margins of cattle farming are already low.

For seven farmers economics played a major role in deciding whether to conduct any possum control themselves. With decreasing profit margins in cattle farming it would become less and less economical to spend money on possum control.

> *"Current cattle prices must be a concern given that, as the returns drops, then so must the concern and the concerted effort to control TB."*

One farmer questioned if the amount paid to the Regional Council could be spent more economically by doing the control themselves on the farm. Another suggested that possum control could be more economically feasible if farmers were supplied with free poison by the Regional Council.

*Available methods of possum and tuberculosis control*

Twenty-five farmers stated that control methods available to them were shooting, trapping or poisoning of possums, but mentioned low motivation and no time as main constraints.

> *"We could put bait stations up, but there is always another job I have to do. If I am not looking after the stock I am doing something else that needs doing."*

In addition six farmers mentioned regular cattle testing and careful stock purchases as a way of controlling TB in their herds. Grazing management was only mentioned by three farmers. One farmer wished for a combined programme with his neighbours by employing a trapper or using big mobile bait stations. Another farmer expressed the wish for training on the use of poisons.

*Wildlife observed by farmers*

Twelve of the beef farmers thought that they had a high number of possums on their farm, whereas all dairy farmers and four beef farmers stated that they saw few or no possums on their farms. Farmers were asked if they knew of any tuberculous wildlife found on their farm, or if they had observed sick possums during daylight hours. Fourteen farmers had not observed any sick possums and did not know of any infected wildlife. Nine farmers remembered that they had seen sick possums during daylight, some several years ago, some in their suspected TB hot-spot areas, but also in some cases on previously managed properties in areas where hardly any TB existed in cattle. Most of these farmers did not make the connection between a sick possum and the risk of tuberculosis transmission or hot-spot areas. Tuberculous possums, ferrets, cats, deer and pigs had been found previously on six of the farms.

*Perceptions about tuberculosis testing and control in the herd*

Farmers' concern about the TB control programme as it was in place at the time of the interviews included that possum control would never be adequate as there were too many places to control, that possum control had to be a continuous effort, and that farmers had started to live with it and did not expect to be off Movement Control for any length of time.

The less than 100% sensitivity of the intradermal tuberculin test was mentioned by eight farmers, one farmer even expressing the view that false positive animals would be acceptable, but false negative would not, as they would allow cattle-to-cattle spread. However, five farmers were apparently unaware of the possibility of false-negative animals in the test, as they believed that buying 'white-tagged' cattle (cattle from infected farms, tagged with an official white tag for identification) would not represent any risk of buying infected animals.

> *"If you were buying cattle that were infected they would show up on the test."*

The specificity of the skin test was only mentioned by one farmer, who believed that one of his animals that reacted positively to the skin-test, but did not show any lesions at slaughter ('NVL' for 'no-visible lesion' animal), was actually infected with *M.avium* rather than *M.bovis*. Another farmer had two animals reacting positively to the skin test, which subsequently reacted to *M.avium* in the comparative skin test. The farmer believed the animals got infected from wild birds when they were grazing by a lake.

*Cost of tuberculosis as perceived by farmers*

The cost of TB control was mainly associated with the extra handling and management required for TB testing, and removing reactors from the herd at times when culling would not be normally done. Some financial loss was also due to compensation not being 100%, to having to sell young animals with official white-tags at a discount, and through lost production in dairy cows. Costs due to possum control, such as Regional Council rates and poison used on the farm were also mentioned. Only five farmers stated that TB had a considerable impact on farm income, two of whom had stud cattle. Eighteen farmers considered the cost of TB as not major, rather as an inconvenience.

> *"[TB] hasn't had a major financial impact for us, even though we had a high number of TB animals last year, only 6-8 were condemned and we received full payment on the others. I guess we lost the production from the 18 heifers."*

> *"[The cost of TB is] not that much, it's just more of an inconvenience."*

For the two farmers with stud cattle in the sample the costs of losing individual animals was considerable, but the loss of the market was financially more detrimental.

> *"We wouldn't want to live with TB because of economic reasons. It has major financial impact on us, being a stud. We even have to consider whether to carry on with the stud. Once we regain accredited status, it will be difficult to get old clients back as they tend to be very loyal and will be committed to a new supplier. That means for us, we will have to find new markets. There will also be a tarnishing affect for a while, and the concern that it may come back again, which may put potential customers off. It will take a long time to build back up again ... We calculated a $40,000 loss in one year due to TB, that is the difference between the potential value and the value we get in the works [slaughterhouse]"*

If stock was going to slaughter anyway, the effect of TB was not considered important.

> *"Other stock were going to the works anyway, so didn't have a major effect on returns."*

In order to minimise the cost of TB ten farmers changed or considered changing from selling young stock live to selling to slaughter only after finishing. However, only two of these farmers changed mainly because of TB, the others stated TB being only part of the reason and general farm economics, and farm management being the other part. One farmer changed his enterprise type from deer to cattle, as he believed farming cattle would be associated with less risk of contracting TB than farming deer.

Apart from these direct costs of TB seven farmers mentioned that TB limits the general farm management options, such as not being able to use certain off-farm grazing options, not being able to sell their animals to anywhere they choose, or easily move to other properties in the case of being a share-milker[1].

### *Sources of information*

Several sources of information regarding tuberculosis, TB control and possum control were brought up in the interviews. Most commonly AgriQuality veterinarians and livestock officers (during TB testing of cattle), Regional Council workers, local veterinary practitioners, discussion groups and media were mentioned. Especially Regional Council staff were often seen as a particularly valuable source of information. Six farmers expressed the view that they benefited very much from meetings organised by the local RAHC (Regional Animal Health Committee) or other organisations with invited speakers from research groups. Twenty-three farmers mentioned a range

[1] A share-milker owns or manages a herd of milking cows in partnership with the owner of the farm on an agreed profit-share basis.

of sources, partly actively seeking information. Five farmers regarded themselves as knowledgeable enough, without the need to seek new information.

The perception of the knowledge of Livestock officers (LOs) varied. Three farmers found them very helpful and knowledgeable, but four farmers were concerned about the LOs' lack of technical, factual knowledge. They found that LOs would only express their own beliefs, but did not have new information at hand. The farmers who commented in more detail about the LOs considered that they had great potential in providing information in that they visit many farmers and can talk to them while testing cattle. The farmers thought the LOs could be used more in disseminating knowledge and to help farmers help themselves.

> *"LOs see more farmers than anyone else and provide a great opportunity to provide farmers with info on TB. They could at least have a brochure, which they dropped off. Farmers may be inclined to read this, if talking to other farmers who also get the brochure."*

### *Willingness to accept Tuberculosis*

Sixteen of the 27 farmers would not want to live with tuberculosis permanently, for economic reasons (both for the herd and the international market), health reasons and having flexible management options. However, eight farmers stated that they have lived with it for long periods, got used to it, and that they could not see tuberculosis eradicated from their farms, especially under the current economic situation.

> *"We have lived with TB for 50 years now. Would love to be free of TB given the choice, but there isn't any."*

Three farmers mentioned that the economics of the farming situation had to be considered, losing a few animals to TB might still make it more economical to graze hill country, rather than avoid TB hot-spots and staying clear of TB.

> *"TB is not something I would live with on the farm but it does depend on how much it is going to cost to get rid of it against the cost of it at low levels – for example the reduced price of sale per head."*

Only one beef finishing farmer was content to deliberately accept TB in his herd. As all of his cattle were going to slaughter he made it a farm policy to buy only 'white-tagged' animals, as these were cheaper.

## General farm management

In general farmers did not regard off-farm grazing, grazing other owners' cattle or their purchasing behaviour as risky practices for getting their cattle infected with TB. Farmers who considered it risky had changed their practices where possible, and other farmers would change if the risk in the individual circumstances was considered high and if they considered it feasible.

### *Purchasing behaviour*

Fourteen farmers reared their own offspring and bred or bought in their breeding bulls. Thirteen farmers bought in 'white-tagged' cattle, mainly because they were cheaper and farmers did not regard them as high-risk animals, as they had been tested clear with the skin test. All except one farmer stated that they did not think this purchasing behaviour had influenced the TB situation on the farm.

Seven farmers did not consider TB at all when purchasing cattle. Some changed this attitude once they had TB in their herd.

### *Selling behaviour*

Sixteen farmers said that TB had no influence on their selling policies, whereas seven farmers (5 BB, 2 DH) indicated that they had changed their selling or farm practices, by reducing the number of cows, moving from selling weaners towards finishing their stock, or by sending stock to slaughter rather than to live markets. Reasons for these changes were of moral (not wanting to spread TB) and economic nature ('white-tagged' animals yielded lower prices, and only had limited markets).

> *"The last few years we've reared bull calves which go to first sale in November. Not doing it this year. Having white tags in the calves has reduced the price received by $30-$40."*

Nine of the farms where TB had no influence on selling policies were already selling their cattle directly to slaughter, while the others kept their regular selling policies and accepted lower prices for their cattle.

### *Pasture shortage as a limiting factor in grazing management*

Two main periods were mentioned for pasture shortage; winter due to lack of pasture growth and summer due to dry weather. Pasture shortage depended on the area the farm was in, lasted typically for two months, ranging from June to October for winter and December to March for summer.

Management of pasture shortage involved feeding supplements (hay, silage or feed crops), using less productive paddocks (bush areas) for cattle, grazing stock off-farm and/or selling stock.

### *Grazing other owners' cattle*

Seven farmers in the sample grazed other owner's cattle on their property. They either grazed cattle from properties related to their own farm (share-farming or relatives; n=5), or only did this sporadically (n=2). None of these farmers considered this practice as high risk for contracting TB infection.

## Grazing management

### *General grazing management*

Grazing management on beef breeding farms was flexible, based on tradition and often on past personal experience. It was changed on demand to meet immediate needs. The only thing fixed on most farms were certain calving paddocks, which were used year after year for calving. These paddocks mostly were less productive and had vegetation that provided cover during the winter months. Thereafter cows were used to clean up rough patches in paddocks all over the farm and were put into less productive areas, whereas the young fattening stock were kept on the better pasture. Most beef breeding farmers described their grazing management as being responsive to feed requirements of cattle and feed availability, which meant that grazing management could not be fixed, but cattle had to be put in any areas where feed was available.

> *"Can't have too fixed a pattern, we have to play it by ear a bit therefore. It's that sort of a farm – often short of feed."*

For dairy farms the grazing was much more fixed, with set routines of grazing rotations, using run-off areas at certain times and for certain stock groups. These farms often used the same system for many years. Young stock (after weaning) were mostly grazed on a run-off or other off-farm grazing arrangements, and only the cows were grazed on the home farm during the milking period. During the winter months, when cows were dried off, they too were shifted to the run-off in order to avoid damage to the high-producing paddocks on the main farm.

All except two of the 27 farmers tried to keep their cattle throughout the year in their respective mobs (e.g. based on age and sex). Only three of the beef farmers had their mobs in separate parts of the farm, on all other beef farms all animals would graze over most of the farm within one year. Three farmers stated that their large number of stock classes and cattle mobs made grazing management complex and difficult.

*Bush grazing*

Bush areas were mostly used by beef farms. Of the 13 beef farms that had bush on their farm, ten used these areas at least for some of the year. In contrast, only four of the dairy farms had bush on their property. On two farms these bush areas were fenced off and excluded from grazing and on one farm these areas were only used in exceptional circumstances.

Most beef breeding farmers used the bush areas for calving their cows (cover, plenty of space, drier), wintering their cattle (on the less productive pasture, in order to save the better, more productive pasture) or as a last resort for times of pasture shortage.

> *"Generally we don't graze in bush. We have tried all sorts of things out there and we finally got down to the fact that we need to feed the cows. So this year we put them in [the bush area] and they did very nicely."*

However, two beef farmers were very conscious of the TB risk and did not even put cattle close to the bush areas.

Three farmers ensured that the time animals spent in the bush areas was short and/or stocking density was low, and therefore the animals were not pushed hard for feed when cattle were put into the bush paddocks. Four farmers used their bush area without taking TB into consideration, because they believed that the vegetation was not conducive to possums, or because they considered the TB risk economically less costly than feeding supplements.

> *"In the wintertime they might as well eat that [grass in bush area] rather than feed them hay."*

Several farms had patches of bush all over the farm, and therefore they did not consider it possible to exclude cattle from these areas.

*Hot-spot grazing*

Of the 19 farmers who had knowledge or suspicion of a TB hot-spot area on their farm, four farmers fenced these areas off and seven farmers tried to consider it when setting up their grazing management. Of the eight farmers that did not take their potential hot-spot areas into consideration, three explained this by not being able to exactly identify such areas, and two farmers by economic reasons, where they did not see any other option without huge expense such as grazing cattle off-farm or feeding supplements. These farmers considered the consequences of TB infection in their cattle herds as being low.

*"I was aware of the TB risk at this stage, but it was more economical to graze off and run the risk of one or two reactors rather than winter the cows at home and feed them supplementary feed."*

Seven farmers tried to incorporate TB hot-spots into their grazing management, by excluding breeding cattle from these areas and only grazing them with younger fattening stock, or by grazing cattle in these areas only after possum control had been conducted. However, two farmers stated that the options for the grazing management were limited.

*"Tried to take this [TB hot-spot] into consideration in the grazing programme, but options were limited, particularly as there wasn't as much cleared land on the farm at that time. We didn't put cows there, but used to put young stock on the hills and got a lot of TB in this group."*

### *Off-farm grazing*

Sixteen farmers (seven beef farmers, nine dairy farmers) used to graze some of their cattle off-farm, either on their own run-offs (n=11), on share-farms (n=4), or on other unrelated farms (n=2). Beef breeding farms mostly used off-farm grazing to finish their cattle before selling to slaughter, whereas dairy farms used these areas all year round for young stock and during winter for cows. Unless beef farmers were linked into a share-farming business, they used less off-farm grazing than dairy farms (n=3 vs. n=9), and often it was only in exceptional circumstances (e.g. drought).

Farmers, who had to find off-farm grazing opportunities for their cattle each year experienced more constraints because of the resistance to 'white-tagged' animals, than farmers having their own run-off or being associated with other farms. These farmers paying for grazing opportunities found it difficult to find other properties that were willing to take 'white-tagged' cattle on for grazing. Consequently many of these farmers bought a property for use as a run-off, in order to avoid this dependence.

*"We went to one place [for grazing] 2-3 years in a row. But [it] has been getting increasingly difficult finding grazing if on MC. Generally we took whatever was going."*

*"We have always been careful with choosing where the heifers go grazing - avoid any farm currently on MC. But now it's getting more difficult as graziers are becoming more cautious about taking cattle that are on MC. In the future we will have to go to a place on MC, which I am reluctant to do, or change policy and winter cattle on the home farm and the newly acquired run-off."*

# Discussion

## *Descriptive analysis of study farms*

Comparing the three farm types studied (BB, BD and DH) a number of differences were found. The ranges of the cumulative incidence of lesioned tuberculous cattle between the three farm types were overlapping, but a trend was still apparent. Beef breeding farms were infected on average for more than 4.5 years, whereas dairy farms were infected on average less than four out of the five years under investigation. The beef breeding farms had a higher incidence of tuberculosis, with cumulative incidences of up to 0.05. One beef breeding farm was extreme with a cumulative incidence of 0.17. However, this farm was in a different location to the other farms (Wellington region) and had one of the lowest percentage of effective land (only 50% of the farm area was used for grazing; half the farm was in bush, gorse and trees and unsuitable for grazing). Additionally this farm had the lowest number of cattle, and these were allowed to graze over large areas. It might be suspected that due to the large area of un-used land the possum population was high, creating ample opportunities for direct contact between possums and cattle. This contact was reported to be a strong potential pathway for transmitting the disease (Sauter and Morris, 1995a).

The beef finishing farms in the present study had an intermediate cumulative TB incidence. A 1985 to 1990 study of TB in the Wairarapa showed beef finishing farms had a higher incidence of tuberculosis than dairy or beef breeding enterprises (Zewdie, 1997). However, the sample size of only three beef finishing farms in the present study was very low. The dairy farms had the lowest range of cumulative TB incidence amongst the three farm types.

The differences in the TB incidence rates between farm type might also be related to the vegetation on the farm. Dairy farms are usually intensive and do not have a lot of bush, whereas beef breeding farms are often high-hill country farms with plenty of bush and scrub, potential possum habitat (Ministry of Agriculture, 1998), a situation that was clearly the case in the present study.

In the present study there was a statistically significant positive association between the incidence of TB lesioned cattle and the number of whole herd TB tests over the five-year period. It is possible that farmers with a high incidence in their cattle herds were more interested in controlling the disease and therefore were prepared to test their cattle more frequently.

The number of whole herd TB tests and the number of years during which the cattle herds were infected within the five-year period in the present study differed also between the three farm types. Dairy farms had on average a greater number of whole herd tests than beef breeding farms. This could be a consequence of the different animal management. Beef breeding farms generally run a higher number of cattle on a much larger area than dairy farms. Thus, it requires more effort to get all animals into the yards for TB testing. The dairy farms in contrast have to bring in their cows daily for milking, making TB testing much easier. However, the higher number of whole herd tests in dairy farms could also be related to a possible greater awareness of TB and concern about it in dairy farms. The low number of whole herd tests in beef finishing farms can be explained by the legislation in place. Until the early 1990s beef finishing farms were not required to test their animals, as most animals were going to slaughter. The number of years infected within this five-year period showed a trend that beef breeding farms were infected for longer than beef finishing and dairy farms, but this association was not statistically significant.

There was no statistical association between the number of whole herd tests and the number of years the herd had been infected. However, the time period of five years is very short and it is expected that it will take some time for frequent testing to have an effect on the TB status of the herd.

### *Methodology*

The present study focused mainly on two areas in the Wairarapa, where TB infection in the possum population existed and wildlife surveys were being conducted. The Wairarapa region was chosen because this study was part of a greater research project being carried out in this region. Furthermore the intervention study (see Chapter 3) to evaluate on-farm control programmes, was to be carried out in the same region. The conclusions drawn from this interview study regarding the tuberculosis situation and grazing management are directly applicable only to the study population in the Wairarapa, although it is likely that the principles derived from these interviews will also apply to other areas in the country.

The data gathered during the interviews regarding tuberculosis and grazing management were less suited for purely quantitative methods, as they were individual and subjective for each farm. Furthermore, as one of the intentions was to gain knowledge about the management on farms without pre-conceived assumptions, qualitative methods were used to develop theories (Strauss and Corbin, 1990) about farm and grazing management, the drivers for specific actions and principles of TB management used on farms. These included the relationship of grazing management to the probability of cattle getting infected with tuberculosis, and its potential for use in conjunction with other TB control measures. Using open-ended, unstructured questions allowed farmers to describe their concepts, TB situation, perceptions of TB, grazing management and reasons for using the specific grazing management, expressed in their own vocabulary. Analysing these unstructured interviews using the 'grounded theory' method, enabled the researcher to find similarities and trends in highly variable and subjective data. The software programme WinMAX98, developed for qualitative data analysis and mostly used in sociology and related fields, greatly facilitated data coding, structuring, retrieval and development of theories. Another method for analysis would have been one based on 'key words', where the individual interview documents are searched for key words. Each occurrence of a key word is then analysed for its combined occurrence with other key words. However, grazing management and the tuberculosis situation on each farm were very complex and therefore described by the individual farmers with a high variability. 'Grounded theory' was the preferred method for analysis.

The number of subjects used in 'grounded theory' studies on human behaviour varies widely from less than ten (Conrad, 1978) to several thousands (Ekins, 1993). However, more important than the number of subjects used is the diversity. Glaser and Strauss (1967), the early developers of 'grounded theory' suggested the use of as many divergent subgroups of the population as possible, including individuals who were likely to challenge the developing behavioural patterns. In the present study nearly complete coverage in the two study areas was obtained, only one farmer was unwilling to participate in the study. Therefore the findings can be considered to represent the views of these communities.

One limitation in the present study was that all interviews were completed by the time the analysis started. This arose because the study was undertaken as a component of a larger, multifaceted TB research programme and therefore its timing had to conform to the needs of the overall study. Thus, the interview procedure could not be progressively adapted in the light of results in order to make full use of the constant comparative method proposed to enhance the effectiveness of 'grounded theory' method. The constant comparative method aims to reassess the emerging theories by changing the interviews and asking different questions. Another characteristic of the constant comparative method is that the collection of events is stopped when no further new concepts are found, a state where 'grounded theory' is said to have reached saturation (Strauss and Corbin, 1990). In the present study, the number of interviews available was small in relation to the variety of answers found and more ideas might have emerged if more interviews were available. However, most of the key theories emerged very quickly and were confirmed by the majority of subsequently analysed interviews. Therefore it is likely that the additional new ideas would not have contributed significantly to the main theories. Nevertheless, for the purpose of designing on-farm TB control methods, which could be used widely, this was sufficient, but it has to be acknowledged that more ideas and new concepts could have led to additional insights or even to new TB control ideas.

### *Interview content analysis*

The following key theories emerged from the study and were considered important in setting up on-farm TB control programmes:

- Many farmers know or have suspicions about potential TB hot-spots on their farm. Dairy farms have less definite knowledge of hot-spots but they also have less high-risk possum habitat than beef farms.

- Farms where TB hot-spots are located within paddocks have a higher TB reactor incidence than farms where TB hot-spots are excluded from grazing by fencing etc.

- Economics plays an important role in decision making by farmers about TB control, both for possum control and for grazing strategies. TB generally is believed not to have a major impact on farm income.

- Farmers are supportive of TB control as a national priority to protect New Zealand's trading position, but, due to economic considerations, vary in their degree of commitment to implementing control measures on their own farms.

- Farmer initiated possum control is sporadic, and the motivation to do it under current circumstances is often lacking or wears off very quickly due to competing work pressures.

- Grazing management on beef farms is flexible, whereas dairy farms have more set routines. Pasture shortage is a limiting factor in setting up grazing regimens. Increased number of stock classes reduces flexibility of grazing management.

- Practices such as grazing off-farm, grazing another owner's cattle on the home farm and purchasing cattle are not regarded as high risk by farmers; if such practices were regarded as risky in the past, then farmers changed them if possible.

- AgriQuality veterinarians and people who visit the farm on animal health business (Livestock officers, Regional Council staff and veterinary practitioners) are the most common source of information. They were seen as having great potential for being an optimal medium for knowledge transfer. Some farmers found Livestock officers very knowledgeable, while they did not meet the requirements of other farmers.

In the following, these key theories and related points are discussed in more detail.

Farmers generally had a good idea about tuberculosis and their specific situation. As dominance was found to be positively related to age and weight (Dickson *et al.*, 1967), the comment of some farmers that the reactor animals were mostly the highest producing, biggest animals in the group, is in agreement with dominance studies performed with cattle/deer and possums (Sauter and Morris, 1995b; Sauter, 1996). Sauter and Morris (1995b) found that animals high in the dominance order were the ones investigating sedated possums, which simulated the behaviour of terminally ill tuberculous possums.

Amongst the farmers in the present study there was variation in the age at which cattle were affected by tuberculosis, some farmers mentioned that TB was occurring in all age groups, whereas others reported that older animals were more affected. However, this would depend very much on where each group of animals was grazed and from the small sample size in this study no generalisations can be made.

With regard to potential TB hot-spots, most farmers (more beef farmers than dairy farmers) had some suspicions or knowledge that certain areas of their farm might be TB hot-spots. However, most dairy farmers did not have definite knowledge of where their cattle picked up TB. This could be related to characteristics of dairy farms, as they do not have many areas with trees or scrub, and often the remaining bush areas are fenced off. However, cattle on dairy farms are usually grazed in high numbers in small paddocks, which means if there was a TB possum in the paddock, then most animals would see it and have the opportunity to interact with it. The cows are also rotated around all paddocks as a group on a fairly short cycle, so there is little scope to discriminate where infection occurred. This is in contrast to the beef breeding farms, which generally graze extensively. Beef breeding farmers were more specific about their potential TB hot-spots. The vegetation mentioned by these farmers as suspected TB-areas, such as gorse, willows or bush, was confirmed to be of high TB risk in a later habitat study (McKenzie, 1999).

The finding that farms with known hot-spots within paddocks experienced a higher tuberculosis incidence than farms without known hot-spots or with fenced off hot-spots, suggests that excluding cattle from hot-spots could have major implications in controlling TB. The farmers who knew about TB hot-spots and excluded them from grazing with cattle, either by fencing off or by not grazing these paddocks with cattle any more, still used the paddocks adjacent to these hot-spot areas. This could indicate that to reduce TB incidence, it is not necessary to keep infected possums out of cattle grazing areas, but that it is sufficient to keep cattle out of these hot-spots based around possum denning areas. Using this in conjunction with the seasonal pattern of tuberculous possum' deaths (see Chapter 3) this leads to potential major on-farm TB control methods: TB in livestock may be reduced by either fencing off hot-spots permanently or temporarily, or by excluding paddocks with hot-spots permanently or seasonally from grazing with cattle. One disadvantage of fencing off hot-spots permanently is the potential expansion of bush area, which might lead to an increased number of hot-spots. However, the main advantage of these methods is that they are of low cost and readily available to farmers, two characteristics that make them powerful tools in the control of the disease.

Farmer-initiated possum control was found to be only sporadic, not continuous. Several reasons were mentioned: low possum density, time constraints, difficulties in controlling possums, and paying Regional Council rates. More dairy farmers than beef farmers mentioned low numbers of possums as a reason for not conducting or continuing their possum control efforts. The reasons for the difference in possum numbers between dairy and beef breeding farms could be two-fold. Regional Council possum control operations started earlier in the main dairy areas and later in the beef areas, but also the vegetation on dairy farms is much less possum-prone than on beef farms, which therefore have a much larger proportion of the farm as possum habitat.

The reasons given for the lack of possum control conducted by farmers, indicates that any further education and agricultural extension of farmers must be targeted towards this field. If farmers are expected to assist in the control of possums, their motivation must be raised. Motivation has to be kept up and reinforced once possum numbers become low. Several farmers in the present study stated that motivation had suffered, and they had actually stopped their possum control efforts as soon as it became apparent that the Regional Council would be undertaking control work on the farm. Others felt that they did not have any responsibility for controlling possums themselves, because they paid possum control rates to the Regional Council. Some farmers also mentioned that individual farm control efforts could not be successful as possums range across farm boundaries, therefore necessitating co-ordinated efforts. This may often be a 'convenient' way to justify avoidance of possum control, by assuming that the neighbours would not do their part of the control and therefore hampering the farmer's own possum control efforts.

Several farmers also mentioned economics as a reason for their lack of TB control. They regarded it as uneconomic to spend money on TB control (equipment, material and labour) under the current low profitability of their farms. In general, farmers did not regard tuberculosis as of major financial importance, unless they were breeding stud cattle. In that case the disease had a major financial impact, as animals had to be sold to slaughter at below their monetary breeding value, as the breeders lost their stud cattle markets. Most other farmers reported only a small loss due to compensation for reactor animals not being 100% or having to sell young stock with white-tags. Most farmers regarded TB and its control mainly as an inconvenience due to the extra animal handling required and/or due to it limiting overall farm management. If farmers sent the majority of their stock to slaughter anyway, TB did not have severe financial consequences. This was also the reason for some of the farmers to change their stock policies towards finishing all of their stock and sending prime cattle to slaughter, rather than selling young stock. By moving to slaughter-only, the cost of TB could be minimised. Thus, if farmers do not associate a significant cost with TB, they are unlikely to see any need for controlling possums and TB on their farms. As more and more farmers move to slaughter-only, cost-effective TB control programmes are required. Therefore, further investigation needs to consider both the costs of TB control programmes and the cost of the disease to the farm. The cost analysis could also investigate changes in the regulation that increase the perceived cost of TB to farmers, such as removal of compensation or direct payment for TB testing.

All these reasons given for the lack of farmer-initiated TB control and for ceasing control efforts by farmers indicate that further investigation should focus on motivational incentives that raise the willingness and motivation to carry out TB control on farm, on incentives that keep and reinforce this motivation and that apply to most farmers, in order to achieve widespread adoption of control programmes. If motivational incentives could be put in place that resulted in widespread adoption of TB control programmes, it might be hypothesised that peer pressure amongst farmers might even lead to complete coverage over time. As economic considerations are a major driver for farmers it is likely that these incentives will have some financial influence, such as decreased Regional Council rates, subsidised poison and bait stations or an insurance scheme for TB (see Chapter 6).

Apart from the field of motivation of farmers, education and extension should also focus on TB testing related issues. Several farmers mentioned issues, such as 'anergic' animals, the wish for a better test, their belief that 'white-tagged' cattle are 'un-infected' or that cattle become infected by birds. Such 'anergic' animals with advanced stages of disease, infected cattle that did not react to the intradermal tuberculin test, but showed lesions (sometimes extensive) at slaughter, are considered to be seldom now with frequent testing, as animals are removed before extensive lesions can develop. It was notable that farmers who had anergic animals in the past were much more aware and put a much higher risk assessment on cattle-to-cattle spread of TB than farmers who had never had an anergic animal.

The less than 100% sensitivity of the intradermal tuberculin test was also mentioned by several farmers as a constraint to successful TB control. Investigations from Australia and New Zealand showed that the sensitivity of the caudal fold test was between 65.6 % and 95.6% (Lepper *et al.*, 1977; Francis *et al.*, 1978; Lepper *et al.*, 1979; Wood *et al.*, 1991; Wood *et al.*, 1992; Ryan, 1992). In the Wairarapa MAF veterinarians use a 'working' figure of 85% ± 5% (G.Pannett, pers. comm. 1999). This would indicate that 10-20% of infected animals are not identified by the intradermal test. In an analytical model of Kean and Barlow (1999) it was found that this low sensitivity was of little consequence within the herd TB testing programmes. The desire of farmers for a better or perfect test has to be met with education programmes. This also applies to the fact that many farmers felt that intradermal tested animals from infected herds ('white-tagged' animals) were identified as 'un-infected'.

Any education and extension of farmers regarding motivation or TB testing issues could be built on existing knowledge transfer methods. The farmers in the study were aware of a wide range of sources of information on TB. However, staff from AgriQuality and the Regional Council, coming directly on to the farm, were mostly mentioned as the first and most important contact, especially the livestock officers (LOs). The impression farmers got from these LOs differed very much amongst farmers, some finding them very knowledgeable, others finding them too subjective and not able to provide information which met the requirements of farmers. These LOs were seen by several farmers as an ideal medium of knowledge transfer, as they were in regular contact with the farmers and often spent several hours on the farm. With adequate training these LOs could educate farmers on issues such as test sensitivity or on-farm control programmes. Veterinary practitioners were also mentioned as a source of information, although not by the majority of farmers, indicating an opportunity for veterinary practitioners to expand their role.

From a national perspective, with the Pest management strategy aim of controlling and eradicating TB, it is encouraging that most farmers would not want to live with TB in their cattle herd permanently. However, the substantial number of farmers who stated that they had got used to it, that they have lived with it for a long time, and that they cannot see TB being eradicated, indicates a strong need for education and agricultural extension.

Economic considerations were also of major importance in general farm management and grazing management. Half of the farmers in the study bought in 'white-tagged' animals, mainly because they were cheaper. These farmers stated that this purchasing behaviour had not affected the TB situation on their farms. Only one farmer believed that TB was introduced by infected cattle rather than having a TB problem on the farm itself. The minor role of cattle movement in creating new TB breakdowns was also reported by Carter *et al.* (1995). Nevertheless these authors stated that the risk could be minimised by adopting a policy of preventing movements from infected herds when reactors were found at the pre movement TB test, a change that has been implemented since June 1997. Farmers also did not consider their off-farm grazing or grazing other owner's cattle as a high-risk practice. They stated that if they had the feeling that these practices caused TB infection in their animals, then they would change them, as long as it was economic to do so. However, to change these practices is often only possible for farmers who have to find new grazing opportunities for their cattle each year. If they had purchased extra land, such as a run-off, it is more difficult and associated with costs to change this. Therefore it is more likely that farmers would continue to use these areas despite the TB risk to their livestock.

One of the aims of the present study was to develop hypotheses for on-farm TB control programmes. Resulting from the key theories of TB hot-spots, the approach of excluding hot-spot areas from grazing by cattle can be developed. To test if this method is practicable, it is necessary to know if the grazing management on farms does allow such an alteration, and incorporation of TB control methods into standard farm management. On beef farms grazing management was found to be flexible, whereas on dairy farms it was more fixed. Beef farmers stated that cattle were put in paddocks *ad hoc* where grass was available, whereas dairy farmers had set routines, with young stock being mostly off farm grazing. Some of the farmers in the study, who tried to take TB hot-spots into consideration, mentioned that only limited options were available to them. This was especially the case in times of pasture shortage, when farmers were more likely to ignore their concerns about possible TB infection from possums, as their main aim was to feed their cattle. This also indicates that economic considerations were one of the most important factors. If it is more economic to risk TB infection by grazing cattle in hot-spot areas rather than purchasing supplements, it is likely that not many farmers will consider TB during these times.

It is therefore proposed that on beef farms, there is potential for excluding TB hot-spots from grazing with cattle for certain high risk periods. For dairy farms this might be more difficult. In addition beef farms generally also have sheep, which could use these hot-spot areas. Dairy farms do not have any other species but could use the grass for supplements. However, first it has to be evaluated whether such a control method of excluding cattle from TB hot-spots during high risk periods is effective or not (see Chapter 3). Secondly the costs of such a control programme and the cost benefits of TB control to the farm have to be established, which might then lead to motivational incentives that make it more economical for farmers to control possums and TB (see Chapter 6). Because beef farms generally present more of a TB control problem than dairy farms, individual farm strategies may well be more effective and necessary on such farms, and this needs to be examined.

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Deer interacting with simulating moribund tuberculous possum

Typical 'interaction' between sheep and simulated moribund tuberculous possum

# Chapter 3

# Effectiveness of on-farm tuberculosis control programmes: Farms located in the Wairarapa

## Abstract

The Australian brushtail possum is the main vector for bovine tuberculosis to cattle and deer in New Zealand. Due to this wildlife reservoir and vector species, control of the disease is complicated and has to involve both livestock and wildlife. In about 23% of the country TB is endemic in possum populations and 3% of all cattle and deer herds are classified as infected with TB. Vector control operations, mainly large scale poisoning programmes conducted by aerial or ground baiting, are expensive and cannot cover all areas with TB in possum populations. And even in some areas where control was conducted, TB in livestock has not been eradicated so far. Thus, increased responsibility for control will be placed on farmers themselves. Therefore it was necessary to evaluate the effectiveness of on-farm control measures available to farmers.

An intervention study involving 67 farms in the Wairarapa was conducted. Two main on-farm control measures were employed on 34 farms: targeted vector control in spring and autumn, and grazing management that excluded cattle from grazing TB hot-spot areas during July and August, and again from November to January. Vector control was conducted by the research team during the first two years of the project, while farmers took over sole responsibility for the continuation of the control measures in the third year. A higher proportion of focused control farms than standard control farms achieved TB clear status for their herds. A lower proportion of focused control than standard control farms had multiple TB-positive animals in the final project years, and the two-year cumulative TB incidence was reduced more in focused control than in standard control farms. Most results did not reach significance at the p=0.05 level, however, the small sample size meant that statistical power was inescapably low. Nevertheless, the study provided evidence that specifically targeted possum control, combined with stock management practices that minimise or prevent contact with infected vectors are effective methods of reducing the herd incidence of TB and the rate at which herds are declared TB-free. These control measures are of low cost and they should easily be implemented and should contribute significantly to the AHB strategy to reduce the herd prevalence of TB.

## Introduction

In New Zealand, the Australian brushtail possum (Trichosurus vulpecula) is not only a pest to native flora and fauna, but also a reservoir host for bovine tuberculosis and a vector of the disease to livestock (Morris *et al.*, 1994). Areas where tuberculosis (TB) is endemic in possum populations are classified as Vector Risk Areas (VRAs). In 1998 about 23% of New Zealand's land area was in zones classified as VRAs (Animal Health Board, 1998a). Thus control of the disease has to be twofold – control in livestock through eradication measures within herds, and control of infected vector populations. This has resulted in complicated and expensive control programmes (Animal Health Board, 2000). Since 1996, New Zealand's TB eradication programme has been carried out under a National Pest Management Strategy administered by the Animal Health Board (Animal Health Board, 2000). The main objective of this strategy is to reduce the number of TB infected cattle and deer herds to achieve internationally recognised freedom from TB within 10 years, in order to protect export market access (Animal Health Board, 2000). This freedom of TB is achieved if 99.8% of all herds have been tested negative for at least three years. At the beginning of 2000 New Zealand has had approximately 97% of herds that have achieved this requirement (Coleman and Livingstone, 2000).

Approximately 10% of New Zealand's land area is currently under some form of continuous TB vector control (Coleman and Livingstone, 2000). The majority of possum control is done by poison-baiting, using aerial and ground application of poison baits (Morgan and Hickling, 2000). Since 1987 all possum control programmes include annual or biennial follow-up programmes that are intended to maintain the possum population at low levels (Coleman and Livingstone, 2000). Most vector control is conducted by Regional Councils and financed in part through the Animal Health Board, which receives levy funding from the cattle and deer industries, and funding from the Crown, complemented by direct funding from the region through rates paid by landowners (Anon, 1998). In 1995 $18 million was spent on vector control (Animal Health Board, 1995), and this expenditure rose to $28.4 million in 1998/99 (Coleman and Livingstone, 2000). These possum control operations have contributed to reducing both the number of cattle and deer herds under quarantine for TB control purposes and the incidence of TB (Pannett, 1995; Livingstone, 1997; Animal Health Board, 2000). However, in many areas eradication of TB from the possum population has not been achieved, necessitating continuous vector control efforts to keep the disease in livestock at low levels (Anon, 1998; Coleman and Livingstone, 2000). Additionally, it is expected that the cost of maintaining the areas already controlled will remain high, and with current technology, will continue long into the future (Animal Health Board, 2000).

As the incidence of TB in cattle and deer herds within VRAs decreases, the marginal return on funds invested in possum control becomes smaller and the (perceived?) justification for spending large amounts of taxpayers' money in VRAs becomes less (Cullen and Bicknell, 2000). Therefore increasing pressure and responsibility will be put on individual farmers to assist in the control of the disease, especially on properties with persistent TB. One of the objectives of the present five-year strategy of the Animal Health Board is 'to encourage individuals to take action against TB on their properties and in their herds' (Animal Health Board, 1995). It is unlikely that farmers can provide the same service currently offered by the Regional Council in terms of possum control (whole farm blanket control), but other complementary methods, assisting the Regional Council control strategies, could be available to farmers.

TB is not evenly distributed within an infected possum population, but is clustered particularly in certain denning areas, typically covering an area with a diameter of approximately 40 meters, ranging from 20 to 120 meters (Pfeiffer, 1994; Hickling, 1995). These areas, commonly referred to as 'TB hot-spots', may persist over many years at the same location or be more sporadic and only persist for relatively short periods (McKenzie *et al.*, 1997; McKenzie, 1999). It appears that environmental risk factors are important in maintaining a TB hot-spot for long periods by influencing the transmission rate of TB (McKenzie *et al.*, 1997). In a study by McKenzie (1999), multiple TB possums were more likely found in flatter land with multiple enclosed dens.

Accumulating knowledge about the spatial epidemiology of TB in possums, suggests that specifically targeted farm management practices may reduce the incidence of TB in livestock. This should lead to cost-effective control methods, that result in more rapid eradication of TB from herds. The objective of the present study was to evaluate the effectiveness of practical, low-cost, on-farm TB control measures, which consisted of targeted vector control and management practices to reduce the risk of transmission from vector to livestock. This chapter presents the effectiveness of these practices in reducing the herd incidence of TB and achieving eradication of TB from the herd, as measured by revocation of TB Infected Status.

## Materials and Methods

An intervention study was conducted with 70 farms that were under Movement Control (MC) restrictions at the time of selection. These were randomly allocated into equal numbers of 'focused control' farms (receiving specific advice and control effort in addition to standard official control) and 'standard control' farms (receiving standard control measures only).

### *Study area*

All farms selected for the study were located in the Wairarapa (Figure 4), a region where TB in cattle has been endemic since at least the 1950s (Shortridge, 1981). Traditional test and slaughter strategies were successfully employed until the late 1960s, when there was initial evidence that possums had become a reservoir for TB (Anon, 1998). Since 1968 tuberculous possums have been found in over 140 different locations in the Wairarapa. Other tuberculous wildlife such as ferrets, stoats, feral deer and pigs have also been found in the Wairarapa during the last two decades (Lugton, 1997; Anon, 1998).

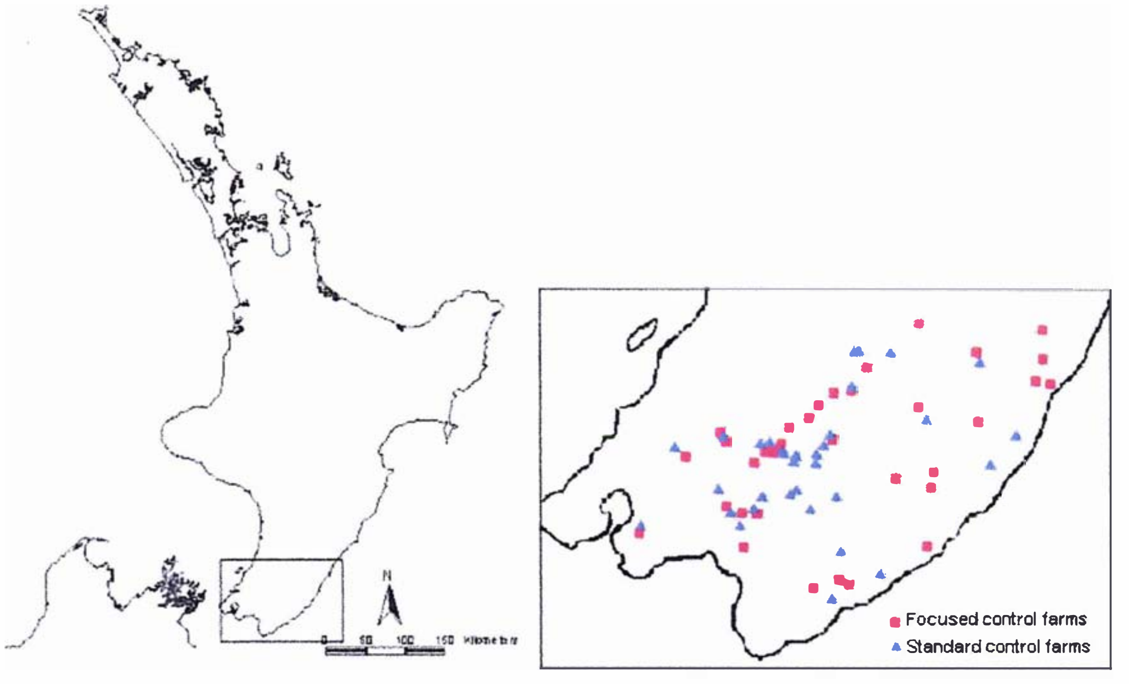


**Figure 4. Location of study farms in the Wairarapa in the North Island of New Zealand.**

## *Possum control efforts by the Regional Council*

Large scale possum control operations were conducted in Eastern and Southern Wairarapa between 1976 and 1980 (Anon, 1998). The TB incidence in cattle decreased by 80% within two years of the initial control operation. Follow-up control work was not conducted, unless the initial operation was found to be ineffective. The TB incidence in cattle started to increase and reached pre-control levels 8-10 years after the initial control operation. During the 1980s only small scale possum control operations were conducted, and TB increased. From 1989 onwards more possum control operations were put in place, increasing the area under control from 5-7,000 hectares to 265,000 hectares in 1997/98 (Anon, 1998). These on-going control efforts resulted in a steady decrease in TB incidence in cattle and deer (Livingstone, 1997).

Farms involved in this study (both focused control, and standard control farms) that were located within a vector control area received control as usually conducted by the Regional Council. Initial vector control programmes by the RC are termed 'Initial operation', any follow-up operations conducted annually or biennially are termed 'maintenance operations'.

### *Farm selection process*

To select the 35 focused control and 35 standard control farms it was necessary to follow several steps. In June 1996 there were 2,702 cattle herds and 167 deer herds in the Wairarapa, of which 9.5% and 11.3%, respectively, were on MC for TB (Anon, 1998). Farms for this project were selected with the help of AgriQuality staff in Masterton between March and June 1996. In a first step all cattle farms on Movement Control were identified. Deer farms were excluded in order to have a more homogeneous group of farms. The second step involved selection of all dairy ('DH') farms and all beef finishing ('beef dry stock', 'BD') farms amongst the farms identified in the first step. Of the beef breeding ('BB') farms only a selection that was judged by AgriQuality veterinarians as being representative of the Wairarapa, was taken into consideration. In the third step, all farms that had only recently come on to MC, small farms, and farms where the veterinarians in AgriQuality felt TB was introduced solely by bought-in animals, were excluded. Additionally, all farms in the Northwest of the Wairarapa were excluded as this area was managed by a different Regional Council. Parts of the area under consideration were subject to Regional Council possum control programmes with various commencement dates, while other parts were not subject to such programmes at the time the study commenced.

This selection process left 170 farms available for the project. A letter asking farmers if they were prepared to participate in the study was mailed at the end of May 1996 with a follow-up letter four weeks later to 40 non-responding farmers. 127 farmers were prepared to participate in the study, 11 farmers stated reasons why they considered their farms as 'unsuitable' for the study and 32 did not reply.

Of the 127 farms whose owners/managers were prepared to participate, 22 came off Movement Control between the first approach (May 1996) and June 1996. The remaining 105 farms consisted of 54 BB farms, 22 BD, 26 DH and 3 Mixed dry stock herds. Of these 105 farms, seventy were randomly selected for consideration as either focused control or standard control farms, using the random number function in MS Excel. Initially a distribution of 30 BB, 20 BD, and 20 DH, in equal numbers within and outside the Regional Council (RC) control area, was desired. However, only 30 farms (14 BB, 8 BD, and 8 DH) outside the RC control area were available. These were randomly assigned to the focused control and standard control groups, keeping numbers per group balanced. Then 40 farms (16 BB, 12 BD and 12 DH) were randomly selected from those within RC control area, and randomly assigned in equal numbers to the focused and standard control groups.

The 35 farmers selected for the focused control group were contacted by phone and the nature of their expected commitment explained. One farmer indicated that he planned to cease farming cattle, one farmer was not prepared to co-operate, and six farmers considered their farm less suited for the project, as they believed they either had bought in their tuberculous animals (rather than being infected from possums) in the past (n=2), or only had a small number of animals on their property (n=1), or had changed their off-farm grazing arrangements as a result of TB infection on previously used land (n=3). For each of these farms a replacement farm was selected randomly from the remaining farms of this herd type and control area, if available. As there were no replacement farms available in non-vector-control areas, a farm assigned as standard control farm for this combination of herd type and control area, was also removed from the list, in order to keep the distribution between focused control and standard control farms equal. As more BD farms had to be removed and no other farms of this herd type were available, more beef breeding farms were selected to keep the total number at 70.

During the programme one focused control farm (BB in non-control area) proved too difficult to work on (location, farm management, farmer co-operation) and was dropped from the study. Two beef finishing farms in the standard control group were dropped out of the study due to following reasons: One farm (BD in non-vector control area) ceased farming cattle between the time of first approach and the start of the programme and a second farm (BD in control area) was on Movement Control at the time of selection, but its herd history was inconsistent and mainly based on 'veterinary directions' rather than evidence of TB. No other beef finishing farms were available for replacement. Therefore it was not possible to balance numbers of farms in each category (herd type and control area). The final distribution of farms available in December 1996 is shown in Table 2. Information on farm characteristics, such as farm size, stock numbers etc. are presented in Chapter 5. No significant differences were found in these variables between focused and standard control farms.

**Table 2. Distribution of focused and standard control farms by herd type and Regional Council vector control area (December 1996).**

| | Focused control farms | Standard control farms |
|---|---|---|
| Beef breeding in vector control area | 10 | 10 |
| Beef breeding in non-vector control area | 6 | 7 |
| Beef finishing in vector control area | 5 | 4 |
| Beef finishing in non-vector control area | 3 | 2 |
| Dairy herd in vector control area | 8 | 7 |
| Dairy herd in non-vector control area | 2 | 3 |
| Total | 34 | 33 |

### *Cattle TB data*

Six BB farms (three focused control, three standard control) and one standard control BD also had deer on their properties. However, these herds had a clear TB status when the farms were selected, and they were not subject to any interventions. Therefore no deer TB testing data was collected.

Cattle TB testing data was obtained from the National Livestock Database (NLDB), which is held by AgriQuality New Zealand (the equivalent of a state field veterinary service) (Ryan, 1997). All records relating to TB testing on farms is recorded and managed in this database on a herd basis. Since 1996, the NLDB has also been linked to Agribase, a national geographically referenced farm database. This allows the linkage between herds and farms to be established by a unique farm identification number. In the Wairarapa, TB testing data held in NLDB dated back to 1979 for most farms.

For each farm the NLDB also records the year in which the Regional Council conducted a possum control operation on this farm. Most operations are conducted between October in that year and June of the calendar year following the recorded date in the database (1st September). It is assumed that these possum control operations only start to have an effect on the TB incidence in livestock herds in the year following the operation.

### *Confirmation of TB status*

All cattle in the Wairarapa are subject to annual TB testing, using the caudal fold skin tuberculin test, which is conducted by livestock officers employed by AgriQuality (Animal Health Board, 1998b). Any cattle that reacted positively to this test was considered TB positive (Animal Health Board, 1998b) unless the animal was serial tested negative thereafter with an ancillary test. If the animal did not get tested with an ancillary test, but went to slaughter, it was considered TB positive, irrespectively of whether visible lesions at slaughter were found or not. The TB status of cull animals, that went to slaughter without being tested first and in which lesions, indicative of TB, were found at slaughter, was determined according to the results of the histological examination. Any positive animal was termed 'TB animal'.

A cattle herd was considered TB positive as long as it was under MC restrictions. Only if the whole herd had obtained two clear TB tests with a minimum of six months in between, the MC restrictions were revoked and the herd considered TB clear. The TB status of one beef dry stock standard control herd was being determined through 'Works monitored', an option where no cattle have to be tested on the farm, provided over 90% of the cattle go to slaughter each year (Animal Health Board, 1998b). Herds that take up this option cannot achieve a Clear TB status, but keep their Works Monitored status, unless infection is found in an animal, thus leading to an Infected status.

In possums, any gross lesions suspect of tuberculosis found at post mortem examination were collected and cultured. If *Mycobacterium bovis* was cultured, the animal was considered tuberculous.

### Farm Visits

The research team consisted of two persons, the author/epidemiologist and one field worker. The author provided the background and technical knowledge to the farmer, which was incorporated through the activities of the field worker into practical, individual farm control measures. There was a close working relationship between the two team members which ensured that uniform information was given by both members to farmers.

The interventions were designed to run for three years. It was intended that the possum control be conducted by the research team during the first two years, whilst the farmers would take responsibility for control in the third study year. In the first year TB hot-spot areas were identified on many farms, using vegetation and slope data (McKenzie, 1999), wildlife surveys and grazing records if available. Once these hot-spots were identified, possum control was specifically targeted towards these areas using trapping and poisoning, supplemented by occasional shooting. As only one staff member was available for possum control, not all farms could be controlled at the same time so possum control was not only conducted in spring and autumn. In the third year of the project, the research team ceased their control effort and encouraged farmers to keep bait stations running and to continue with other measures.

To identify hot-spot areas, grazing records and cattle TB testing results were analysed, in conjunction with analysis of farm-specific vegetation and slope data. Results from TB hot-spot studies indicated that habitat influences the risk of a tuberculous possum being present in particular locations on farms. These locations can be predicted with acceptable sensitivity and specificity using satellite vegetation mapping and analysis of slope data (Hickling and Efford, 1996; McKenzie, 1999). This procedure was used on most participating farms. In many cases the TB reactors occurred in one specific age group or grazing group, therefore indicating that this group was exposed to one or more tuberculous possums in paddocks grazed since shortly before the last TB test. The paddocks used six weeks prior to the previous TB test were also taken into account, in order to allow for animals that became infected prior to the previous test but did not react then. Any suspicions which farmers put forward of likely TB hot-spot areas were also taken into consideration. Traps and bait stations were then set in these likely or suspected hot-spot areas.

In addition to these trapping visits, regular visits on the focused control farms were made by the author, to conduct interviews and review the TB situation. During the first visit to the farm in July/August 1996 the project and planned interventions were explained and information regarding basic farm characteristics, TB situation and high TB risk areas collected. At the second visit the planned interventions were modified and adapted to each individual farm with the help of the farmers and/or manager. During the third and fourth visit the questionnaire (Chapter 5) was conducted with the farmer/manager. The subsequent visits focused mainly on the review and the achievement of the imposed control measures. If unexpected TB related issues occurred, farm visits were performed outside the regular schedule to discuss and review the situation and the possible control methods. The first four visits were made within a period of 15 to 18 months. If herds came off MC early on in the project, only two visits were made within the first 18 months, whereby farmers were interviewed during the second visit. In the second year no specific time table was set up for farm visits, they mostly arose out of TB testing sequences and their results on the farms. Phone calls were scheduled in between the farm visits in order to maintain information flow between research team and farmer. Their frequency varied considerably between farms, some farms only receiving less than five, others more than ten.

During the whole duration of the project, farmers were actively encouraged by the epidemiologist and the field worker to use grazing management to keep cattle out of TB hot-spots during winter and summer months.

In May 1997 a group meeting was arranged, where all farmers were invited to discuss the project up to that point and to visit the study site of the longitudinal study at Castlepoint (Pfeiffer and Morris, 1991; Pfeiffer, 1994) and hear about vaccination trials being conducted concurrently by other researchers.

## *TB control measures employed in this study*

### Basis of the hypothesis

Previous research showed that tuberculous possums are not evenly distributed on a farm, but clustered in hot-spots (McKenzie, 1999). The results of an interview analysis regarding farm management (see Chapter 2) indicated that farms with recognised TB hot-spots within paddocks had a higher incidence of TB in cattle grazing these areas than farms that specifically grazed their cattle away from TB hot-spots or did not have any TB hot-spots on their property. Additionally, behavioural studies with possums/ferrets and cattle/deer strongly indicated that TB is transmitted from wildlife species directly to cattle and deer grazing close by, e.g. sniffing and licking terminally ill tuberculous possums (Sauter and Morris, 1995). It was also found that a single intensive possum control operation in an area is not sufficient to eradicate TB permanently from livestock in that area (Coleman and Livingstone, 2000). Even after conducting vector control for several years, infection in the possum population can persist. The persistence of infection within TB hot-spot areas, reinforced by the immigration of infected possums, is considered to be the source of the continuing infection (Caley *et al.*, 1999).

Since 1989 data on TB in possums had been collected in a longitudinal study on the epidemiology of TB in possums conducted on a 23 ha study site in Castlepoint (Pfeiffer and Morris, 1991; Pfeiffer, 1994). Data from these studies has been extracted to produce graphs of the average monthly point prevalence (Figure 5) and the time when tuberculous possums died (Figure 6), which forms the basis for the seasonal targeted control measures.

For calculating the average monthly point prevalence of tuberculous possums in Figure 5, all possums with clinically detectable tuberculous lesions were taken into account. Palpation of superficial lymph nodes is the only practical way in which TB can be detected in live possums (Pfeiffer and Morris, 1991; Jackson, 1995), and suspect lesions detected in this way were confirmed by culture of lymph node aspirate. From this graph it can be seen that the highest prevalence of tuberculous possums occurs during the Southern Hemisphere summer, with a slight peak in winter.

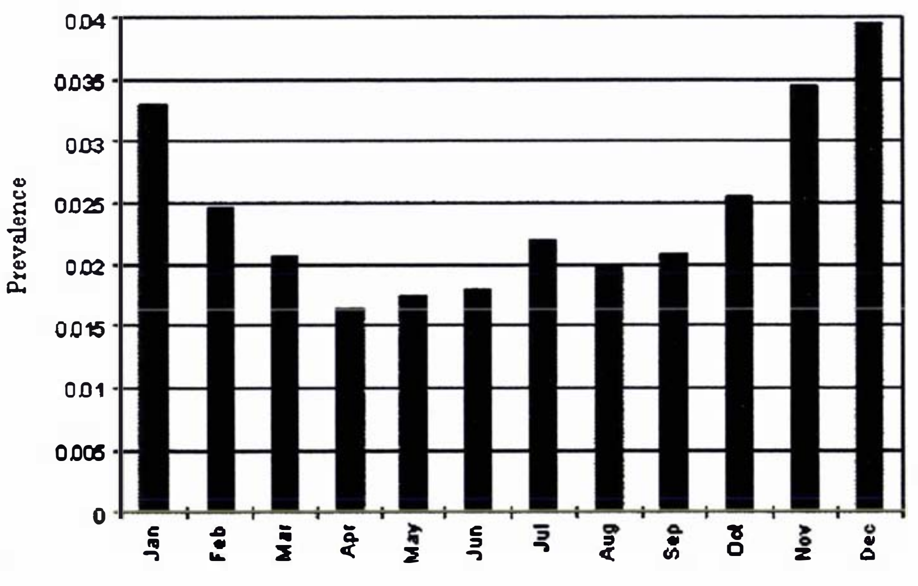


**Figure 5. Average monthly point prevalence of TB in possums (data obtained from the longitudinal study in Castlepoint).**

In Figure 6 the seasonality of tuberculous possums' deaths is shown, calculated by the number of TB-possums found dead per month, divided by the Jolly-Seber estimate (Ibrahim and Trpis, 1986) of number of possums living on the study site. There is a much stronger winter peak than summer peak. As tuberculous possums show abnormal behaviour mostly only in the late stages of the disease, these dying possums are the critical factor in the transmission of TB to cattle. Normally nocturnal possums can be seen out in daylight, attracting the attention and investigation of cattle and deer and thus providing opportunities for close contact between the species (Sauter and Morris, 1995).

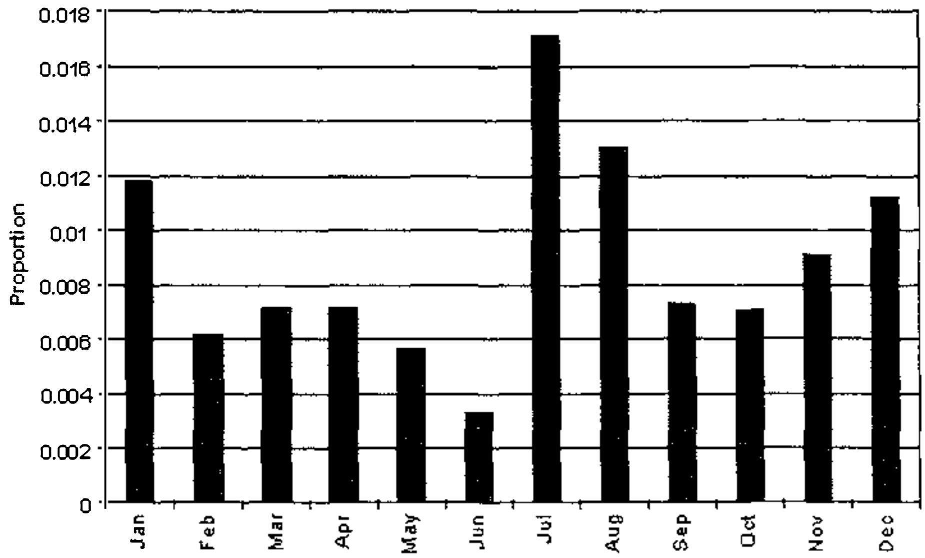


**Figure 6. Proportion of possums dying from tuberculosis per month of population at risk.**

These findings led to the hypothesis that if the direct contact between terminally ill tuberculous possums and livestock can be prevented or reduced, then the TB incidence in cattle or deer herds should also be reduced.

Two main methods were investigated for their effectiveness: targeted localised possum control, and grazing management of cattle in hot-spot areas. In the following the combination of these two methods is called 'on-farm control measures'.

## Targeted localised possum control

The targeted approach of possum control is a novel method evaluated in this study. The official vector control conducted by RC was a 'blanket' approach, covering the whole area of a farm and usually an entire locality, typically 20,000 to 50,000 ha. A targeted approach is more likely to be more cost-effective, particularly for farms with persistent TB problems. Therefore it was important to identify TB hot-spots on the individual farms.

Localised possum control in TB hot-spot areas was intended to reduce the number of tuberculous possums in these areas. As the monthly prevalence of tuberculous possums showed a strong summer and a lesser winter peak (Figure 6), possum control was targeted to occur in spring and autumn, to reduce both the number of infectious TB possums over summer, and the successful establishment of young immigrant possums on farms in autumn, and on a smaller scale in spring. These young possums, some of which are infected with TB during rearing by an infected mother, disperse from their natal area into new areas principally in autumn, smaller numbers disperse in spring. These juveniles are very important in spreading infection, but are particularly susceptible to control when they are establishing in a new location. Possum control during this time will therefore reduce the establishment of juvenile possums, but also the number of possums in the area and with it the number of possible contacts between the possums, which subsequently should result in a lower number of tuberculous possums. It was intended to conduct localised possum control on all of the farms twice every year, however, due to time constraints this was only possible on four of the farms. The other farms were only controlled once a year.

During the first two years of the project, all carcasses of possums were recovered and submitted to a post mortem examination (Jackson *et al.*, 1995a). Therefore localised possum control was done by using leg-hold traps (Victor No. 1½ Soft Catch (Montague and Warburton, 2000)) or by bait stations, using a cyanide poison (Feratox®), which acted instantly (Eason *et al.*, 2000).

Up to 80 traps and 20 bait stations were used at any one time on a farm. These were shifted around the farm, covering likely and possible hot-spot areas. Traps were set along locations that showed evidence of territorial marking, feeding activities or signs of possum movement ('runs'). Traps were set every night and checked the next morning. Traps were lured with apples coated in flour and cinnamon, while bait stations were filled with special feed pellets, in which encapsulated cyanide pellets were mixed at a rate of approximately eight poison pellets to one bait station.

Trapping and poisoning usually continued for 10 to 14 days, farms with large farm sizes and many or large suspect hot-spot areas were trapped for up to four weeks. Thereafter the traps and bait stations were moved to the next farm. Especially in the dairy farms, which only had small areas to be covered by possum control, it was possible to conduct possum control on two farms at the same time. On two focused control farms, where RC control involved trapping of possums, instead of poisoning, the RC staff members collected the carcasses and submitted them to the research team for post mortem examination.

Possums, hedgehogs and ferrets caught in leg-hold traps were humanely killed (using a sharp blow to the head or by lethal injection of 20% barbiturate). All animals caught were identified with the trap number they were caught in and transported to a central place for detailed post mortem examination. Any gross lesions suspect of TB were collected and cultured.

In the third year of the project, five to 15 bait stations, depending on number and size of hot-spot areas were set up permanently in likely or identified hot-spot areas and filled with a slow acting brodifacoum poison (Talon®) (Eason *et al.*, 2000). Additional poison was left with the farmer, who was expected to check the bait stations and if necessary to refill them.

### Livestock grazing management practices

Livestock grazing management practices were intended to keep cattle/deer out of TB hot-spot areas, mainly during summer and winter, when the proportion of dying tuberculous possums was greatest (November to January and July and August, see Figure 6). The aim was to prevent the direct contact between sick tuberculous possums and livestock during these critical times.

Farmers were advised to change their grazing routine in such a way, that during these critical months, cattle did not graze in any paddocks with suspected or known hot-spots. If paddocks themselves did not have such hot-spots, but were within 30 to 50 metres of one, the advice was not to graze cattle in these paddocks either, or if grazing is necessary in this paddock to put up a temporary fence that would keep cattle outside this distance of the hot-spot. On beef breeding farms it was recommended to put sheep in these paddocks during these times, as they were less likely to interact with possums (Sauter and Morris, 1995).

However, the final decision regarding grazing management lay with the farmers and they had to judge if it was possible or not. If it was impossible to exclude high risk paddocks from grazing it was suggested that farmers continue possum control during the time of grazing, either by trapping or by shooting.

Farmers were also encouraged to keep grazing records in order to facilitate the later identification of hot-spots if TB positive animals were found. Biannual TB testing was also strongly recommended, firstly to help identify hot-spots, and secondly to eliminate any tuberculous cattle as soon as possible from the herd.

## ***Analysis of data***

The frequency and time of vector control operations conducted by the Regional Council on focused and standard control farms was analysed in order to establish any differences between the two farm groups, that could have influenced the outcome of the present study.

It was not possible to determine exactly how many farmers complied with the management advice given to them, the research team had to rely on the information given by farmers. In addition, when targeted possum control and grazing management was employed, it was not feasible to distinguish between the individual effects. However, as the possum control had been done in the first two years of the project by the research team, all farms within the focused control farm group were regarded as having received TB control measures, independent of whether management advice was followed or not.

TB testing data was analysed for the time on MC, the herd TB status of farms and thus the number of farms on MC at the end of the study, the number of TB animals on the farm irrespective of the herd size, the two-year cumulative TB incidence and its reduction versus the pre-project levels of 1995/96. Differences between focused and standard control farms were tested for significance using the Mann-Whitney U test for categorical data and Chi-squared tests for continuous data (Bortz, 1993).

The database management software Microsoft Access 97 (Microsoft Corporation, Redmond, WA) and spreadsheet software Microsoft Excel 97 (Microsoft Corporation, Redmond, WA) were used to store and manipulate the data. Statistical analyses were conducted using NCSS 2000 (Number Cruncher Statistical Systems, Kaysville, Utah, U.S.A.), and SPSS for Windows version 9.0.1 (SPSS Inc. Headquarters, Chicago, Illinois, U.S.A.). The power analysis was done in Power and Precision, release 1.20 (Borenstein, Rothstein, Cohen, U.S.A.).

## Results

### *Power analysis*

Retrospective power analysis was used to provide insight into the scale of study which would have been required to achieve significance for each of the variables evaluated.

In order to establish the statistical power to detect any difference between focused and standard control farms, a power analysis was conducted, using data gathered in this study to provide accurate estimates of variance. Figure 7 shows the relationship between sample size and power to detect differences in the proportion of farms remaining on Movement Control. With 30% of standard control farms remaining on Movement Control and a sample size of 35 farms in each group, the desired power of 80% would have been obtained, if only 5% (i.e. two instead of the seven observed) of the focused control farms had remained on Movement Control. If 20% of the focused control farms and 30% of the standard control farms remained on Movement Control then a sample size of 294 farms per group would have been required in order to obtain a power of 80%. With the current sample size a power of 16% was achieved.

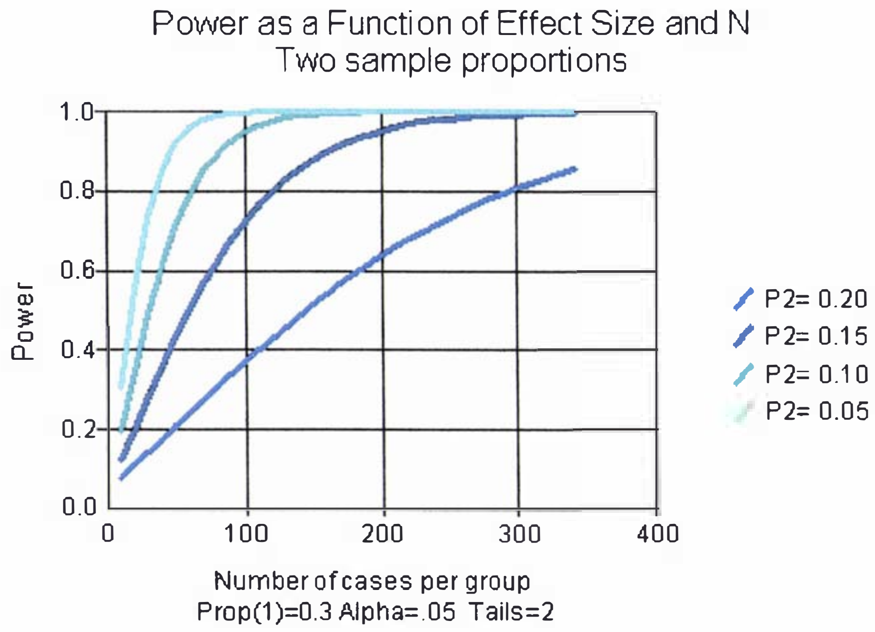


**Figure 7. Relationship between power and sample size at four different proportions of focused control farms and 30% of standard control farms remaining on Movement Control.**

To detect a difference in the two-year cumulative incidence of TB using 35 focused control and 35 standard control farms and a difference of 0.013 in cumulative incidence, this study had a power of 22%, using a common standard deviation of 0.045. With this sample size a difference in cumulative incidence of 0.031 would have been necessary to obtain a power of 80%. To detect, with 80% power, the difference of 0.013 observed in this study, a sample size of 190 farms in each group would have been necessary. Figure 8 shows the relationship between sample size and power to detect a difference in cumulative incidence between the two groups of magnitude 0.01 and 0.02.

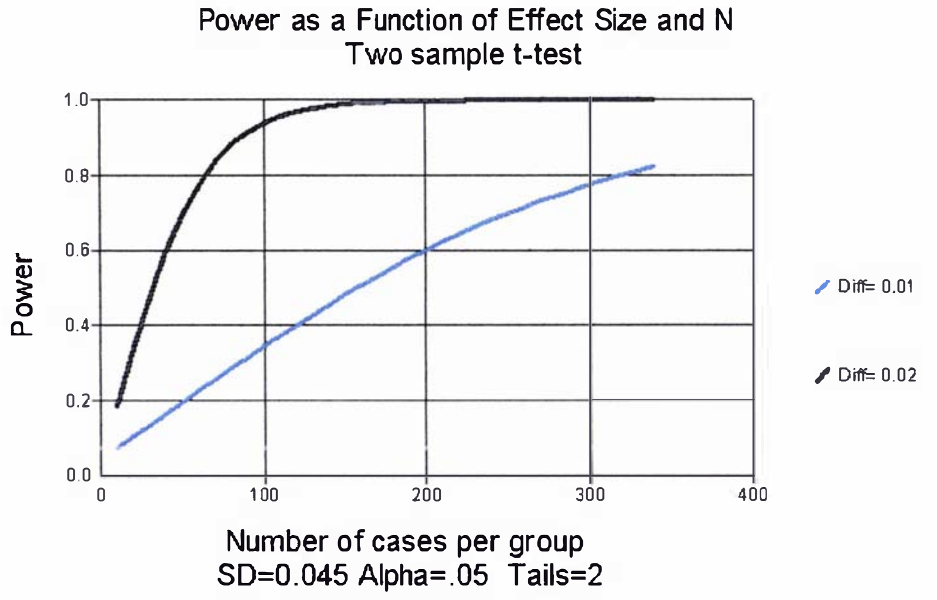


**Figure 8. Relationship between sample size and power to detect a difference in cumulative incidence of TB of 0.01 and 0.02 between focused and standard control farms with a common standard deviation of 0.045.**

### *Vector control conducted on focused control farms by the research team*

Due to time constraints by the research team and factors relating to the individual TB situation, not all the farms were visited an equal number of times, and control was not conducted on all farms at the same time due to time constraints. However, all the farms went through the sequence identifying hot-spots – possum control/grazing control – maintaining bait stations/conducting own control.

In total 28 of the 34 focused control farms underwent possum control by the research team. Of the other six farms, one (BB, ID10) did no possum control, but implemented only grazing control by keeping cattle out of the suspected TB hot-spot area. It subsequently achieved and maintained Clear TB status. Another relatively small 30 ha farm (BD, ID6) conducted its own possum control with shooting and bait stations. The farm came off Movement Control in the second year of the project, but because of drought conditions the farmer grazed the cattle on a different farm, where one of his animals became infected, thus causing the herd to revert to Infected status. The other four farms not receiving intensive possum control by the research team (2 BD, 1DH, 1 BB) had received intensive possum control by the Regional Council in the past and had no suspected high-risk areas for TB on their farms. Three of these four farms came off Movement Control during the first year and the fourth farm (BD) came off during the last year of the project. Approximately half the farmers in any one year incorporated the recommended grazing management, depending on management constraints and other considerations in management decisions.

In the third year of the project, 33 farms remained in the study. One farm had ceased farming cattle. On 25 of these farms bait stations using Talon®, a dicoumarin-poison, were set up. The remaining nine farms either had their own possum programme in place (denoted with 'Farmer control' in Table 3), were at that time involved in an intensive RC vector control programme (denoted with 'RC' in Table 3), or had a TB Clear status and no suspect high-risk TB areas (denoted with 'None' in Table 3). The number of bait stations set up depended on the size of the farm, the number and size of suspect/known hot-spot areas and the willingness of the farmer to keep them going. Relatively more bait stations were set up on farms where the farmer had shown active control and interest during the previous two years. Due to the action mechanism of the poison in the bait stations, no possum carcasses could be recovered. These control efforts are therefore not included in Table 3.

On nine of the focused control farms, tuberculous feral animals were found during project activities. Because tuberculous possums were not found on the other farms, this did not mean, that they did not have any TB hot-spots on the farm. Therefore any suspect areas continued to be controlled. On seven of the farms where tuberculous animals were found, one or more tuberculous possums were found, on one farm tuberculous ferrets and on one farm a tuberculous possum, ferret and hedgehog were found within the same hot spot area. On average 89 possums were trapped on each of the farms (range from 3 to 405). On beef breeding farms, on average 144 (range 4 – 405) possums were caught, on beef finishing farms on average 11 (range 3 – 21) and on dairy farms on average 30 (range 3 – 71) possums were caught.

Table 3 gives the details of possum control by the research team per farm. The cyanide-bait stations used had eight poison pellets in the station, therefore these stations had the potential of killing eight possums. For the calculation of trap nights on each farm, the bait stations were arbitrarily judged the equivalent of five traps, as it was difficult to assess how many poison pellets were left amongst the feed pellets. Farms that came off MC early in the project (denoted by [b] in Table 3) generally received less control in the second year of the study.

**Table 3. Details of possum trapping and poisoning on the focused control farms, together with their effective farmed area.**

| Farm ID | Total effective farm size (ha) | Total number of trap and poison nights (during 1st and 2nd yr) | Total number of possums caught (during 1st and 2nd yr) | Tuberculous feral animals (found during 1st and 2nd yr) | Number of bait stations set up in third year[a] |
|---|---|---|---|---|---|
| **Beef breeding farms** | | | | | |
| 2 | 1600 | 1282 | 405 | | 12 |
| 3 | 1880 | 249 | 114 | | 10 |
| 4 | 800 | 400 | 43 | | 8 |
| 5 | 729 | 205 | 126 | | 16 |
| 8[b] | 122 | 342 | 53 | | 5 |
| 10 | 1200 | Only grazing control | | | Grazing control |
| 13[b] | 1270 | 207 | 7 | | 5 |
| 17 | 56 | 200 | 28 | | 4 |
| 23 | 2900 | 703 | 132 | 1 possum | 20 by RC |
| 25 | 1215 | 382 | 43 | | 8 |
| 26[b] | 1500 | Possum control by RC only | | | None |
| 27 | 1075 | 732 | 114 | 1 possum<br>1 ferret<br>1 hedgehog | 5 |
| 28 | 4500 | 413 plus 1600 by farmer control | 360 | 2 possums<br>4 ferrets | RC |
| 31 | 1145 | 385 | 67 | | 6 |
| 32 | 1185 | 590 | 267 | 1 possum | 10 |
| 34 | 800 | 513 | 252 | 1 possum<br>1 ferret | 18 |
| **Beef dry stock farms** | | | | | |
| 1 | 323 | 361 | 9 | | 10 |
| 6 | 30 | Possum control by farmer only | | 2 possums | Farmer control |
| 7[b] | 300 | 96 | 21 | | 7 |
| 12[b] | 110 | Possum control by RC only | | | None |
| 15[b] | 18 | 57 | 10 | | 4 |
| 24 | 133 | Possum control by farmer and RC only | | | None |
| 29[b] | 590 | 168 | 3 | | 5 |
| 33 | 36 | Possum control by farmer in first year | | 1 possum | No cattle |
| **Dairy farms** | | | | | |
| 9 | 1045 | 596 | 21 | | None |
| 11[b] | 153 | 45 | 18 | | 3 |
| 14[b] | 60 | 157 | 21 | | 5 |
| 16[b] | 76 | 68 | 6 | | 4 |
| 18 | 154 | 283 | 3 | | 6 |
| 19 | 195 | 1885 | 34 | 1 possum | 10 |
| 20 | 221 | 285 | 55 | | 5 |
| 21 | 200 | 450 | 32 | 8 ferrets | 6 |
| 22[b] | 110 | 294 | 71 | | 5 |
| 30[b] | 104 | Possum control by RC only | | | None |

[a] 'Farmer control' if farmers conducted their own vector control already and were not in need of bait stations; 'No cattle' this farmed ceased farming cattle in the third year; 'None' if the farm had a TB clear status and no suspect/known hot-spots.
[b] Farm came off MC before 12/1997

### *Vector control by Regional Councils*

In total the focused control farms had 42 and the standard control farms 40 'initial' vector control operations by RC, as recorded in the NLDB. The percentage of focused and standard control farms being under RC vector control programmes from 1988 to 1999 is shown in Figure 9. Eight focused control farms and eight standard control farms had received a second round of vector control operations, several years after the conclusion of the first one. For the analysis only the date of the first initial vector operation was used. There was no significant difference in the dates of initial vector control operations between focused and standard control farms (Mann-Whitney U test, Z=-0.935, p=0.350).

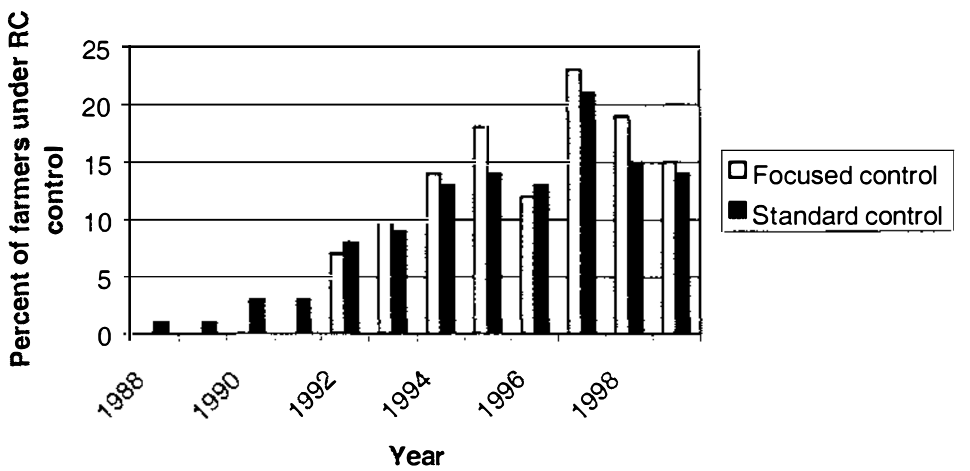


**Figure 9. Percentage of farms under RC vector control, assuming that a control operation lasts for four years.**

Three standard control farms received initial vector control prior to 1992, the first year six of the focused control farms had received vector control. Vector control was equally irregular for both farm groups.

Setting the duration of any control operation to a maximum of 4 years, then the focused control farms had on average 2.55 years of control prior to July 1996, the commencement of the project, whereas the standard control farms had 2.92 years control (Mann-Whitney U test, Z=1.22, p=0.222).

## *Analysis of tuberculosis testing records*

### Time spent on Movement Control and Herd TB status at the end of the project

All 67 focused and standard control farms were on Movement Control (MC) at the beginning of the project in July 1996. Seven of the focused control farms and eight of the standard control farms had one clear test just prior to the commencement of the project.

The median time spent on MC within the pre-project period (1994 until 1996) was 28.5 months for the focused control farms (n=34), and 29 months for the standard control farms (n=33). For the study period (1997 until 1999) the median time on MC was 15 months for the focused control farms (n=33, and 11 for the standard control farms (n=28).

During the three years of the project 30 (90.9 %) of the 33 remaining focused control farms came off MC, whereas 22 (78.6 %) of the remaining 28 standard control farms came off MC (Fisher's exact test p=0.28). Five of the focused control farms and three of the standard control farms subsequently became infected again and were put back on MC restrictions. On average these five focused control farms had 8.8 TB-free months in between the MC periods; the three standard control farms had on average 7.7 months in between. Three (9.1 %) of the 33 focused control farms and six (21.4 %) of the 28 standard control farms did not come off MC at all during the time of the project (Fisher exact test, p=0.279).

One of the five focused control farms that came off MC and subsequently became re-infected, was conducting its own intensive possum control on the study property. However, due to drought the farmer had to graze his cattle n a neighbouring property that was known to be infected with TB. The cattle were all tested clear before they left the home farm. When they returned after five months, they were tested again, and one animal reacted to the skin-test, and subsequently was found at slaughter to contain lesions. All remaining animals grazed thereafter on the home property and subsequently tested clear. As the main purpose of the study was to evaluate the effectiveness of on-farm control measures, this farm was therefore classified as 'Off MC' in the analysis. The farmers of the nine standard control farms that were under MC at the end of 1999, all stated that they suspected their home-farm, but not run-offs or other grazing options, as being the source for the TB infection in their cattle.

Table 4 gives the TB status at the end of the project in December 1999 for both groups of farms.

**Table 4. Number of focused and standard control farms by TB status at the end of the intervention programme (December 1999).**

| TB status | Focused control farms | | | Standard control farms | | | p-value |
|---|---|---|---|---|---|---|---|
| | n | % of remaining herds | % of total herds | n | % of remaining herds | % of total herds | (Chi-squared test) |
| Clear Status (Off MC) | 26 | 78.8 | 76.5 | 19 | 67.9 | 57.6 | 0.33 (remaining herds)<br>0.10 (all herds) |
| Infected Status with reactors in last test | 6 | 18.2 | 17.6 | 6 | 21.4 | 18.2 | |
| Infected Status with one clear whole herd test | 1 | 3.0 | 2.9 | 3 | 10.7 | 9.1 | |
| Ceased farming cattle[a] | 1 | | 2.9 | 5 | | 15.2 | 0.11 |
| Total | 34 | | | 33 | | | |

[a]during the project period 1996-1999

Table 4 shows that 15% of the standard control farms and 3% of the focused control farms ceased farming cattle during the study period (Fisher exact test p=0.105). The reasons given by the six farmers for ceasing to farm cattle were a mix of personal and enterprise business reasons. Two farmers retired, one concentrated more on off-farm employment and the other three farmers stated reduced profitability of cattle as a result of general economics and TB in their herd. Table 4 shows also that of the farms still farming cattle, 79% of the focused control farms and 68% (Clear status plus Works monitored) of the standard control farms were off MC at the end of the project.

Comparing herd TB status within each of the herd types (DH, BB, BD), the project achieved a higher differential impact relative to standard control farms in the beef breeding farms than in the other two herd types, which were cleared of infection in most cases in both groups (Table 5). All focused control dairy and focused control beef dry stock farms came off MC during the time of the project. However, subsequently one dairy farm was re-infected. In the beef breeding farm group 81% of focused control BB farms and 57% of standard control BB farms came off MC during the time of the project (Fisher's exact test p=0.236). However, three beef breeding farms in the focused control and three in the standard control farm group subsequently became re-infected, leaving 63% of focused control and 36% of standard control beef breeding farms off MC at the end of the project in December 1999 ($\chi^2$ = 2.14, p=0.143), considering only beef breeding farms which were still in cattle production at the end of the project.

**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).**

| Farm Group | Herd type | I -> C | I -> C -> I | I -> I | I -> D | I ->C ->D | Total |
|---|---|---|---|---|---|---|---|
| Focused control | All farms | 26 | 4 | 3 | | 1 | 34 |
| | BB | 10 | 3 | 3 | | | 16 |
| | BD | 7 | | | | 1 | 8 |
| | DH | 9 | 1 | | | | 10 |
| Standard control | All farms | 19 | 3 | 6 | 3 | 2 | 33 |
| | BB | 5 | 3 | 6 | 1 | 2 | 17 |
| | BD | 4 | | | 2 | | 6 |
| | DH | 10 | | | | | 10 |

## Number of TB cattle

As the annual pattern of TB cattle numbers is variable and dependent on test dates, any small changes can result in misleading patterns. Thus the present analysis used two-year blocks, representing the periods prior to the study, initial study period and late study period. Figure 10 and Table 6 show the percentage of focused and standard control farms that had at least one, two or three reactors in any one of the pairs of 1995/96; 1997/98 and 1998/99. Although by the final year (1999) proportionately fewer focused control farms still had reactors, when two-year blocks were considered the difference in this particular indicator was not yet apparent for the 98/99 block. Of the 33 focused control farms, 13 had reactors in 1998 and/or in 1999, while 11 of 28 standard control farms had reactors in 1998 and/or 1999. However, in the last two years of the project a lower percentage of focused control farms than standard control farms had two or more reactors (Figure 10). The chi-squared test result for the difference between the focused control and the standard control farms for having two or more reactors was $\chi^2$=3.45 (p=0.063). The difference for having three or more reactors was $\chi^2$=5.09 (p=0.024), indicating that the control measures achieved a significant lower likelihood of having three or more reactors in any one year.

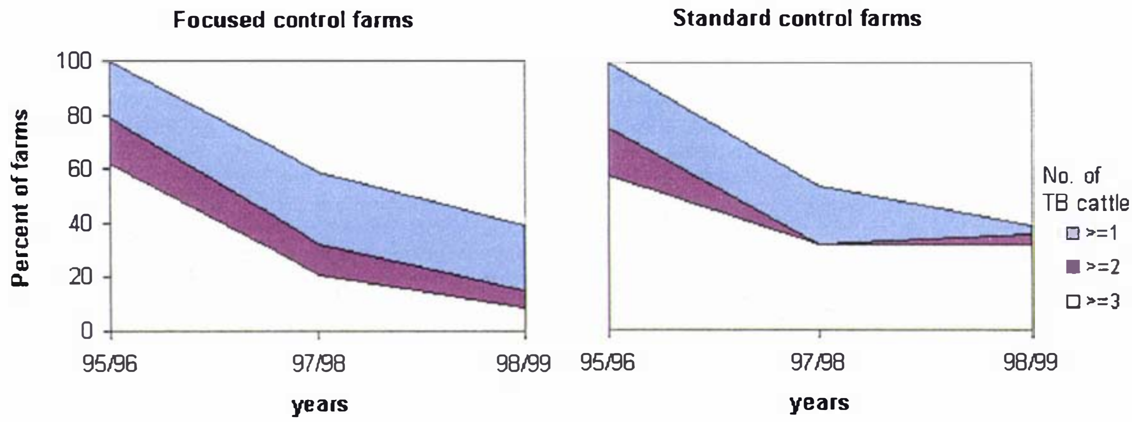


**Figure 10. Percent of focused and standard control farms that had equal or more than one, two, or three reactors in any one of the two years.**

**Table 6. Number of focused and standard control farms with one, two or more reactors in any one of the two years.**

| | Focused control farms | | | | Standard control farms | | | |
|---|---|---|---|---|---|---|---|---|
| Years | ≥ 1 TB animal | ≥ 2 TB animals | ≥ 3 TB animals | n farm cattle | ≥ 1 TB animal | ≥ 2 TB animals | ≥ 3 TB animals | n farm cattle |
| 95/96 | 34 | 27 | 21 | 34 | 33 | 25 | 19 | 33 |
| 97/98 | 20 | 11 | 7 | 34 | 15 | 9 | 9 | 28 |
| 98/99 | 13 | 5 | 3 | 33 | 11 | 10 | 9 | 28 |

## Cumulative incidence and its reduction over three years

For focused and standard control farms the two-year cumulative incidence at the end of the project was compared with the one of the two years prior to the project (Table 7).

**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.**

| Group | Cum inc. 1995/96 | Cum inc. 1997/98 | Reduction vs. 95/96 | Cum inc. 1998/99 | Reduction vs. 95/96 |
|---|---|---|---|---|---|
| All farms included in the study | | | | | |
| Focused control farms | 0.0629 | 0.0138 | 78.1 % | 0.0034 | 94.6 % |
| Standard control farms | 0.0354 | 0.0165 | 53.4 % | 0.0161 | 54.5 % |
| Only farms included that existed at the end of the project: | | | | | |
| Focused control farms | 0.0486 | 0.0090 | 81.5 % | 0.0034 | 93.0 % |
| Standard control farms | 0.0350 | 0.0165 | 52.9 % | 0.0161 | 54.0 % |

The Mann-Whitney U-test for detecting a difference in the cumulative incidence yielded a z-value of 0.0125 (p=0.990) for the 1995/96 period, z=0.4056 (p=0.685) for 1997/98, and z=0.1553 (p=0.877) for the 1998/99 period.

Figure 11 and Figure 12 present frequency histograms of the two-year cumulative incidence for focused and standard control farms for the period prior to commencement of the study (Figure 11) and for the last two years of the project (Figure 12).

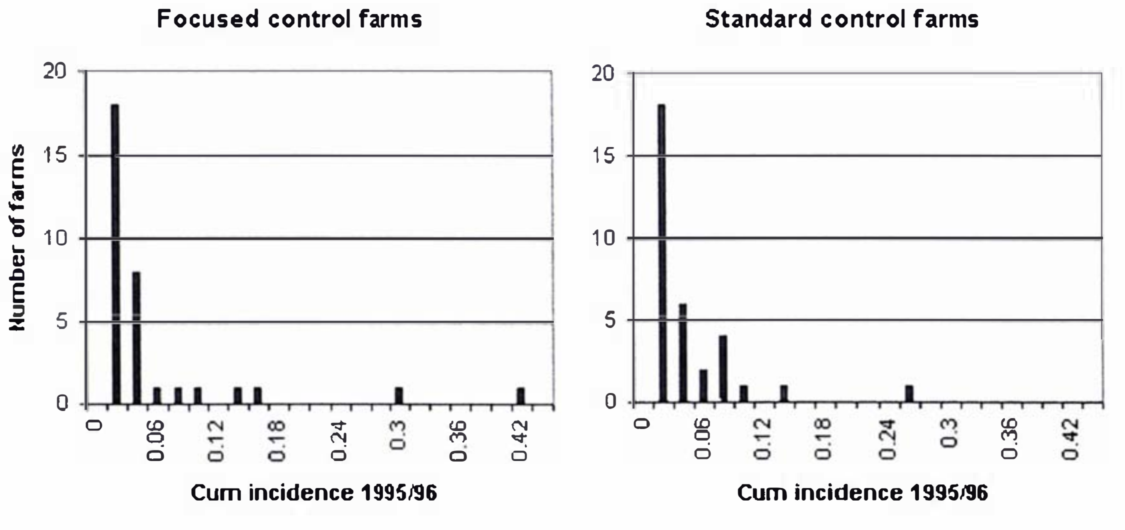


**Figure 11. Frequency histogram of pre-study cumulative incidence of TB animals in 1995/96 for focused and standard control farms.**

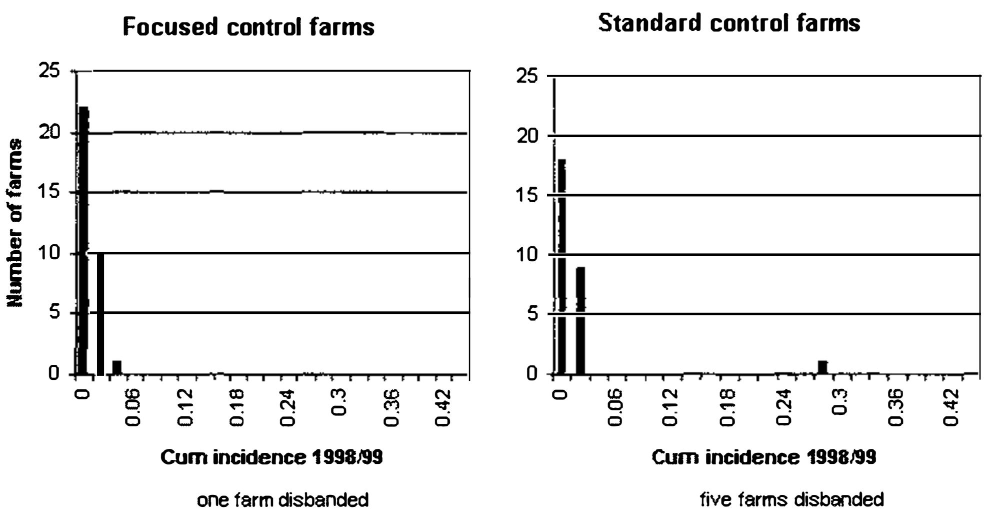


**Figure 12. Frequency histogram of cumulative incidence of TB animals 1998/99 for focused and standard control farms.**

Table 8, Figure 13 and Figure 14 present the two-year cumulative incidences of TB animals (pre-project and end of project), stratified by herd enterprise type and farm group. In Table 8 the reduction in cumulative incidence achieved over the three years is also given.

**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.)**

| Group | Herd type | Cum Inc. 1995/96 | Cum Inc 1998/99 | Reduction |
|---|---|---|---|---|
| Focused control farms | BB | 0.0321 (n=16) | 0.0043 (n=16) | 86.6 % |
| | BD | 0.1714 (n=8) | 0.0030 (n=7) | 98.2 % |
| | DH | 0.0254 (n=10) | 0.0024 (n=10) | 90.6 % |
| Standard control farms | BB | 0.0497 (n=17) | 0.0308 (n=14) | 38.0 % |
| | BD | 0.0254 (n=6) | 0.0000 (n=4) | 100 % |
| | DH | 0.0169 (n=10) | 0.0019 (n=10) | 88.8% |

Dairy and beef finishing farms in both groups had a similar reduction in cumulative incidence (Table 8). However, the beef breeding farms in the focused control farm group achieved a higher reduction than the ones in the standard control farm group.

The Mann-Whitney U-test for detecting a difference in the cumulative incidence between focused and standard control farms yielded a z-value of 1.1026 (p=0.270) for the beef breeding farms, z=0.8956 (p=0.370) for the beef finishing farms, and z=0.4323 (p=0.665) for the dairy herds.

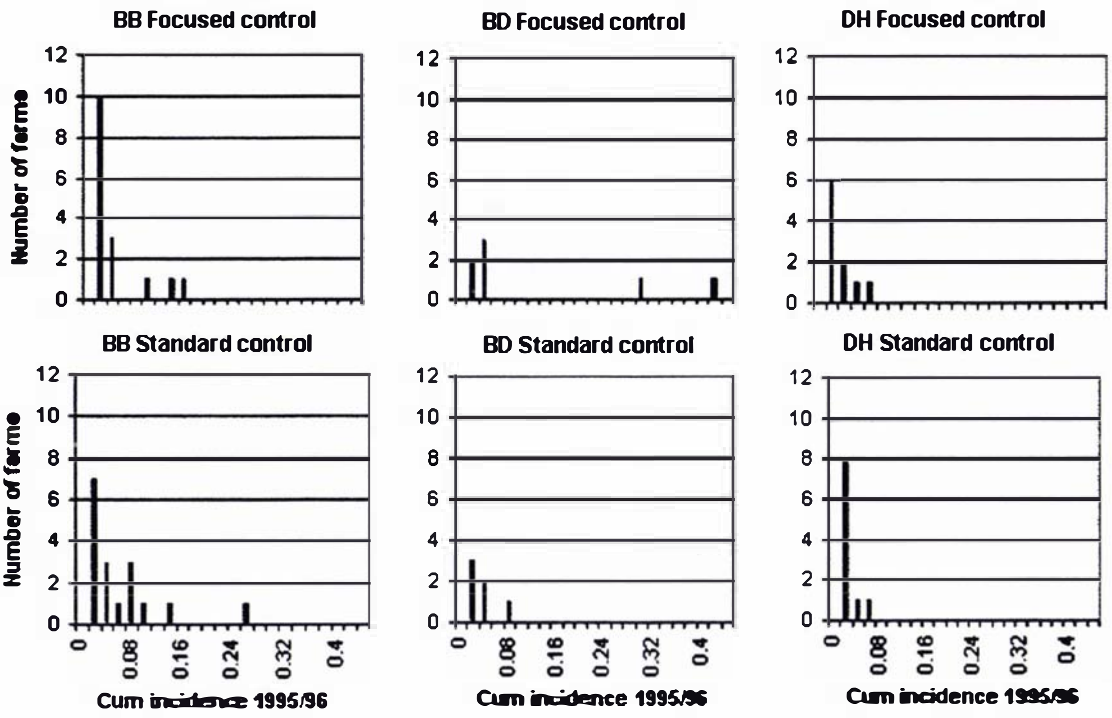


**Figure 13. Distribution of 2yr cumulative incidence (skin test reactors plus lesioned culls) for 1995/96, stratified by farm group and herd type.**

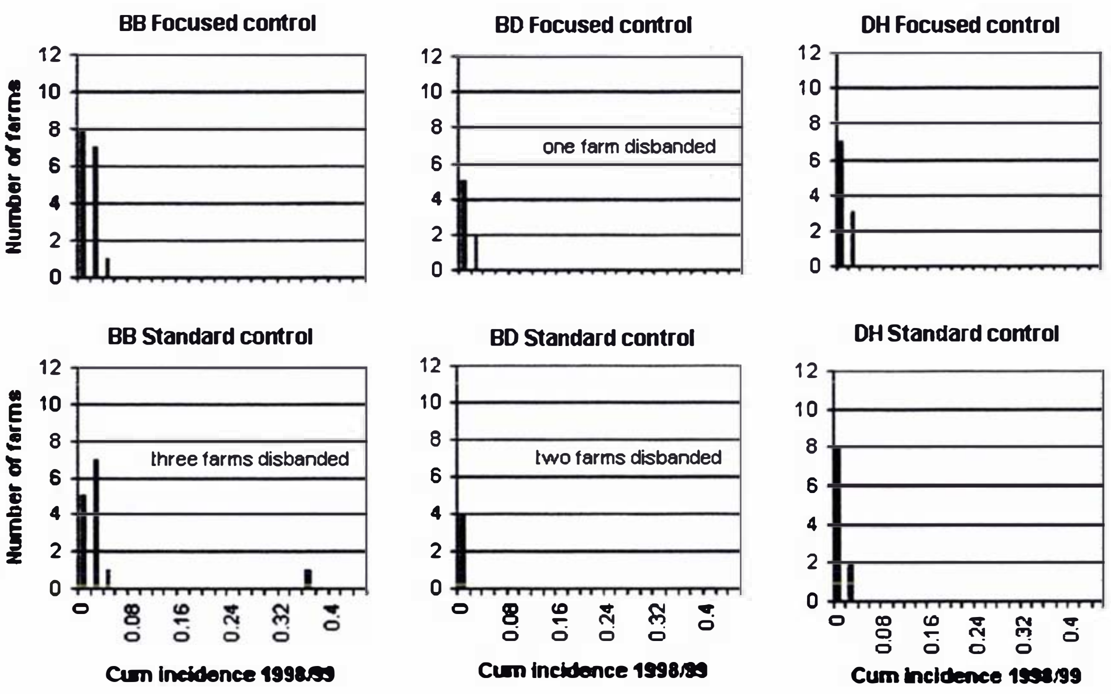


**Figure 14. Distribution of 2yr cumulative incidence (skin test reactors plus lesioned culls) for 1998/99, stratified by farm group and herd type.**

The control measures employed in this study achieved a higher reduction in two-year cumulative incidence in non-RC control areas than in control areas (Table 9).

**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.**

| Group | RC Control | Cum inc. 1995/96 | Cum inc. 1998/99 | Reduction |
|---|---|---|---|---|
| Focused control farms | Yes | 0.0166 (n=18) | 0.0034 (n=18) | 79.5 % |
| | No | 0.0719 (n=16) | 0.0054 (n=15) | 92.5 % |
| Standard control farms | Yes | 0.0179 (n=17) | 0.0004 (n=15) | 97.8 % |
| | No | 0.0346 (n=16) | 0.0231 (n=13) | 33.2 % |

## Discussion

This study was the first intensive intervention programme that has evaluated the effect of specific targeted control methods on TB outcomes in livestock. These control methods consisted of targeted hot-spot possum control in autumn and spring, and grazing management during winter and summer. While the differences found between the focused and standard control farms were mostly not statistically significant because of the limited number of herds which could be included, the study nevertheless provides valuable information on trends of such low-cost, practical on-farm control measures, consisting of targeted possum control and grazing management.

The number of farms in the study, 35 focused control and 35 standard control farms, was set by capacity for conducting the field work and the number of farmers available, not to meet statistical power requirements. A sample size of 200 to 300 farms per group would have been needed to obtain statistical significance with the results obtained in this study. It was recognised that an intensive study of this nature involving 35 focused control farms would be unlikely to achieve statistical significance in most variables and the primary aim was to evaluate the technology and determine whether evidence of a pattern of response could be detected. Consistency of data with that of other studies (Chapter 4) would provide strength to the interpretation of data even if the results are not statistically significant. While most of the differences found in this study were not significant by conventional standards it is proposed that the overall pattern of differences, though individually not significant, when combined provide valuable evidence for the effectiveness of the control measures.

Focused control farms were significantly less likely to have multiple TB animals in the last two years of the project than the standard control farms. Other differences, which did not reach significance at p=0.05, were: A higher proportion of focused control than standard control farms came off MC during the three years of the project, a higher proportion of focused control than standard control farms were off MC at the end of the project, a lower proportion of focused control farms than standard control farms remained continuously infected, and focused control farms achieved a higher reduction in cumulative TB incidence. All these results point in the same direction – that focused control farms achieved more effective TB control than standard control farms. These results therefore support the effectiveness of the implemented control measures. The only outcome that differed from this direction was the median time spent under movement control by focused and standard control farms, which might be attributable to the higher pre-study cumulative TB incidence on focused control farms.

Although the difference was not significant, the focused control farms had a higher pre-study cumulative incidence than the standard control farms. Thus it might be argued that it was easier for them to reduce the cumulative incidence, as it might be easier to reduce the reactor numbers from five to two, than from one to zero. However, the result that more focused control than standard control farms came off MC during the study period cannot be explained by the higher initial incidence. Therefore, a more realistic interpretation is that the focused control farms were if anything the more difficult farms of the total group, even though allocation was randomly.

It was expected that a number of standard control and focused control farms would come off MC, even without any additional targeted control implemented, and the percentage of standard control farms which achieved this is similar to the percentage of all farms over the Wairarapa/Wellington region (63.5%) coming off MC between 1995 and 1999 (Animal Health Board, 1999).

There were no differences in the achievements of dairy and beef dry stock farms between the focused control and the standard control farm group. Between 90% and 100% of both groups achieved a Clear TB status by the end of the project and a similar reduction in two-year cumulative TB incidence. In contrast, a higher proportion of beef breeding farms in the focused control group than in the standard control group obtained Clear TB status (63% versus 36%). Also the focused control beef breeding farms achieved on average a higher reduction in cumulative incidence than the standard control beef breeding farms (85% versus 38%) and in the standard control beef breeding group one farm had a high TB cumulative incidence in 1998/99, whereas there were no longer any high-incidence focused control farms. Although these differences were not significant at the alpha level of 0.5, the number of farms in this enterprise category only comprised 30 farms in total. It is likely that the differences in success between the herd types are due to farm characteristics. Dairy and beef dry stock farms are generally on more productive land with less potential possum habitat, thus less likelihood of having persistent TB hot-spots on farm. Targeted vector control cannot offer any additional benefits on these farms over standard RC vector control, since standard control was able to virtually eliminate TB from these farms without the need for extra effort. In contrast, the beef breeding farms have generally larger farm sizes and more possum habitat, therefore a higher likelihood of more hot-spots and of greater contact between livestock and diseased possums. Standard control did not seem to be able to reliably reduce the likelihood of these contacts to a low level, thus additional targeted control was beneficial. The differences found in the study between the herd types might therefore suggest that the implication of the suggested control measures is especially effective on the beef breeding farms or possibly on farms with these habitat characteristics. It is therefore proposed that a similar study is conducted using only beef breeding farms. If a group of 35 beef breeding farms had achieved the same proportional changes against 35 standard control farms as in the present study, this would not only support the present study, but the results would also be significant at the conventional statistical level of p=0.05.

The differences found in this study cannot be attributed to the official vector control provided by the RC, as focused and standard control farms received a similar amount of official control by this organisation. On farms that did not receive RC control effort prior to the study period, the TB incidence was reduced much more on focused control farms than on standard control farms (92% versus 33%), whereas the standard control farms achieved a marginally higher reduction on farms that had previously received RC control (98% versus 80%). This would suggest that the employment of targeted on-farm control measures can be effective, and may match the results of the much more expensive blanket control undertaken by RCs. Often farmers believe that they cannot have any worthwhile effect on TB control at farm level, and that they need regional possum control to make progress; the results in this study show that this might not be correct. Further studies should address this in more detail.

When evaluating this study, one has to take two additional factors into account: the study was evaluated after only three years, and it was done under realistic conditions of commercial farming. It was recognised that the control measures would take some time to have an effect on the TB outcomes measured, mainly as the animals are mostly tested only annually or biannually and therefore there is a considerable lag before improvements in TB control show up in TB testing results. Due to the sensitivity of the caudal fold skin tuberculin test, about 20% of infected cattle may be incorrectly classified as 'negative' (Ryan *et al.*, 1991). Because of these factors, it was expected that reactor rates would decline gradually. The one significant result was the lower number of focused control farms having multiple reactors in any one year. It is therefore likely that if a fourth year had been included in the study, the difference in the number of farms coming off

MC may have been greater, as it is more likely that farms with only one reactor come off MC within one year than farms with more than two reactors.

Within this context also the likelihood of cattle-to-cattle transmission has to be considered. In the present study there were no means to differentiate between vector-to-cattle and cattle-to-cattle transmission. It is known that cattle-to-cattle transmission can occur in the absence of wildlife infection (Menzies and Neill, 2000), but also in New Zealand with infected feral populations (Barlow *et al.*, 1997a; Barlow *et al.*, 1997b). The results of a simulation model using no within-herd transmission, consistently underestimated the observed number of reactors after control strategies (Barlow *et al.*, 1997a). In a model fitted to the Hohotaka area in NZ, it was deduced that cattle-to-cattle transmission contributed between 20% and 32% of the infections prior to the control of wildlife, which is below the threshold needed for maintaining the disease without input from infectious wildlife. It was concluded that the control of wildlife vectors was the most effective method of reducing cattle TB. The model suggested that the reduction in transmission of TB from wildlife will result in an equal proportional reduction in cattle reactor rates (Kean and Barlow, 1999). It cannot be excluded that cattle-to-cattle transmission occurred within some of the study herds, which might have influenced the rate of decline of reactor numbers on these farms.

The second point to consider in evaluating the present study, the fact that the study was done under realistic commercial farming conditions, means these conditions could not be perfectly controlled. We know of two farmers in the focused control group who have not followed-up the vector control work in the third year. Other farms followed the vector control recommendations, but were not able to implement the grazing recommendations. If it had been possible to implement all control measures on all farms the TB outcomes on focused control farms might have been more different from the outcomes in the standard control farms.

To illustrate the effectiveness of employing control measures in reducing TB on farms, two focused control beef breeding farms are discussed in more detail here: The first farm never received any externally provided possum control, such as by the RC. The farmer himself employed a possum trapper for several years. The trapper, who was skinning all possums for commercial purposes, suspected some possums were tuberculous on the basis of typical lesions. The farm had a continuous problem with TB and the farmer made the decision to graze only sheep in the areas where the trapper found the suspected tuberculous possums. By the time the project started, this farm had already used this practice for one year, without employing the trapper any more. The farm came off MC within another year and has stayed clear ever since. This farm shows that grazing management on its own may be highly effective in reducing the risk of spread of TB from vectors to cattle, if the population of tuberculous possums is small and localised. The influence of earlier on-farm control is difficult to assess in this case.

On the second focused control farm, a tuberculous possum was found during the wildlife survey. The farm had been infected for at least 13 years. By setting up grazing plans that avoided this high risk area and by conducting possum control in this area, the farm managed to come off MC for the first time. This farmer kept strictly to the recommendations given to him, he followed the grazing management over all three years and he was very dedicated to the possum control effort. At the end of 2000 (one year after the study concluded) he had another clear TB test and achieved the status of C3, something he had never believed to be possible. This outcome shows that by following the specific grazing and possum control recommendations, TB can be eliminated from cattle on farms with TB hot spots.

One crucial component of this study was the knowledge about TB hot-spots, which formed the basis for targeted possum control, rather than relying entirely on whole-farm approaches, as used in the standard control system. It would have been desirable to conduct a detailed wildlife survey on each of the farms to obtain more exact data on suspect TB hot-spot areas. However, the time and resources required were not available. On nine of the focused control farms tuberculous feral animals were found. This does not mean that on the other farms no tuberculous animals were present, since with low prevalence of TB in feral animals the sampling intensity was not sufficient to have high detection sensitivity. The aim was to reduce possum populations in all parts of the farm considered to be potential hot-spots, since the goal was to achieve TB freedom.

The second crucial components of this study was the close working relationship between the research team and farmers, which was partly achieved by using only two persons in the research team. One was a research veterinarian, and the other one a field worker, who had been managing a farm for many years. This combination proved to be highly effective, as various farmers could relate more to one than to the other. Often, farmers would tell one team member more than the other, or accept advice more readily from one person than from the other. The field worker was considered by many farmers as their equal, as one of their own. The close working relationship between the veterinarian and the field worker resulted in practical solutions, often a compromise between what would be desirable and what was possible. So the study could be argued to have achieved what Syme called for in intervention studies with humans relating to smoking and coronary diseases: "experts must learn to be creative and inventive enough to become experts in the role of not being an expert" in order to achieve familiarity with the real community (Syme, 1998). Often, farmers were more readily prepared to try out certain control methods once the field worker told them about his own experience on the farms, therefore the advice was seen less as theoretical science. By spending several days or even weeks on the farms, farmers could observe the work being put into vector control on their property and the autopsies of feral animals. Often, the enthusiasm of the research team was conveyed to the farmers. However, this enthusiasm and motivation required boosters from time to time, either by frequent phone calls or farm visits. Essentially the 'hands-on' practice of the research team empowered the farmers to assist TB control on their own farms. This empowerment was found to be a crucial part of smoking related intervention studies (Syme, 1998). Involving farmers in possum control and the decision process of setting up specific grazing routines, was a part of assisting farmers in their own learning process (Walker and Bell, 1994).

For the analysis of reactor numbers it was decided not merely to use the number of lesioned animals, the criterion AgriQuality is using to determine the TB status of the herd. If only animals with lesions typical of TB at slaughter were included in the analysis, animals with very small lesions would have been classified as negative although they were truly infected. For the analysis it was assumed that all skin test positive animals were true TB infected animals, unless they tested negative in an ancillary test. Using this criterion was judged to give results closest to the true status of the herd, than the less accurate system currently used by AgriQuality. In the Wairarapa generally no herds under MC are eligible for ancillary testing (Animal Health Board, 1998b).

Interestingly, a greater proportion of standard control than focused control farms ceased farming cattle during the three years (15% versus 3%). Although this difference was not statistically significant at the 0.05 level, it was marginally above 0.10. While TB was not the only reason to cease farming cattle on those farms, TB was always mentioned among other reasons. Financial margins in farming are very narrow – and having a herd infected with TB, these farmers felt, reduced these margins. As the farms were allocated randomly to focused control and standard control groups, but five standard control farms stopped farming cattle while only one focused control farm did so, it is possible that some focused control farms saw in the project new hope for controlling TB on their farms, and thus the hope of being able to sell their cattle without discount and therefore increasing the profit margins. If more TB infected herds than non-infected herds go out of farming cattle, this will lead to a reduction in the number of herds infected, without necessarily indicating that TB is becoming less prevalent in the Wairarapa. In contrast, the indicator for wildlife infection is removed and if no vector control is conducted any more on these farms, tuberculous possum populations might increase and dispersing juveniles might spread into neighbouring areas, therefore posing a higher risk to farms in the same area in a few years time.

The on-farm control measures tested in this study can be adapted to each individual farm, and can incorporate new control methods, such as vaccination of possums. Research into this field is making good progress (S.Norton, pers. comm., 2000) and it provides an effective measure which is complementary to poisoning possums. The devices for vaccination are intended to be less work-intensive than bait stations to operate, and by shifting the vaccination devices around the farm, the whole of the farmed area can be covered.

In order to achieve effective control and eradication of TB in livestock, it is necessary that national organisations and farmers work together on the control programme. Therefore a greater awareness for effective on-farm control methods has to be created. Farmers have to be convinced that it is possible for them to help in the control and to achieve control of TB on their farms. Using targeted vector control on farms as well as on the regional level could result in a cost-effective use of the available resources. With the availability of computer expert systems, such as EpiMAN(TB) (McKenzie, 1999) identification of TB hot-spots is made easier and provides the basis for targeted vector control, therefore facilitating the use of such on-farm control measures. According to Morris *et al.* (1995), farmers are more likely to adopt innovations or new ideas if they had been tested on other farms in the area. As the present intervention study was conducted not on research farms, but on commercial, randomly selected farms, the first step in disseminating the knowledge has been undertaken, and should be reinforced by follow-up extension programmes, such as discussion groups, media and for example using livestock officers who come regularly on to the farm to TB test cattle (for their importance see Chapter 2). However, the adoption of such on-farm control measures not only depends on their effectiveness, but also on the availability of resources and the prospect of production gains (Morris *et al.*, 1995) (see also Chapter 6).

### *Conclusions*

The study has provided evidence that specifically targeted possum control, combined with stock management practices that minimise or prevent contact with infected vectors are effective methods of reducing the herd incidence of TB and the rate at which herds are declared TB-free. These strategies are low cost, and are not technologically intensive or complex. They should be easily adopted and should contribute significantly to the AHB strategy to reduce the herd prevalence of TB.

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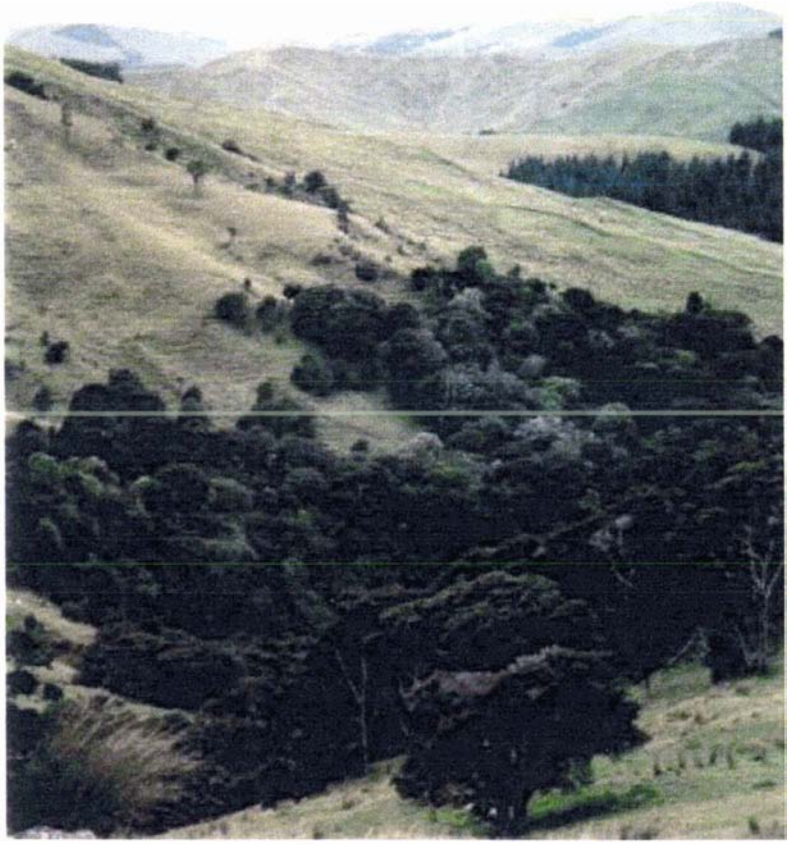
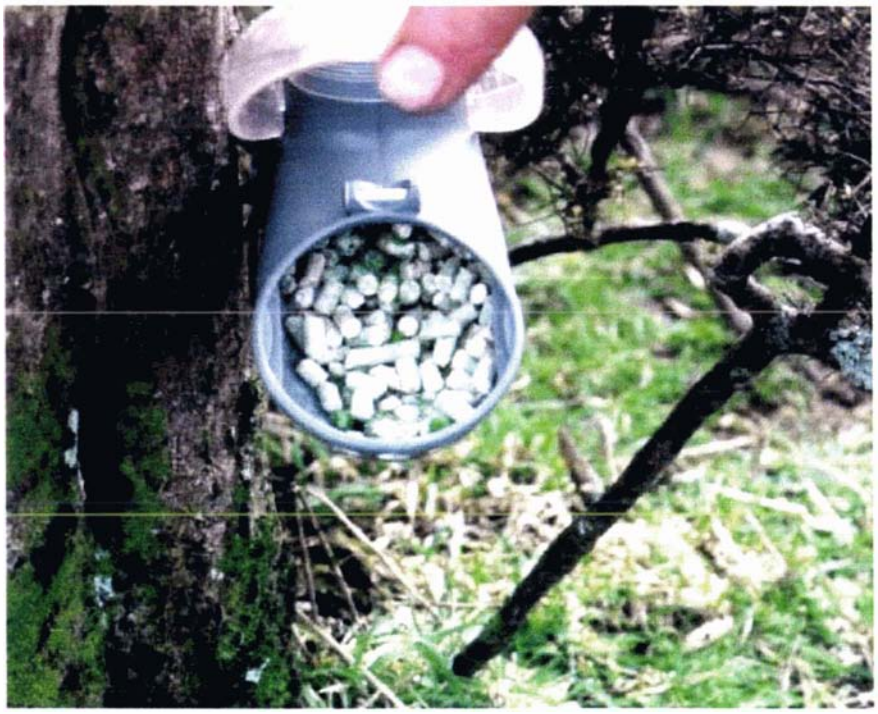


**Bush area on farm in Wairarapa**



**Cyanide pellets (in between feed pellets) used for localised possum control**

# Chapter 4

## Effectiveness of on-farm tuberculosis control programmes: Comparison of Wairarapa Study with a Contemporary National Study

## Abstract

In New Zealand bovine tuberculosis is transmitted from vector species to livestock, thus complicating the control and eradication of the disease. The main wildlife reservoir and vector is the Australian brushtail possum. Control of the disease involves livestock and vector species, resulting in expensive control programmes. Therefore other control programmes have to be investigated, including measures that can be applied at the farm level. Farmers are increasingly expected to take greater responsibility for the TB problem on their own properties.

In four areas with endemic wildlife infection, an intervention study was conducted by a national organisation. The study involved 35 focused control farms (receiving interventions) and 68 standard control farms (receiving no interventions). A multi-disciplinary team of researchers, pest control staff and veterinary staff, together with the farmer developed a customised, farm-specific plan for controlling and/or eradicating TB on each of the focused control farms. The team was active for two years, reviewing and adapting the plans frequently. Implementation of the control work was the sole responsibility of the farmers.

The evaluation of the effectiveness of the control measures indicated that focused control farms had an advantage over standard control farms. The two-year cumulative TB incidence was reduced more on focused control than standard control farms, especially on farms with persistent TB problems.

The effectiveness of this intervention study was also compared with that of the Wairarapa project (Chapter 3). In the Wairarapa project a higher proportion of focused control farms achieved clear TB herd status and the reduction in cumulative TB incidence was greater for the Wairarapa than the national project focused control farms. It was concluded that the hands-on operational approach taken in the Wairarapa project was more successful than the team advisory approach used in the national project.

## Introduction

In New Zealand the Australian brushtail possum (*Trichosurus vulpecula*) is a reservoir host for bovine tuberculosis and a vector of the disease to livestock (Morris *et al.*, 1994). In some areas of New Zealand also other feral animals, such as ferrets or stoats, are suspected of transmitting tuberculosis to livestock (Ragg *et al.*, 1995). The existence of feral reservoir species necessitates not only control of TB in cattle and deer, but also in feral animals. However, these feral control operations are very expensive (Animal Health Board, 1995). Therefore other control options have to be investigated that require the assistance of farmers, not only in a financial way, but also in a direct way of controlling his/her own property. In the national pest management strategy paper of the Animal Health Board (1995; 2000) one of the objectives was to 'encourage farmers to take greater responsibility for the Bovine TB problem on their individual farms and in their area and region'. Out of this objective the present study was developed as a pilot programme, in which farmers of herds infected with TB were advised with a customised plan for controlling and/or eradicating TB on their farm (Rhodes, 1997). As a result of previous submissions on the draft pest strategy the project adopted a team approach in providing advice and support for farmers.

The present chapter describes this national project, evaluates its effectiveness and compares it with the Wairarapa project (Chapter 3). Four main objectives of the national project were identified, as stated by the organisers who conducted this project (Rhodes, 1997):

- 'to assist in changing farmer attitude toward TB and self-motivated on-farm control'
- 'to reduce the length of time the herd remained on Movement Control'
- 'to reduce the within-herd TB prevalence' and
- 'to maintain a high health status for the herd over time'

It was considered important that farmers have ownership of an effective programme for the management of TB on their farm (Rhodes, 1997).

## Materials and Methods

### *Study areas*

The study was conducted in four areas of New Zealand: Taumarunui, Marlborough, West Coast and Otago. Figure 15 presents the location of focused control and standard control farms.

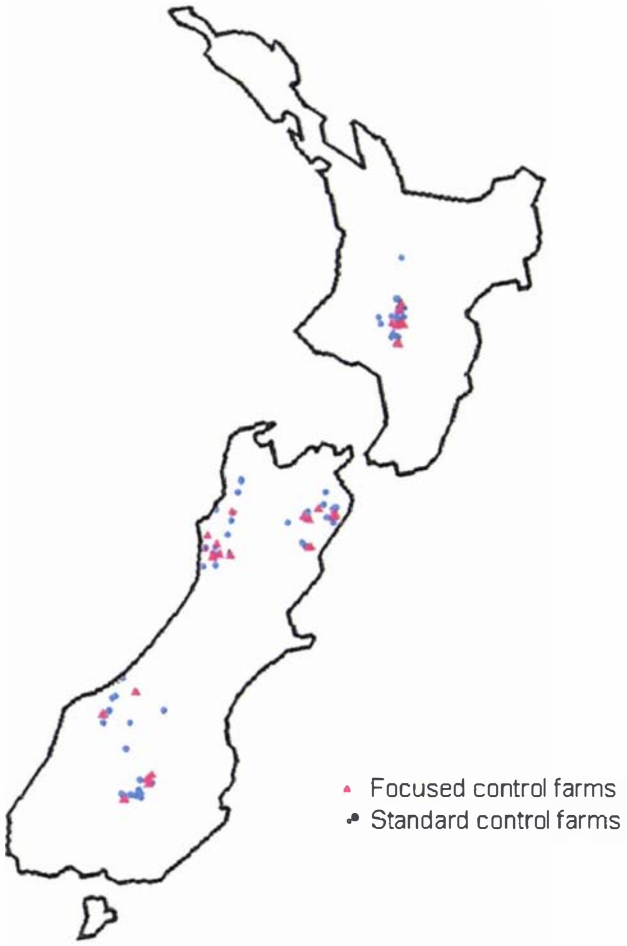



**Figure 15. Study farm locations within four areas of New Zealand**

## *Farm selection process*

The project was targeted towards cattle and deer herds which either had a high TB prevalence or a long history of persistent TB occurrence (Rhodes, 1997). Prospective participants were also selected for their willingness to take pro-active action. Farmers were screened for their positive outlook and their willingness to take control and accept responsibility.

The focused control farms were divided into two groups: 'high' and 'low' incidence, whereby herds with more than five TB animals in any infection period (which might have extended over several years) were classified as 'high' incidence herds.

Under the original project plan standard control farms were to be selected prospectively at the start of the project. However, this was not achieved. Therefore, the standard control farms were selected retrospectively at the end of the project, in early 2000. The criteria to match the farms were area, herd type and a similar herd history for the time period 1993 to 1996. These criteria were given to a

MAF officer, who had access to all national TB testing data. MAF then selected two farms for each of the focused control farms, achieving as good a match as possible. In a second step, the herd histories were checked to determine if they would fit in the respective categories 'high' and 'low'. Four farms were excluded for not having enough TB animals. In the third step the veterinary officers in the various study regions were approached with the list of farms to attain their opinion on the suitability of the farms. On this basis some farms were additionally excluded, as they were disbanded or had new owners or were otherwise not a good match to the focused control farm. In the fourth step the veterinary officers were asked to select replacement suitable farms for each excluded standard control farm originally selected. It was hoped that the veterinary officers could select one additional farm for each focused control farm, to allow for drop-outs. However, this was not possible as not enough TB farms were available in most regions. Therefore only 68 standard control farms could be found, instead of the desired 70.

After all standard control farms had been selected, contact was made with all the farmers, both focused control and standard control. By phone the nature of the study, the nature of the comparison between the two projects (national and Wairarapa) and the nature of the questionnaire was explained to the farmers. The questionnaire (see Appendix IV, p. 339) was developed in conjunction with the leaders of the national one-on-one project and also used with the farmers in the Wairarapa project. It was left to the farmers to decide if they wanted to answer the questions on the phone or by mail. In both cases the questionnaire was mailed out to the farmers. If no reply had been obtained within three weeks, another phone call was made as a reminder, often resulting in sending out the questionnaire a second time. Intensive phone follow-up was undertaken to achieve maximum compliance. Once the questionnaires were returned, the answers were entered into the database and if questions had been left unanswered, the farmer was phoned to clarify these.

### *Methods employed*

A multi-skilled team was chosen for each farm, including the farmer, a farmer mentor, the AgriQuality veterinarian, the private veterinarian servicing the farm, a pest control specialist and a farm management consultant (Rhodes, 1997). In total five farmer mentors were selected, one for each region, except Otago with two. These mentors were mainly facilitators between the representatives of the different organisations.

For each farm this team set up a management plan. The team planned to have an annual review of each property, plus additional three follow-up visits by the consultant to review the plan and progress in completing it (Rhodes, 1997). In the first management meeting the aims and goals of the farmer were elucidated and the possibility of TB management and control assessed. The meeting resulted in a detailed management plan, which the farmer tried to implement. The plan was reviewed within the group several times during the project, sometimes up to six times, in order to revise and adapt it to changed circumstances.

TB control involved pest management strategies, such as possum and ferret control using traps and bait stations and TB management strategies, such as frequent testing of livestock. On some farms feral animal surveys were conducted, on others the farmers were trained to recognise tuberculous lesions when conducting an autopsy of feral animals. In some areas, especially in the West Coast region, the Regional Council conducted major vector control.

### *Cattle and deer TB data and confirmation of TB status*

Cattle and deer TB testing data, dates on vector control and the confirmation of TB status in cattle and deer were as described in Chapter 3, for the Wairarapa project.

All cattle and deer are subject to annual TB testing. Any cattle/deer that reacted positive to this test was considered TB positive (Animal Health Board, 1998) unless the animal was serial tested negative thereafter with an ancillary test. If the animal did not get tested with an ancillary test, but went to slaughter, it was considered TB positive, irrespectively of whether visible lesions at slaughter were found or not. The TB status of cull animals, that went to slaughter without being tested first and in which lesions, indicative of TB, were found at slaughter, was determined according to the results of the histological examination. Any positive animal was termed 'TB animal'.

A cattle/deer herd was kept under Movement Control restrictions (Infected TB status), until it had two clear whole herd tests with a minimum of six months in between (when the herd achieved Clear TB status).

### *Analysis of data*

The project was actively conducted from mid 1995 to mid 1997 on the farms. For the analysis a full three-year period was required in order to compare the study with the contemporary Wairarapa study. Therefore tuberculosis data was used from 1993 until the end of 1998. The years 1993 and 1994 were used as a pre-project period and the years 1997 and 1998 as the final project period.

Information on cattle and deer TB herd testing data and dates for possum control operations conducted by the Regional Council were obtained from the National Livestock Database (NLDB), which is held by AgriQuality New Zealand (the state veterinary service) (Ryan, 1997).

The database management software Microsoft Access 97 (Microsoft Corporation, Redmond, WA) and spreadsheet software Microsoft Excel 97 (Microsoft Corporation, Redmond, WA) were used to store and manipulate the data. Statistical analyses were conducted using NCSS 2000 (Number Cruncher Statistical Systems, Kaysville, Utah, U.S.A.), and SPSS for Windows version 9.0.1 (SPSS Inc. Headquarters, Chicago, Illinois, U.S.A.).

## Results

### *Vector control conducted on the project farms by the Regional Council*

In total 38 initial vector control programmes were conducted on focused control farms and 76 on standard control farms. The percentage of focused and standard control farms being under RC vector control programmes from 1984 to 1998 is shown in Figure 16. The graph assumes that each control operation lasted four years.

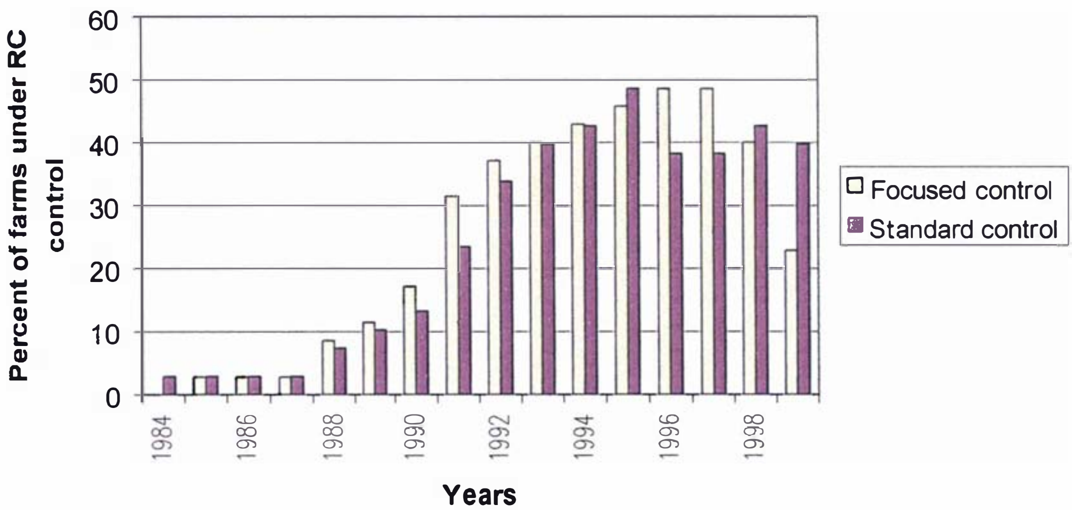



**Figure 16. Percent of farms under RC vector control, assuming that a control operation lasts for four years.**

Prior to the start of the project 30 initial vector control programmes were performed on focused control farms and 52 on standard control farms. From the beginning of the project to the end of 1998 seven focused control farms and 18 standard control farms received vector control by the Regional Councils. Overall the distribution of RC vector control operations was similar for focused and standard control farms.

### *Analysis of tuberculosis testing records*

For all available farms (35 focused control and 68 standard control farms) TB data was obtained.

### Time spent on Movement Control and herd TB status at the end of the project

All 35 focused control and 68 standard control farms were on Movement Control at the beginning of the project in mid 1995. For the three years project period (1996 to 1998) a focused control farm spent on average 22.44 months under Movement Control restrictions, while a standard control farm spent 20.66 months under Movement Control (median focused control farms 23.5 months, median standard control farms 21.0 months; Mann-Whitney U test Z=0.66, p=0.51). Figure 17 presents the frequency histogram for the time spent on MC for focused and standard control farms.

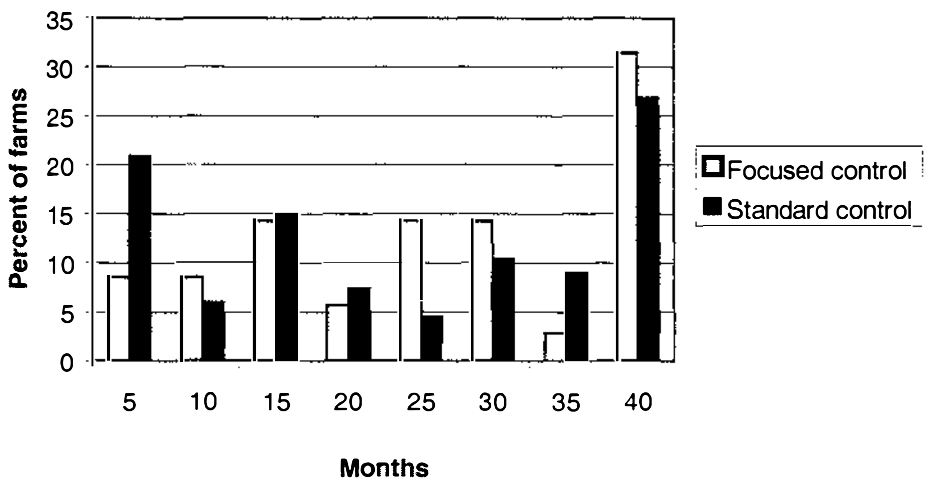



**Figure 17. Time (in months) spent on Movement control by focused and standard control farms between 1996 and 1998.**

By the end of the project, in December 1998, a higher percentage of focused than standard control farms had infected herds (Table 10), however this difference was not statistically significant ($\chi^2$=1.41, p=0.236).

**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**

| TB status | Focused control farms | Standard control farms |
|---|---|---|
| Clear Status (Off MC) | 15 (42.9 %) | 37 (54.4 %) |
| Infected Status | 20 (57.1 %) | 30 (44.1 %) |
| Ceased farming cattle | --- | 1 (1.5%) |
| Total | 35 | 68 |

From 1/1/1996 until the end of 1998 23 (65.7 %) focused control farms and 44 (64.7 %) standard control farms came off MC ($\chi^2$=0.01, p=0.919). Eight focused control farms and six standard control farms subsequently became infected again and were put back on MC restrictions. One of the standard control farms that came off MC ceased to farm cattle in the final year of the study.

Table 11 presents the number of farms on and off Movement Control at the end of 1998 for each herd type, comparing focused control versus standard control farms. For deer and beef finishing farms the focused control group achieved the same results as the standard control, whereas the results in the focused control beef breeding and dairy herd were less successful than in the standard control group. However, the number of farms in the beef finishing and the dairy group were smaller than for the other two herd types.

**Table 11. comparing TB status at end of 1998 within herd type, in brackets percentage of farms in that herd type group.**

| Herd type | Focused control farms | Standard control farms |
|---|---|---|
| Deer | 3 Clear (50 %) | 5 Clear (50 %) |
| | 3 infected (50 %) | 5 Infected (50 %) |
| BB | 11 Clear (45.8 %) | 29 Clear (59.2 %) |
| | 13 Infected (54.2 %) | 20 Infected (40.8 %) |
| BD | 1 Infected (100 %) | 1 Infected (100 %) |
| DH | 1 Clear (25 %) | 4 Clear (50 %) |
| | 3 Infected (75 %) | 4 Infected (50 %) |

## Number of TB animals

Due to the strong variation in the annual pattern of TB cattle and deer numbers, depending on animal numbers present on farm and on test dates, small changes in these factors can result in misleading patterns. Thus the present analysis used two-year blocks, representing the periods prior to the study, initial study period and late study period.

Figure 18 and Table 12 present the proportion of focused and standard control farms that had at least one, two and three or more TB animals in any one year of the pairs of 1993/94, 1996/97 and 1997/98. Although a similar percentage of farms still had TB animals in the final year (1998), the graphs show that the focused control farms had a more rapid decline in TB animal numbers than the standard control farms. There were no significant differences in the number of TB animals between focused and standard control farms (two or more TB animals: $\chi^2$=0.22, p=0.64; three or more TB animals: $\chi^2$=0.01, p=0.91).

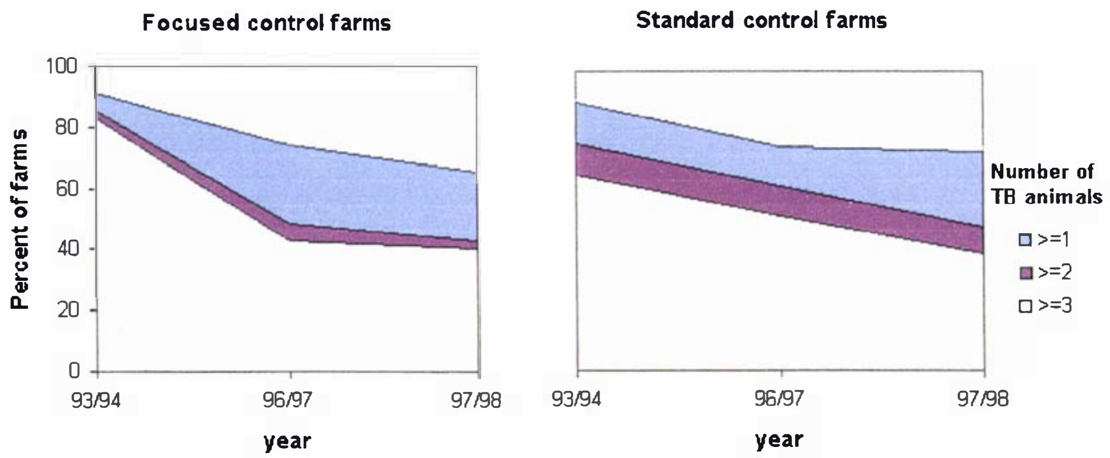



**Figure 18. Proportion of farms with one, two, three or more TB animals in the years 1993/94; 95/96 and 98/99 for focused control and standard control farms.**

**Table 12. Number of focused and standard control farms with one, two or more TB animals in any one of the two years.**

| | Focused control farms | | | | Standard control farms | | | |
|---|---|---|---|---|---|---|---|---|
| Years | ≥ 1 TB animal | ≥ 2 TB animals | ≥ 3 TB animals | n farm cattle | ≥ 1 TB animal | ≥ 2 TB animals | ≥ 3 TB animals | n farm cattle |
| 93/94 | 32 | 30 | 29 | 35 | 59 | 50 | 43 | 66 |
| 96/97 | 26 | 17 | 15 | 35 | 51 | 42 | 35 | 68 |
| 97/98 | 23 | 15 | 14 | 35 | 49 | 32 | 26 | 67 |

## Cumulative TB incidence and its reduction over three years

The cumulative incidence was calculated by dividing the total number of TB animals by the average number of animals tested in whole-herd tests during the interval. Table 13 shows that the average pre-project cumulative incidence was higher for the focused control than the standard control farms. This difference was significant at the 0.05 level (Mann-Whitney U test, Z=2.44, p=0.0146). The focused control farms achieved on average a reduction of 62% in the two-year cumulative TB incidence, whereas the standard control farms only achieved a reduction of 29%. A higher proportion of focused than standard control farms achieved 100% reduction in the two-year cumulative incidence (n=17, 49% of focused control farms; n=22, 33% of standard control farms, $\chi^2$=2.41, p=0.1205) (Figure 19). Overall the difference in the reduction between focused and standard control farms was not statistically significant (Mann-Whitney U test, Z=1.70, p=0.090).

**Table 13. Average two-year cumulative TB incidence (Cum inc.) for national focused and standard control farms**

| | Cum inc. 93/94 | Cum inc. 97/98 | Reduction |
|---|---|---|---|
| Focused control farms | 0.0457 | 0.0175 | 61.8 % |
| Standard control farms | 0.0318 | 0.0224 | 28.6 % |

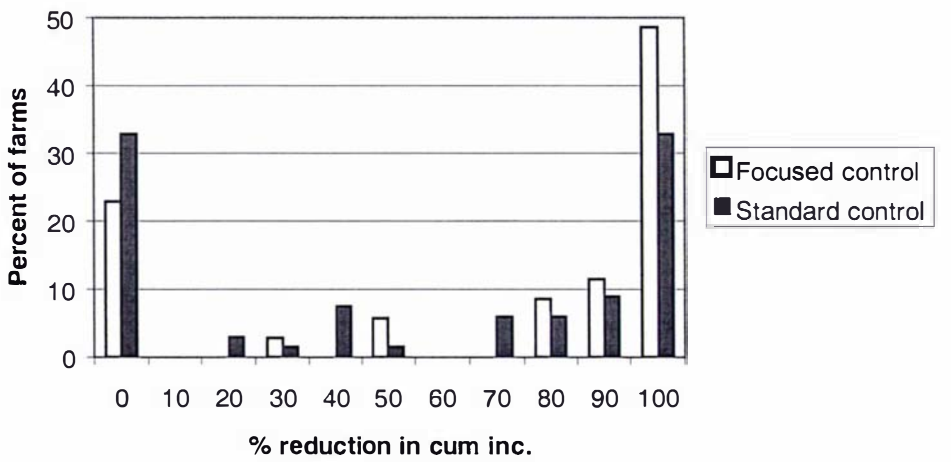



**Figure 19. Reduction in cumulative TB incidence between 1993/94 and 1997/98 for focused and standard control farms.**

The two-year cumulative incidence was also compared between the different herd types of the two farm groups (Figure 20). As there was only one beef finishing farm in each farm group, these farms were combined with the beef breeding farms to form a combined group called 'beef farms'. Table 14 gives the cumulative incidence for the period 1993/94 and for 1997/98, stratified by herd type and farm group and the reduction achieved in each group. The focused control farm group had greater reduction in all herd types than the standard control group. However, the focused control group farms had a greater cumulative TB incidence to start with than the standard control farms. Especially in the deer farms it is noticeable that the focused control farms had a very high reduction in cumulative incidence whereas the standard control farms had a five-times higher cumulative incidence in 1997/98 than in 1993/94.

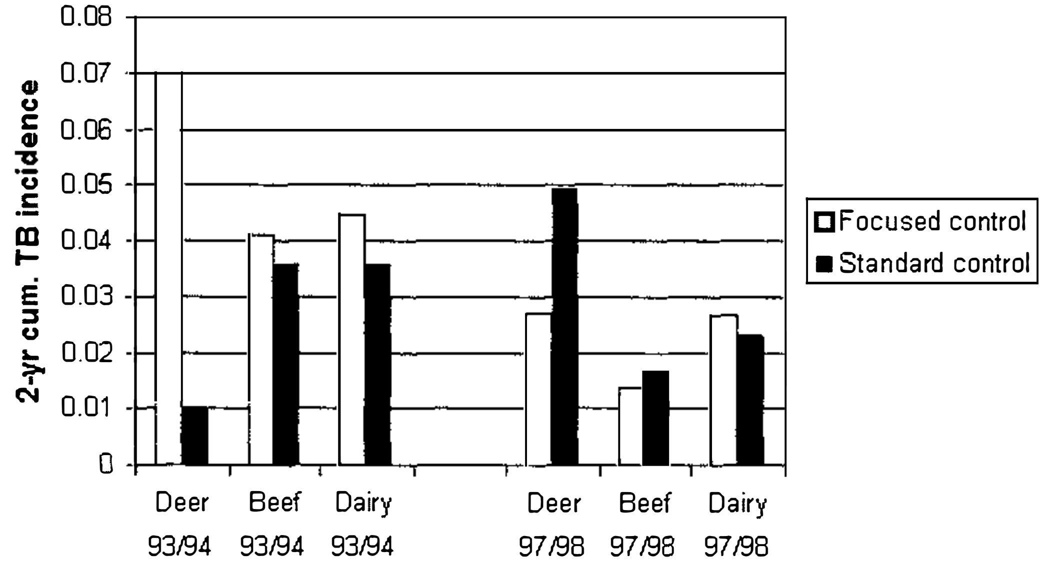



**Figure 20. Cumulative TB incidence in different herd types of focused and standard control farms for 1993/94 and 1997/98.**

**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.**

| | Herd type (number of farms) | Cum inc. 93/94 | Cum inc. 97/98 | Reduction |
|---|---|---|---|---|
| Focused control farms | Deer (6) | 0.07004 | 0.02698 | 61.5 % |
| | Beef (25) | 0.041 | 0.01372 | 66.5 % |
| | DH (4) | 0.04478 | 0.0265 | 40.8 % |
| Standard control farms | Deer (10) | 0.00991 | 0.04953 | Increase |
| | Beef (49) | 0.03565 | 0.01671 | 53.1 % |
| | DH (8) | 0.03581 | 0.02309 | 35.5 % |

The two-year cumulative TB incidence was also compared between the four regions where the project was performed. Table 15 presents the reduction in two-year cumulative incidence between focused and standard control farms and regions. All farm groups in the four regions, except the standard control farms in Otago, achieved a reduction in cumulative incidence from 1993/94 to 1997/98. In Marlborough and West Coast the focused control farms achieved a slightly higher reduction than the standard control farms. In Taumarunui the standard control farms achieved a better result than the focused control farms.

**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).**

| | Region | Cum inc. 93/94 | Cum inc. 97/98 | Reduction |
|---|---|---|---|---|
| Focused control | Marlborough | 0.0372 (n=8) | 0.0075 (n=8) | 79.84 % |
| | Otago | 0.0475 (n=9) | 0.0167 (n=10) | 64.84 % |
| | Taumarunui | 0.0486 (n=9) | 0.0130 (n=9) | 73.25 % |
| | West Coast | 0.0490 (n=8) | 0.0335 (n=8) | 31.63 % |
| Standard control | Marlborough | 0.0249 (n=15) | 0.0062 (n=16) | 75.10 % |
| | Otago | 0.0131 (n=17) | 0.0287 (n=18) | Increase |
| | Taumarunui | 0.0286 (n=18) | 0.0063 (n=18) | 77.97 % |
| | West Coast | 0.0616 (n=16) | 0.0481 (n=16) | 21.92 % |

Table 16 gives the two-year cumulative TB incidence for the years 1993/94 and 1997/98 for focused and standard control farms stratified on whether they had received vector control programmes by the Regional Council before the start of the project. The focused control farms achieved better results than the standard control farms, both farms that received control prior to the start of the project and farms that did not receive official vector control prior to the project.

**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).**

| | RC Control | Cum inc. 1993/94 | Cum inc. 1997/98 | Reduction |
|---|---|---|---|---|
| Focused control farms | Yes | 0.0467 (n=27) | 0.0197 (n=28) | 57.8 % |
| | No | 0.0420 (n=7) | 0.0085 (n=7) | 79.8 % |
| Standard control farms | Yes | 0.0379 (n=51) | 0.0231 (n=51) | 39.1 % |
| | No | 0.0110 (n=15) | 0.0120 (n=16) | Increase |

### *Comparison of the national project with the Wairarapa project*

#### Comparing only cattle farms

In a first step only the cattle farms which took part in the national project were compared with the cattle farms studied in the Wairarapa project (see Chapter 3). Table 17 presents the number of Wairarapa and national project cattle farms and their TB status at the end of the projects. A statistically significantly greater percentage of Wairarapa focused control farms than national focused control farms were off Movement Control ($\chi^2$=9.10, p=0.0026), indicating that the Wairarapa intervention study resulted in more cattle farms coming off Movement control restrictions than the national project. A slightly greater percentage of Wairarapa standard control farms than National standard control farms were off MC, however, this difference was not statistically significant ($\chi^2$=1.07, p=0.3000).

**Table 17. TB status of Wairarapa and national cattle study farms at the end of the projects.**

| | Wairarapa focused control | National focused control | Wairarapa standard control | National standard control |
|---|---|---|---|---|
| Clear Status | 26 (78.8%) | 12 (41.4%) | 19 (67.9%) | 32 (56.1%) |
| Infected Status | 7 (21.2%) | 17 (58.6%) | 9 (32.1%) | 25 (43.9%) |
| Total number | 33 | 29 | 28 | 57 |

In the final year of the projects a lower percentage of Wairarapa than national focused control cattle farms had two or more TB animals ($\chi^2$=4.76, p=0.0291). The Wairarapa standard control farms and the national standard control farms were similar ($\chi^2$=1.05, p=0.3049 for two or more TB animals). Table 18 presents the number of cattle farms having at least one, two or three TB animals in the final study year.

**Table 18. Number of Wairarapa and national study cattle farms with one, two, three or more TB animals in the final study year.**

| TB animal number in final project year | Wairarapa focused control | National focused control | Wairarapa standard control | National standard control |
|---|---|---|---|---|
| ≥ 1 | 7 (21.2%) | 12 (41.4%) | 8 (28.6%) | 24 (42.1%) |
| ≥ 2 | 3 (9.1%) | 9 (31.0%) | 5 (17.9%) | 16 (28.1%) |
| ≥ 3 | 1 (3.0%) | 7 (24.1%) | 3 (10.7%) | 14 (24.6%) |
| Total no. of farms | 33 | 29 | 28 | 57 |

In order to allow comparison between the two projects, the time periods 1993/94 and 1997/98 were chosen for the national study and 1995/96 and 1998/99 for the Wairarapa project. This way, the two years prior to the commencement of any work on the farms were taken as a reference point for the last two years in each project.

Table 19 presents the two-year cumulative TB incidence for focused and standard control farms in the national and the Wairarapa project and the reduction in incidence achieved by the four farm groups. The Wairarapa focused control farms achieved a much higher reduction in cumulative TB incidence than the national focused control farms, whereas the standard control farms in both projects achieved a similar reduction in incidence of about 50%.

**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).**

| | **Cum inc. 1993/94** | **Cum inc. 1997/98** | **Reduction** |
|---|---|---|---|
| National Focused control | 0.0425 (n=28) | 0.0160 (n=28) | 62.4 % |
| National Standard control | 0.0351 (n=53) | 0.0173 (n=54) | 50.7% |
| | **Cum inc. 1995/96** | **Cum inc. 1998/99** | **Reduction** |
| Wairarapa Focused control | 0.0629 (n=34) | 0.0034 (n=33) | 94.6 % |
| Wairarapa Standard control | 0.0354 (n=33) | 0.0161 (n=28) | 54.5 % |

The reduction in cumulative incidence on each individual cattle farm was also compared between farms of the national and the Wairarapa project. If a herd had an increase in cumulative incidence, the reduction was set to zero. In Figure 21 the reduction in cumulative TB incidence is presented for the two Wairarapa and the two national programme farm groups.

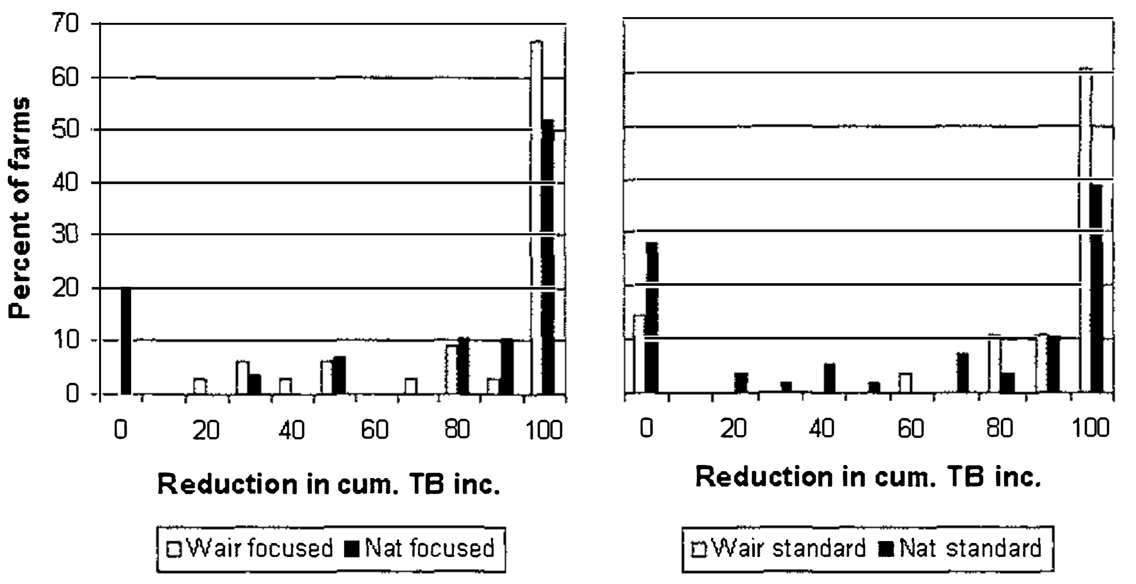



**Figure 21. Comparison of reduction in cumulative TB incidence achieved on individual cattle farms of Wairarapa and national focused and standard control farms.**

Figure 21 shows that none of the Wairarapa focused control farms had a reduction of less than 17%, whereas five of the national focused control farms had an increase in cumulative incidence (reduction=0 in the graph). Furthermore, a greater percentage of Wairarapa than national focused control farms had 100% reduction. However, this difference was not statistically significant (Mann-Whitney U-test z=-1,637, p=0.102, mean rank National 27.76, n=29; mean rank Wairarapa 34.79, n=33).

Figure 21 also shows that a higher percentage of national standard control farms than Wairarapa standard control farms had an increase in cumulative incidence, and a lower percentage of national standard control farms had 100% reduction. This difference was significant (Mann-Whitney U test z=-2.496, p=0.013, mean rank Wairarapa 52.16, n=28; mean rank National 38.50, n=57), indicating that the Wairarapa standard control farms achieved a higher reduction in cumulative incidence than the national standard control farms.

## Comparing all farms

Table 20 presents the TB status of Wairarapa and national study farms at the end of the projects. A statistically significant higher percentage of Wairarapa focused control farms had a Clear TB status than national focused control farms ($\chi^2$=9.16, p=0.0025), indicating that the Wairarapa intervention study got more farms off Movement Control restrictions than the national focused control study. No statistically significant difference was found between the Wairarapa and national standard control farms ($\chi^2$=1.30, p=0.2538).

**Table 20. TB status of Wairarapa and national study farms at the end of the projects.**

| | Wairarapa focused control | National focused control | Wairarapa standard control | National standard control |
|---|---|---|---|---|
| Clear Status | 26 (78.8%) | 15 (42.9%) | 19 (67.9%) | 37 (55.2%) |
| Infected Status | 7 (21.2%) | 20 (57.1%) | 9 (32.1%) | 30 (44.8%) |
| Total number | 33 | 35 | 28 | 67 |

In the final year of the projects a lower percentage of Wairarapa than national focused control cattle farms had two or more TB animals ($\chi^2$=5.18, p=0.0228). No statistically significant difference between the Wairarapa and national standard control farms was found ($\chi^2$=1.81, p=0.1789 for two or more TB animals). Table 21 presents the number of farms having at least one, two or three TB animals in the final study year.

**Table 21. Number of Wairarapa and national study farms with at least one, two or three TB animals in the final study year.**

| TB animal number in final project year | Wairarapa focused control | National focused control | Wairarapa standard control | National standard control |
|---|---|---|---|---|
| ≥ 1 | 7 (21.2%) | 15 (42.9%) | 8 (28.6%) | 30 (44.8%) |
| ≥ 2 | 3 (9.1%) | 11 (31.4%) | 5 (17.9%) | 21 (31.3%) |
| ≥ 3 | 1 (3.0%) | 9 (25.7%) | 3 (10.7%) | 19 (28.4%) |
| Total no. of farms | 33 | 35 | 28 | 67 |

The reduction in cumulative incidence on each individual farms was also compared between farms of the national focused control and the Wairarapa focused control farm group. If a herd had an increase in cumulative incidence, the reduction was set to zero. The Mann-Whitney U-test indicated a significant difference in reduction between the two project farms (z=-2.096, p=0.036), indicating that the Wairarapa focused control farms (n=33) achieved a higher reduction than the national focused control farms (n=35) (mean rank Wairarapa: 39.39, mean rank National: 29.89). Also the Wairarapa standard control farms (n=28) achieved higher reductions than the national standard control farms (n=67) (Mann-Whitney U test z=-3.088, p=0.002, mean rank Wairarapa 61.05, mean rank National 42.54). Table 22 presents the overall cumulative incidence prior to the projects and at the end of the projects for the national and Wairarapa focused and standard control farms.

**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).**

| | Cum inc. 1993/94 | Cum inc. 1997/98 | Reduction |
|---|---|---|---|
| National Focused control | 0.0457 (n=35) | 0.0175 (n=35) | 61.8 % |
| National Standard control | 0.0318 (n=66) | 0.0224 (n=67) | 28.6% |
| | **Cum inc. 1995/96** | **Cum inc. 1998/99** | **Reduction** |
| Wairarapa Focused control | 0.0629 (n=34) | 0.0034 (n=33) | 94.6 % |
| Wairarapa Standard control | 0.0354 (n=33) | 0.0161 (n=28) | 54.5 % |

# Discussion

## *Evaluation of the national one-on-one project*

This project was, together with the Wairarapa project (Chapter 3), the first intensive intervention study, evaluating on farm advice activities on vector and livestock control to reduce TB in livestock. No statistically significant results were expected with the limited number of farms used in the project. Nevertheless, the evaluation provided valuable evidence that on-farm advice, followed by on-farm control measures in the form of vector control and grazing management, can reduce TB incidence in livestock.

The farms selected in the national one-on-one study were not a representative sample of the farms in New Zealand; the farmers were selected specifically for their motivation and outlook towards more effective TB control. This might make interpretation of the results in relation to the wider population of infected herds problematical, but the project was only intended as a pilot study and no statistically significant results could be expected with only 35 focused control farms. It was considered more important to have pro-active farmers in the group, rather than spending time and money on farms where the farmer was not interested in applying the management plan (Rhodes, 1997). The study was totally reliant on farmers complying with the management plan set up within the team. Two of the objectives of the study were to show if on-farm control methods could reduce the within-herd TB prevalence or reduce the time spent on MC. Therefore it was considered important by those responsible for managing the project to have participants who would comply with the management plan and apply it, to show if such on-farm control methods can have an effect on TB.

Although a random sample of farmers could have indicated the percentage of farmers complying with such on-farm control programmes, the costs involved would have been too high for a farm not applying the methods. Including more than 35 farms in the study was not possible due to time constraints of the individual team members. All members had regular occupations and time was limited.

It would have been more advantageous if the selection of the standard control farms had taken place at the time when the focused control farms had been selected, as originally planned. In selecting standard control farms only three years later, potential selection biases could not be excluded. Such biases are well recognised problems of retrospect ve selection of controls and are difficult to prevent although they can be minimised. All possible effort was made to avoid such biases when selecting the standard control farms. The use of two standard control farms per focused control farm applied to this situation a recognised method of reducing uncontrollable selection bias in case control studies (Kleinbaum *et al.*, 1982), because the standard control farms had to be selected retrospectively, much as would be done for controls in a case control study. However, it was very difficult to find standard control farms with high TB incidence.

The multi-disciplinary approach taken in this study is increasingly used in agricultural extension (Paine, 1993; McRae *et al.*, 1993), providing each team member with insights from different fields. Furthermore, farmers were only advised on management changes and practices, but the implementation of these control measures was left to farmers themselves, thus resulting in a very high participatory approach. The participation of farmers in planning and implementing changes is advocated by many authors, such as Chambers *et al.* (1989); Röling and Engel (1991); Pyke and Johnstone (2000); Verkerk *et al.* (2000).

The evaluation of the project found differences in the cumulative incidence and its reduction between focused and standard control farms. The pre-project cumulative TB incidence (1993/94) was significantly higher for focused control farms than for standard control farms, indicating that bias existed between focused control and standard control farms. This bias could therefore mean that the focused control farms had a higher potential to show reduction in cumulative TB incidence than the standard control farms, as it might be easier for farms with several TB animals to reduce this number than farms with only one TB animal. However, on the other hand, it is also possible that the focused control farms were the more difficult farms than the standard control farms.

Over the three years of the project evaluation, the focused control farms achieved a reduction in cumulative incidence of 62%, while the standard control farms achieved 29% reduction. This result could be in part a result of the bias. However, although the difference was not significant, a higher proportion of focused control farms than standard control farms achieved 100% reduction in cumulative incidence (49% versus 33%). This result cannot be explained by the higher pre-project cumulative incidence.

It was noticeable that the overall high reduction in cumulative incidence in the focused control farms was mainly due to the deer herds. The focused control deer herd achieved a reduction of over 60%, whereas the standard control deer herds experienced an increase in cumulative incidence. The beef and dairy focused control farms only achieved a slightly higher reduction than the standard control farms (67% versus 53% reduction for the beef farms, and 41% versus 36% for the dairy farms). Therefore it is concluded that the project was particularly successful for the deer farms involved in the project.

In three of the four study areas the focused control farms achieved a higher reduction in cumulative incidence than the standard control farms, whereas in one area (Taumarunui) the standard control farms were slightly more successful.

The project achieved a higher reduction in cumulative TB incidence especially in areas, where no RC vector control had been conducted. In these areas the focused control farms achieved a reduction of 80%, while the standard control farms had no reduction at all, but an increase in cumulative incidence. However, the project also achieved a higher reduction in cumulative incidence in areas where vector control work had been conducted by the RC (58% in focused control farms versus 39% in standard control farms).

There were no differences in the time and the frequency of vector control programmes conducted by the Regional Councils between focused and standard control farms. Therefore, the differences found relating to TB in livestock, cannot be attributed to these official control programmes, but to the interventions conducted on the focused control farms.

TB parameters measured in focused and standard control farms that were similar in the two farm groups were: the time spent on MC, the number of farms coming off MC during the project period, and the number of TB animals per farm at the end of the project. However, the statistically significant difference in the pre-project cumulative TB incidence between focused control and standard control farms could also have had an influence on these parameters. Fifty percent of deer farms (focused control as well as standard control farms) were still on MC at the end of the project, whereas the standard control beef and dairy farms achieved a higher percentage of farms off MC than the focused control farms. If the standard control farms were the less severely affected farms, then it would have been easier for them to clear their infection entirely than for the focused control farms.

In judging the effect of the on-farm control measures employed in this project, one also has to take into account that the project was evaluated after only three and a half years. It was expected that the control measures would take some time to have an effect on TB outcomes measures, especially as animals are mostly tested only annually or biannually and therefore there is a considerable lag before improvements in TB control show up in TB testing results. The sensitivity of the skin test is not perfect (Ryan *et al.*, 1991), resulting in incorrectly classified 'test negative' animals, causing a gradual decline in TB in livestock.

Overall the results indicate an advantage over the standard control farms, indicating that the interventions implemented provided additional benefits in reducing TB incidence in livestock on farms with persistent problems, independent of official vector control programmes conducted by the Regional Councils.

### *Comparison between national and Wairarapa project*

In order to ensure direct comparison between the national and the Wairarapa project, the effectiveness of the two projects was first evaluated using only cattle farms. The Wairarapa project achieved a significantly higher proportion of cattle farms coming off Movement Control than the national project, indicating a higher success in the Wairarapa project. This is also supported by a lower percentage of farms in the Wairarapa having multiple TB animals, and a higher reduction in cumulative incidence achieved on Wairarapa focused control farms. Using all farms, including the deer farms of the national project, these differences were even more pronounced.

As there were no statistically significant differences between the performances on standard control cattle farms in the two projects, it can be concluded that the significant differences in the two focused control farm groups was attributable to the interventions conducted. Thus it can be concluded that the interventions used in the Wairarapa project, using a small team with hands-on practice, was more successful than using a large team with an advisory role only. Furthermore, the results obtained in the Wairarapa project are more reliable, as the farms were selected randomly, therefore providing valid representativeness. In the national project only the focused control farms were chosen at the start of the project, and the standard control farms had to be selected retrospectively some years later, thereby possibly reducing the interpretability of the results.

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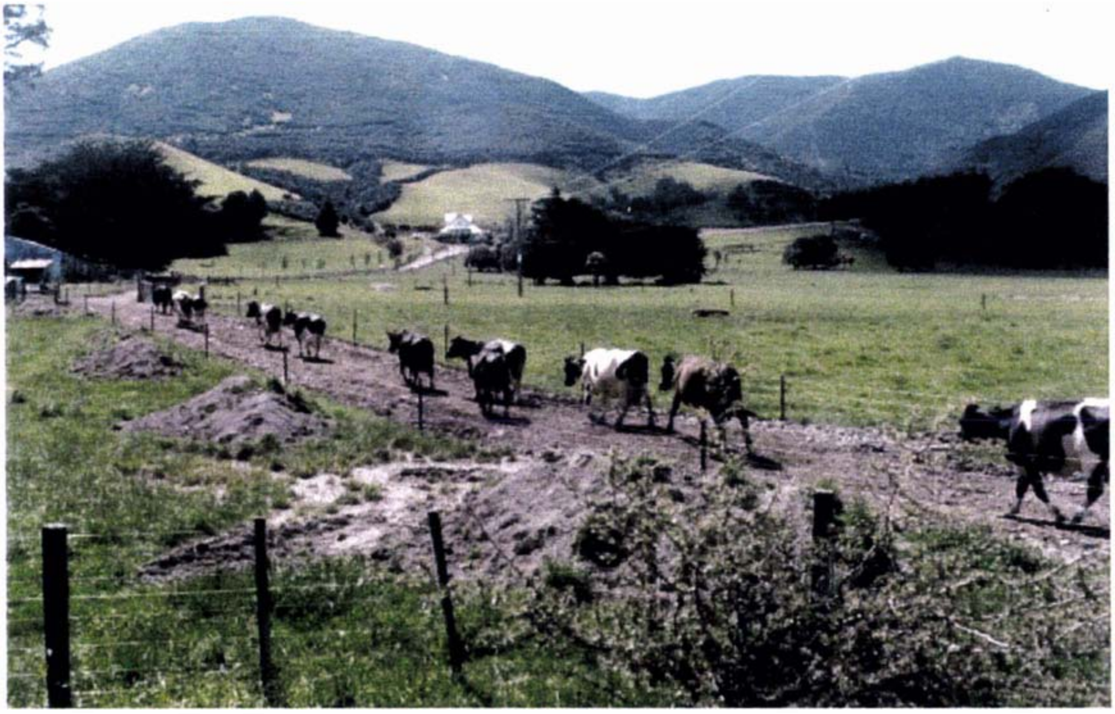
**Beef farm in the Wairarapa**



**Dairy farm in the Wairarapa**

# Chapter 5

# Attitudes of farmers to bovine tuberculosis control in New Zealand

## Abstract

The Australian brushtail possum is the main wildlife vector for bovine tuberculosis in cattle and deer in New Zealand. Thus, control and eradication is complicated and cost intensive. There is an increased call for farmers to have more responsibility for control measures themselves. For promoting the adoption of effective on-farm control measures, it is necessary to know the beliefs and attitudes of farmers towards TB and its control. A questionnaire survey was conducted with farmers involved in two intervention studies, evaluating the effectiveness of such on-farm control measures (Chapters 3 and 4), plus a group of 42 farmers whose herds were classified as TB free. In total 205 farmers responded to the questionnaire. The questionnaire sought demographic information of the farm, information about farm and stock management, TB and vector control, and attitudes towards TB and its control. Farmers were surveyed by personal interviews, phone or mail.

There were only slight differences in the farm demographic variables between the two farm groups within each of the intervention studies, indicating that the random allocation of farms into focused and standard control farm group was effective in the Wairarapa study and to a lesser degree in the national study. Overall farmers regarded TB eradication as being important, however most farmers interviewed in this study were not in favour of stricter Movement Control regulations, removal of compensation or having to pay TB testing costs directly. Many farmers saw Government and Regional Council as being responsible for eradicating TB and saw no need to conduct control programmes themselves. Thus, future eradication strategies should include farmer motivation, possible on-farm control strategies and financial incentive packages for farms adopting these control measures.

## Introduction

Control and eradication of bovine tuberculosis (TB) in New Zealand is complicated by the existence of wildlife species that are both reservoirs of TB and vectors for the disease to livestock. The Australian brushtail possum (Trichosurus vulpecula) is the main vector for the disease in livestock (Morris and Pfeiffer, 1995). Current TB eradication strategies have been successful in reducing the number of infected cattle and deer herds, as well as reducing the incidence of TB within herds (Animal Health Board, 2000). However, these programmes are cost intensive and with the decreasing prevalence of TB it may become more difficult to justify spending much of taxpayers' money on continuous vector control (Animal Health Board, 2000). It is important that continuing effort is made to improve both the effectiveness and the efficiency of TB control in New

Zealand. This is more likely to be achieved if farmers take greater responsibility for the control of TB on their own farms, rather than leaving control as the responsibility of a national body. The proposed new strategy for TB management places increasing emphasis on farmers being responsible for funding control rather than Government.

On-farm control programmes provide an effective way for farmers to assist the control of TB (see Chapters 3 and 4), however, they have to be promoted effectively. Effective promotion is dependent on understanding the existing attitudes and beliefs of farmers so that extension and education programmes can be tailored accordingly. The present study involved farmers participating in the Wairarapa project (Chapter 3) and the National one-on-one project (Chapter 4), each project consisting of a group of 'focused control' and 'standard control' farms. The study had three main objectives: (i) to understand the characteristics of the farms on which on-farm TB control interventions were conducted within the two projects; (ii) to identify differences between the focused and standard control farms in the two projects; and (iii) to identify current attitudes of farmers towards TB control. It collected information on general farm management, TB management and attitudes towards TB and its control.

## Materials and Methods

### *Surveys*

A questionnaire survey was conducted with farmers that had been involved in two projects which were designed to evaluate the impact of on-farm control measures on the tuberculosis situation in their herds (Wairarapa – Chapter 3 and National project – Chapter 4). The questionnaire was developed in conjunction with Chris Carter (AgriQuality) and Tony Rhodes (Agriculture New Zealand), the main co-ordinators of the National project. It was designed to explore farmers' attitudes and to obtain general information on the two farm groups in each project. The questionnaire was extensive, with questions seeking demographic information of the farm, information about farm and stock management, TB and vector control, and attitudes towards TB and its control (see Appendix IV, p. 339). Details of the groups of farmers involved with each project are described below.

#### Wairarapa project farms

For the Wairarapa project, 70 TB-infected farms were selected randomly and half were allocated to each of the 'focused control' and the 'standard control' groups (for more details see Chapters 3 and

4). An on-farm programme, involving targeted possum control and targeted grazing management was employed on focused control farms for three years from 1997 to 1999. Standard control farms received the standard official TB control. All farmers in the focused and standard control groups were surveyed using the questionnaire described above. As the focused control farmers were visited on a regular basis, the questionnaire was conducted in two parts with these farmers. The first part, asking about farm and stock management, was filled in with the farmers/managers at an interview during the third farm visit (1997). The second part of the questionnaire, asking about farmer attitudes and effort put into TB control, was mostly conducted during the fourth farm visit in early 1998. This was before focused control farmers were responsible for maintaining vector control themselves as a part of the intervention project. This way the vector control efforts of focused control farmers could be compared with those on standard control farms. The standard control farms were surveyed by a combination of personal interviews, phone and mail towards the end of the project in early 1999, when the whole questionnaire was completed at one time. Only minimal information was obtained for two standard control farms as the farmers had passed away during the last year of the project. Information for these two farms was obtained from family members, who could not answer all the questions, especially the ones regarding attitudes.

A group of 70 farmers, whose herds had been clear of TB for at least five years was randomly selected in the Wairarapa in 1999 to act as a comparative group for the TB-infected farms. These herds are described as 'non-TB' farms. This group was surveyed by mailing a shorter modified version of the questionnaire. The questionnaire omitted all questions regarding TB history and its control on farms, but included all questions relating to attitudes towards TB. A second letter and questionnaire was sent out to forty non-respondents four weeks later. In total 42 of the 70 farmers in the non-TB group replied with completed questionnaires.

Details on the number of farms involved and responding to the questionnaire are given in Table 23.

### National project farms

For the National project, 35 farms in four TB endemic areas were selected by AgriQuality (then Ministry of Agriculture and Fisheries) to implement an on-farm TB management programme. These farmers were chosen mainly on the basis of their past TB herd history and partly on positive farmer motivation/outlook, which was ascertained in screening interviews held with potential participating farmers. For two years focused vector control and management interventions were conducted on these 35 'focused control' farms. Retrospectively seventy 'standard control' farms were randomly selected to match the area and enterprise type of the focused control farms (for more details see Chapter 4).

Both the focused and standard control farmers involved in the National project were surveyed in 2000, after the project had concluded. Farmers were initially contacted by telephone to explain the nature of the study and the nature of the comparison between the Wairarapa and the National projects. It was then left to the farmers to decide if they wanted to answer the questions on the telephone or by mail. In both cases the questionnaire was mailed out to the farmers. If no reply had been obtained within three weeks, another telephone call was made as a reminder, often resulting in a second questionnaire being sent. A lot of effort was put into contacting farmers to remind them of the questionnaires, sometimes telephoning up to eight times. Once the questionnaires were returned, the answers were entered into the database and if questions were left unanswered, the farmer was phoned to clarify these. Table 23 presents a summary of the number of farmers involved in the intervention project, the number that responded to the questionnaire, and the method of data collection for each group. The National project (see Chapter 4) involved 35 focused control and 68 standard control farms. It was not possible to obtain survey information from one focused control and three standard control farms. Additionally one focused control and two standard control farms counted for two farms. These farms involved different herd types run at separate locations, but managed by the same owner/herd manager. For the evaluation of the questionnaires these farms were considered as only one farm each, thus avoiding duplicated answers. This resulted in 33 focused control and 63 standard control farms being involved in the questionnaire survey.

A national group of non-TB farms was not selected for comparison within this project, but were surveyed and described in a concurrent study (Corner *et al.*, 2000).

**Table 23. Number of farmers responding to the questionnaire in the Wairarapa and National project.**

| Number of farms | | Wairarapa Focused control | Wairarapa Standard control | Wairarapa non-TB | National Focused control | National Standard control |
|---|---|---|---|---|---|---|
| Involved in intervention study | | 34 | 33 | -- | 35 | 68 |
| Responded to questionnaire | | 34 | 33[a] | 42 | 33[b] | 63[c] |
| Non-respondents | | -- | -- | 28 | 1 | 3 |
| Information collected using | Interview | 34 | 10 | -- | -- | -- |
| | Phone | -- | 5 | -- | 20 | 18 |
| | Mail | -- | 18 | 42 | 13 | 45 |

[a] Only minimal information could be obtained on two farms
[b] one farm counted for two farms (different herd type and separate farm units)
[c] two farms counted for two farms each (different herd type and separate farm units)

### Definition of terms used

Farm enterprise types were referred to as 'Beef breeding' (BB), 'Beef dry stock' (BD), 'Dairy' (DH), and 'Deer'.

'White-tagged' cattle were cattle identified with an official white Movement Control ear tag. They originated from a herd with a TB status of 'Infected'.

'TB reactor cattle/deer' was any animal that was tested positive in any official TB test (mostly caudal fold tuberculin skin test).

'AHB' is the abbreviation for the Animal Health Board, the national organisation responsible for co-ordinating and setting up TB control and eradication schemes.

### Analysis of data

Responses to the survey for the group of Wairarapa farmers and the National farmers were analysed separately, as the methods used to select each group were different.

Descriptive analysis was used to identify patterns and trends in the data and to compare the responses for different groups of farmers. Open-ended questions were handled by developing a number of different themes from the responses to each question. They were coded by assigning each response to one or more of the themes, irrespective of the tone of any comments made to this question.

In total there were over 80 variables, with up to five categories within each variable. Screening these variables for differences between the categories, would have resulted in numerous individual statistical tests, thus severely increasing the likelihood of type I and type II errors. Therefore all the variables were initially screened visually and only variables with a difference between the groups were tested statistically. Three main families of variables were created: general farm characteristics, TB related issues and attitudes. Within each of the variable families a Bonferroni correction term of 20 was set, resulting in application of an alpha of 0.0025 (Ott, 1988). This was a conservative method, resulting in a small Type I error probability, but a large Type II error probability.

As many continuous variables showed a skewed distribution, non-parametric tests such as Mann-Whitney U tests and Kruskal-Wallis tests were used to compare the answer categories between the farm groups (Bortz, 1993). For post-hoc tests the critical Z-value was set at 3.2915 where the p-value was 0.05 divided by 3 times the correction term, accounting for a correction factor of 60.

Chi-squared tests were used to compare proportions and counts. If in a contingency table any cell had an expected cell count of less than five, the exact p-values were calculated (Agresti, 1990).

Data was stored and manipulated in the database management software Microsoft Access 97 (Microsoft Corporation, Redmond, WA) and spreadsheet software Microsoft Excel 97 (Microsoft Corporation, Redmond, WA). NCSS 2000 (Number Cruncher Statistical Systems, Kaysville, Utah, U.S.A.), and SPSS for Windows version 9.0.1 (SPSS Inc. Headquarters, Chicago, Illinois, U.S.A.) were used for statistical analyses.

## Results

Results for the surveys of the Wairarapa group of farmers and the National group of farmers are presented separately.

### *Wairarapa farms*

The information for the Focused control farms was collected over a period of two years. For the analysis of farm management and characteristics, stock management, TB risk assessment, costs and stock management the information collected in 1997 on focused control farms (first part of the questionnaire) was used, whereas the information regarding attitudes was collected in 1998 on focused control farms. The only information collected twice or three times on focused control farms, were stock numbers and amount of control effort, farmers put into vector control. For the analysis the information regarding these issues collected on the focused control farms in 1998 (at the time of the second part of the questionnaire) was compared with the information collected on the standard control farms early 1999. This way, the third year of the project, where the farmers were responsible for maintaining the vector control, did not influence the comparison.

### General farm characteristics

General farm characteristics were compared for focused and standard control farms. Stock numbers for the focused, the standard control, and the non-TB farms were taken as of June 1998.

Farmers were asked for the size of their home farm (both total and effective hectares), the size of other owned land, locally leased land and other leased land. Farmers also provided information on income and labour units. Table 24 presents some of the characteristics for the three farm groups.

**Table 24. General characteristics of focused control, standard control, and non-TB farms.**

| | Focused control (n=34)[a] | Standard control (n=33) | Non-TB (n=42) |
|---|---|---|---|
| Farmed area (ha) [b] | 759.9 ha | 695.3 ha | 239.07 |
| Number of farms using off-farm grazing | 11 (32.4 %) | 12 (36.4 %) | 27 (64.3%) |
| Average self-concept value [c] | 3.19 (n=33) | 3.16 (n=31) | 3.15 (n=37) |
| Income from cattle (% of total income) | 59.79 | 64.94 | 71.56 |
| Income from sheep (% of total income) | 36.15 | 29.66 | 26.0 |
| Income from deer (% of total income) | 1.18 | 4.38 | 2.44 |
| Full time labour units on farm | 2.1 (n=34) | 2.2 (n=32) | 1.5 (n=41) |

[a] gives the sample size for each farm group, unless otherwise stated
[b] is the total number of effective hectares on the home property, plus other owned land if less than 100km away, plus leased land if less than 100km away
[c] from Seabrook (1984)

Between 60% and 72% of the total farm income was generated through cattle in all three groups. Non-TB farms had the lowest number of labour units, which is consistent with their smaller average farm size.

The distribution of farm size across all three groups is shown in Figure 22. About a quarter of the farms (25.6%) were smaller than 100 effective hectares.


**Figure 22. Effective farm size distribution of all farms included in the Wairarapa study.**

On average the non-TB farms were smaller than the focused and standard control farms (239 versus 728 hectares), however this was not statistically significant when the Bonferroni correction was applied (Kruskal-Wallis test $\chi^2$=8.20, 2 df, p=0.017, which is according to the multiple test correction applied in this study greater than 0.0025 and therefore not statistically significant). Figure 23 gives Violin plots for the effective farmed area on focused control, standard control and non-TB farms.

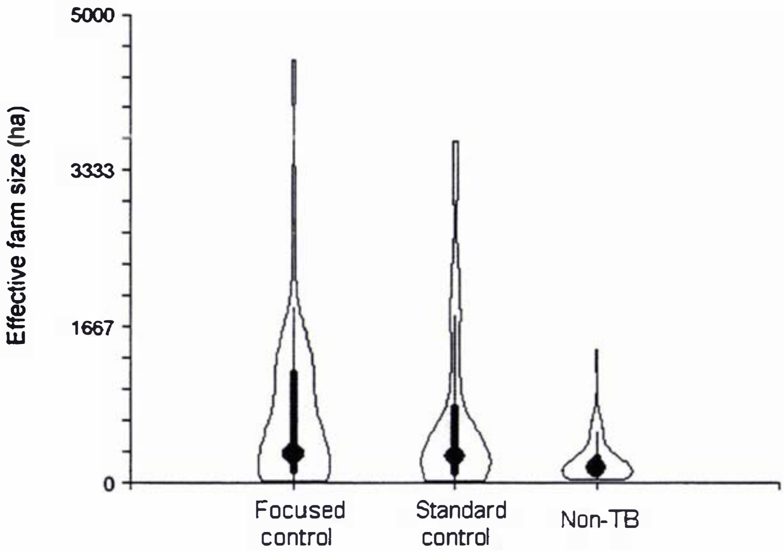



**Figure 23. Violin plots for effective farmed area of Wairarapa focused control, standard control and non-TB farms.**

Table 25 presents the average effective farm size for the different enterprise types in the three farm groups. Of the non-TB farms a higher percentage of farms were dairy enterprises (54.8% versus 30% in focused and standard control farms).

**Table 25. Average farmed area stratified by herd type and Wairarapa farm group (with range in brackets).**

| | Focused control farms | | Standard control farms | | Non-TB farms | |
|---|---|---|---|---|---|---|
| BB | 1373.6 (56 – 4500) | n=16 | 1165.4 (25 – 3644) | n=17 | 392.2 (35 – 1419) | n=15 |
| BD | 192.5 (18 – 590) | n=8 | 213.0 (78 – 374) | n=6 | 306.5 (46 – 510) | n=4 |
| DH | 231.8 (60 – 1045) | n=10 | 185.5 (68 –308) | n=10 | 127.5 (31 – 226) | n=23 |

The farms in the Wairarapa study comprised on average 4851 livestock units (s.e.=606.58; n=108; median 2455.9 SU). On average the herds (n=108) comprised 1990 cattle SU (s.e.=188.15; median 1545.7 SU; see Figure 24), 2794 sheep SU (s.e.=508.51; median 80 SU) and 42 deer SU (s.e.=21.06; median 0 SU). Only 64 of the 108 farms had sheep and only nine had deer on their properties. Cattle comprised an average proportion of 0.64 (s.e.=0.035; median 0.70) of total livestock units on the farms. Figure 25 presents the violin plots of the proportion of cattle for the three farm groups. The non-TB farms had the highest proportion of cattle, with a median of 1.0, indicating that no livestock other than cattle were kept on the farm. The differences seen in the plots were not statistically significant (Kruskal-Wallis test $\chi^2$=1.49, 2 df, p=0.476). The average cattle density on the Wairarapa farms was 7.7 SU per effective hectare of land (s.e.=0.59; median=5.76; see Figure 26). There was no difference in the cattle density between the three farm groups (Kruskal-Wallis test $\chi^2$=3.43, 2 df, p=0.179).

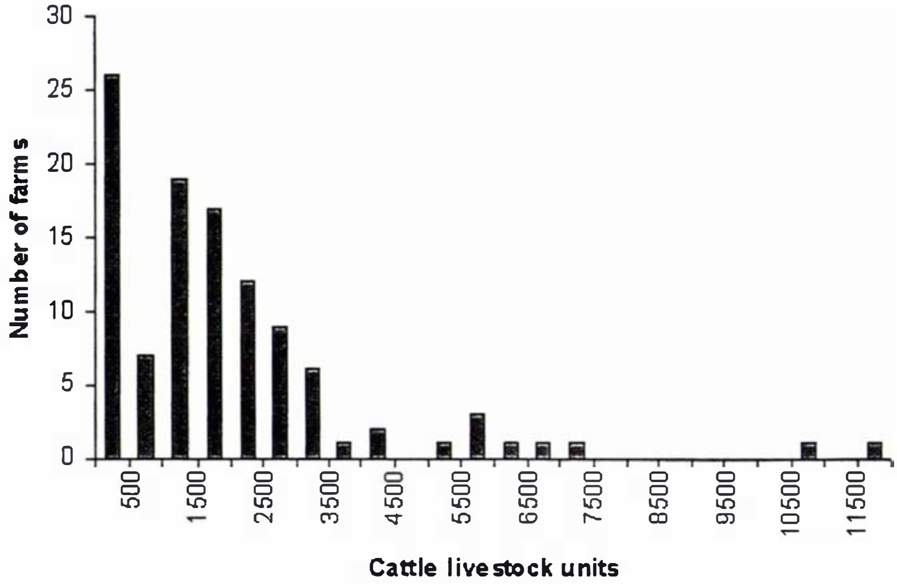



**Figure 24. Cattle herd size distribution of farms included in the study in livestock units.**

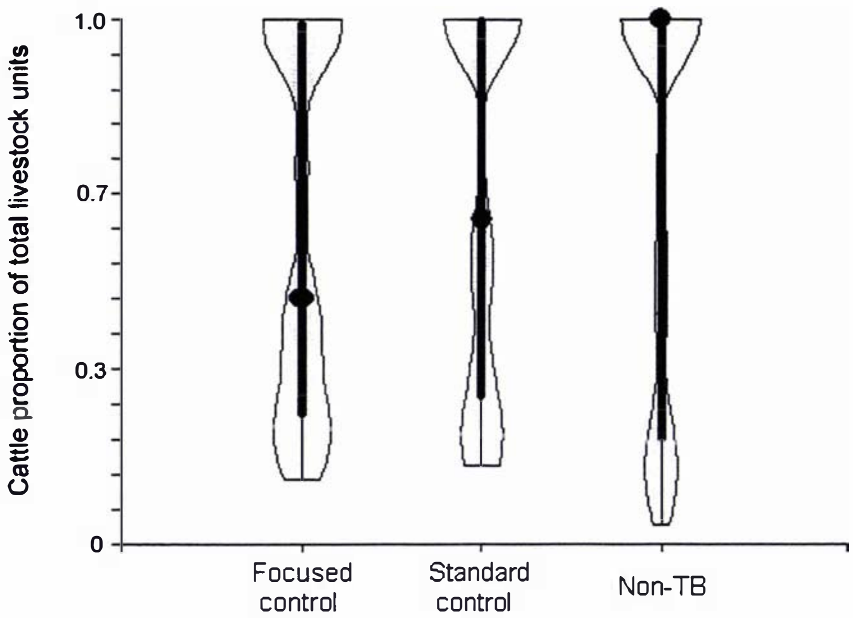



**Figure 25. Violin plots for the cattle proportion of total livestock units for focused control, standard control, and non-TB farms.**

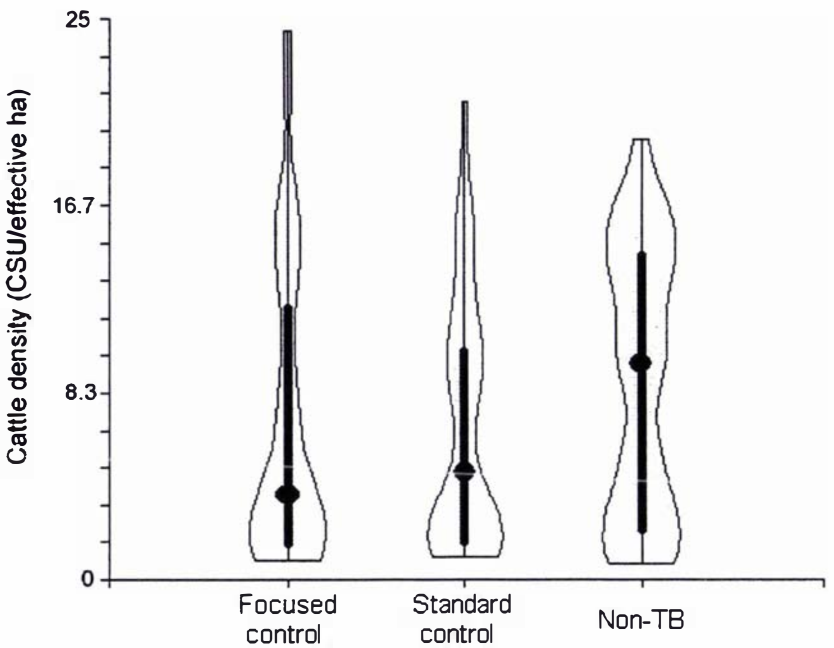



**Figure 26. Violin plots for cattle density on focused control, standard control, and non-TB farms.**

## Herd manager

The median age of herd managers across all farm groups was in the range 40-50 years (Figure 27). The age distributions were bell curve shaped with smaller numbers of farmers being in the extremities and the majority of farmers being in the central age groups.

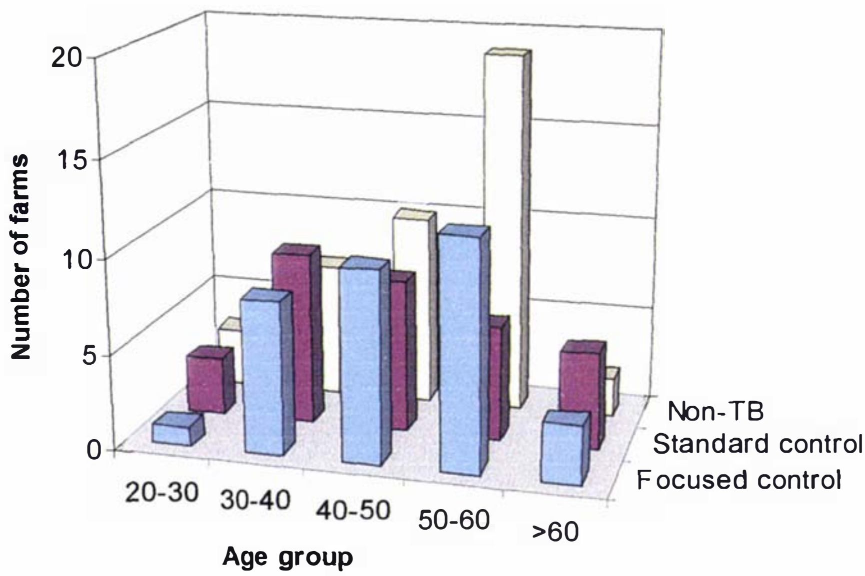



**Figure 27. Distribution of age groups of herd managers on focused control, standard control, and non-TB farms.**

Ninety-eight percent (n=106) of farmers were male, 93.6% (n=102) lived on the farm, 21.1% (n=23) had additional employment, and 83.5% (n=91) of farmers stated that their farm income was covering their living expenses. Sixty-six percent (n=72) of interviewees owned the farm, 14% (n=15) were share milkers and 13% (n=14) were managers. Fifty-six percent of farmers (n=61) considered themselves to be the main decision makers for the farm. On average farmers had worked 15.9 years (s.e. 1.13, n=106, median 12.5) on their current farm. Overall they had worked an average 25.1 years (s.e. 1.27, n=107, median 24) on a farm. Nineteen percent of herd managers (n=20 of 107 farmers with information) started their farming job without a farming background, whereas 75.7% (n=81) were brought up on a farm. Sixty-six percent of herd managers (n=71 of 107) had no formal farming-specific qualification.

Interviewees were also asked to fill in a self-concept form, which was adapted from Seabrook (1984). This part of the questionnaire was filled in by a total of 101 farmers. Figure 28 shows the arithmetic means of personality traits for focused control, standard control, and non-TB farmers.

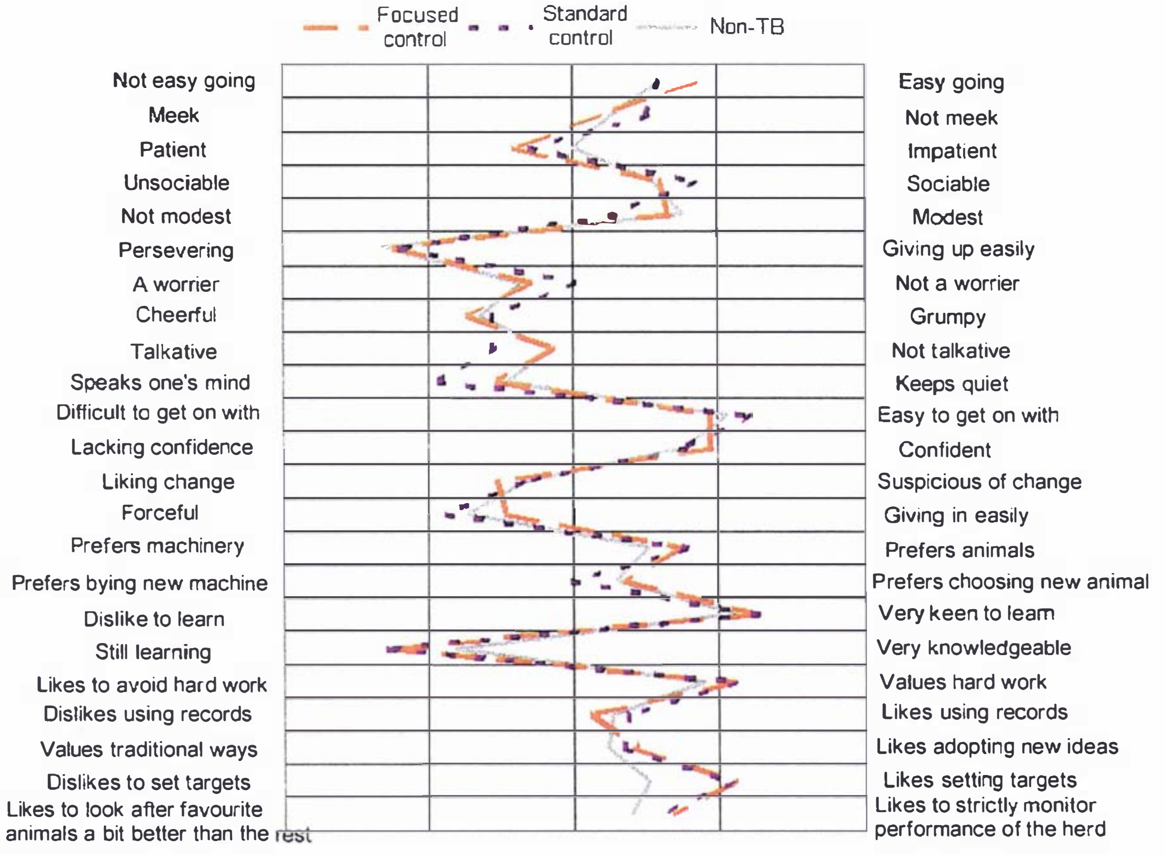



**Figure 28. Personality trait means for focused control, standard control, and non-TB farmers (adapted from Seabrook, 1984)**

Figure 28 suggests that the focused control farmers were more likely to 'speak their mind' and 'preferred to buy new machinery' than the other two farm groups. The graph also suggests that non-TB farmers were less inclined to 'set targets', were more 'impatient' and considered themselves more knowledgeable than the focused and standard control farmers (comparing non-TB farms with focused control/standard control farms, Mann-Whitney U test: 'knowledgeable' Z=-2.5808, p=0.010; set targets: Z=-2.729, p=0.019). Comparing all three farm groups with each other, the one variable which was most different was 'still learning/very knowledgeable' (Kruskal-Wallis $\chi^2$=6.69, 2 df, p=0.035). A higher proportion of non-TB farmers believed that they were very knowledgeable and were less likely to consider themselves as 'still learning' compared to focused and standard control farmers.

## Stock management

Table 26 presents the results stock movements on and off the farm for the three farm groups. Information collected during the first part of the questionnaire in 1997 was used for the focused control farms. This information could not be obtained for one of the standard control farms.

**Table 26. Information on stock movements on and off farms for focused control, standard control, and non-TB farms.**

| | | Focused control farms (n=34) | Standard control farms (n=32) | Non-TB farms (n=42) |
|---|---|---|---|---|
| White Tagged cattle bought | Yes | 7 (20.6%) | 9 (28.1%) | 1 (2.4%) |
| | No | 27 (79.4%) | 23 (71.9%) | 41 (97.6%) |
| Buying frequency | Every year | 15 (44.1%) | 11 (34.4%) | 9 (21.4%) |
| | Now and again | 3 (8.8%) | 10 (31.2%) | 13 (31.0%) |
| | Other/never[a] | 16 (47.1%) | 11 (34.4%) | 20 (47.6%) |
| Trading importance | Crucial | 10 (29.4%) | 5 (15.6%) | 4 (9.5%) |
| | Important | 2 (5.9%) | 2 (6.2%) | 9 (21.4%) |
| | Moderately | 5 (14.7%) | 3 (9.4%) | 11 (26.2%) |
| | Minor/unimport. | 17 (50.0%) | 22 (68.8%) | 16 (38.1%) |
| | Not stated | | | 2 (4.8%) |

[a] farms that only bought in single bulls for breeding purposes were classified under 'other'

There was a difference in the frequency of buying white-tagged cattle amongst the three farm groups ($\chi^2$=9.95, 2 df, p=0.007), however after applying the Bonferroni correction term, this was no longer significant. The non-TB farms had the lowest frequency of buying in white-tagged cattle.

There was no significant difference in the buying frequency between the three farm groups ($\chi^2$=8.71, 4 df, p=0.067). Of the farms that bought in stock, only four focused control and six standard control farms took TB and the herd history of the animals into account, whereas 13 focused control and eight standard control farms took production requirements into account. Of the non-TB farmers, 12 took TB and 13 took production requirements into account.

Ten (29.4%) focused control and eight (25.8% of 31 farms with relevant information) standard control farmers indicated that they had changed their stock selling policies due to having TB in their herds. Five (14.7%) focused control and four (of 31 farms with relevant information, 12.9%) standard control farmers also indicated that they had changed their mix of stock classes. Most farmers changed from selling weaners to finishing more stock themselves.

## TB risk assessment

Farmers were asked about the TB situation in their own herd. As part of this they were asked what reason they suspected for the TB infection in their herd, and if they knew or suspected areas on their farm properties that could be classified as TB hot-spots and if so, whether they grazed cattle in these areas or not. To compare the data between focused and standard control farms, the information collected at the first part of the questionnaire was used for the TB high risk areas. This ensured, that wildlife surveys, which were conducted as a part of the project, did not severely influence the outcome, as only a few properties had been subject to wildlife surveys by that time. Table 27 presents information on these subjects.

Most farmers regarded infected wildlife as the source of TB infection in their herds. Neighbouring herds and stock movements on and off farms were only mentioned by a minority of farmers.

A higher proportion of focused control than standard control or non-TB farmers knew or suspected high risk areas for TB on their farms. However, this difference was not statistically significant ($\chi^2$=3.96, 1 df, p=0.046). A lower percentage of focused control than standard control farmers grazed their cattle in TB high-risk areas (68% vs. 83%).

Focused control farms had the greatest awareness of the TB situation of their neighbouring herds, whereas 21% of the standard control and 41% of the non-TB farmers did not know whether their neighbours were infected or not.

**Table 27. Information on the TB situation and perception of focused control, standard control, and non-TB farms.**

| | | Focused control (n=34) | Standard control (n=33) | Non-TB (n=42) |
|---|---|---|---|---|
| TB problem classification | Continuous | 8 (23.5%) | 11 (33.3%) | -- |
| | On and off | 13 (38.2%) | 7 (21.2%) | -- |
| | Seldom | 2 (5.9%) | 4 (12.1%) | 23 (54.8%) |
| | No problem anymore | 11 (32.4%) | 11 (33.3%) | -- |
| | Never | -- | -- | 18 (42.9%) |
| | Not stated | -- | -- | 1 (2.4%) |
| Reason for TB infection[a] | TB feral animals | 25 (73.5%) | 26 (78.8%) | |
| | Neighbouring herds | 5 (14.7%) | 6 (18.2%) | |
| | Stock movements | 7 (20.6%) | 8 (24.2%) | |
| High risk areas for TB suspected on farm | Yes | 25 (73.5%) | 18 (54.5%) | 22 (52.4%) |
| | No | 8 (23.5%) | 11 (33.3%) | 15 (35.7%) |
| | Unknown/not stated | 1 (3.0%) | 4 (12.1%) | 5 (11.9%) |
| Graze cattle in high risk areas | Yes | 17 (68.0%) | 15 (83.3%) | 17 (77.3%) |
| | No | 8 (32.0%) | 3 (16.7%) | 5 (22.7%) |
| Any neighbouring farms infected with TB | Yes | 20 (58.8%) | 22 (66.7%) | 16 (38.1%) |
| | No | 10 (29.4%) | 4 (12.1%) | 9 (21.4%) |
| | Unknown | 4 (11.8%) | 7 (21.2%) | 17 (40.5%) |
| Reactor numbers over last three years | Increased | 2 (5.9%) | 0 | |
| | Decreased | 21 (61.8%) | 23 (69.7%) | |
| | No change/not stated | 11 (32.3%) | 10 (30.3%) | |

[a] multiple answers were possible

## Vectors and vector control on farms

Farmers were asked how likely they thought contact was between their livestock and feral animals. Table 28 presents the data for possums and ferrets stratified for focused control, standard control and non-TB farms. More focused control farmers than standard control and non-TB farmers believed there was a high likelihood that livestock had contact with possums or ferrets. However this was not statistically significant ($\chi^2$=3.38, 1 df, p=0.066 for contact with possums, and $\chi^2$=3.71, 1df, p=0.054 for contact with ferrets between Wairarapa focused and standard control farms).

**Table 28. Assumed likelihood of contact between possums/ferrets and livestock, as indicated by focused control, standard control, and non-TB farmers.**

| | | Focused control | Standard control | Non-TB |
|---|---|---|---|---|
| Likelihood of contact with possums | Very likely | 24 (70.6%) | 15 (45.5%) | 14 (33.3%) |
| | Possible | 6 (17.6%) | 10 (30.3%) | 18 (42.9%) |
| | Unlikely | 4 (11.8) | 2 (6.1%) | 2 (4.8%) |
| | Unknown / not stated | 0 | 6 (18.2%) | 8 (19.0%) |
| Likelihood of contact with ferrets | Very likely | 17 (50.0%) | 8 (24.2%) | 10 (23.8%) |
| | Possible | 10 (29.4%) | 13 (39.4%) | 18 (42.9%) |
| | Unlikely | 4 (11.8%) | 3 (9.1%) | 0 |
| | Unknown / not stated | 3 (8.8%) | 9 (27.3%) | 14 (33.3%) |

Farmers were also asked about vector control on their properties, what percentage of land was controlled by themselves and/or by the Regional Council and how much time was spent on these controls (see Table 29 and Figure 29). For this comparison the data collected in 1998, when the second part of the questionnaire was conducted, was used for the focused control farms. During this time vector control was performed by the research team, not by the farmers, therefore it did not influence the time spent on vector control by farmers themselves. For two standard control farms no relevant information could be obtained.

**Table 29. Vector control by Regional Council and farmers as stated by focused control, standard control, and non-TB farmers.**

| | | Focused control (n=34) | Standard control (n=31) | Non-TB (n=42) |
|---|---|---|---|---|
| Avg % of farm controlled by RC[a] | | 76.5% (n=29) | 79.3% (n=22) | 67.0% (n=23) |
| Avg % of farm controlled by farmer[a] | | 40.4% (n=29) | 65.5% (n=20) | 83.0% (n=30) |
| Regional Council control | Increased | 22 (64.7%) | 7 (21.2%) | 4 (9.5%) |
| | Decreased | 2 (8.7%) | 11 (33.3%) | 10 (23.8%) |
| Farmer Control | Increased | 18 (52.9%) | 6 (18.2%) | 2 (4.8%) |
| | Decreased | 3 (11.8%) | 8 (24.2%) | 17 (40.5%) |
| Farmer Control (days/year) | = 0 | 5 (14.7%) | 10 (32.3%) | 14 (33.3%) |
| | > 0 | 29 (85.3%) | 20 (64.5%) | 26 (61.9%) |
| | | (median 20, avg 36.4, range 3 – 192) | (median 17, avg 22.9, range 1 – 72) | (median 8.5, avg 15.9, range 1 – 110) |
| | Not stated | 0 | 1 (3.2%) | 2 (4.8%) |
| Regional Council (days/year) | = 0 | 8 (23.5%) | 7 (22.6%) | 19 (45.2%) |
| | > 0 | 26 (76.5%) | 23 (74.2%) | 21 (50.0%) |
| | | (median 10, avg 13.8, range 3 – 42) | (median 10, avg 14.4, range 2 – 50) | (median 5, avg 5.4, range 1 – 10) |
| | Not stated | 0 | 1 (3.2%) | 2 (4.8%) |
| Farmer Control | Regularly | 7 (20.6%) | 5 (16.1%) | 9 (21.4%) |

[a] according to the farmer

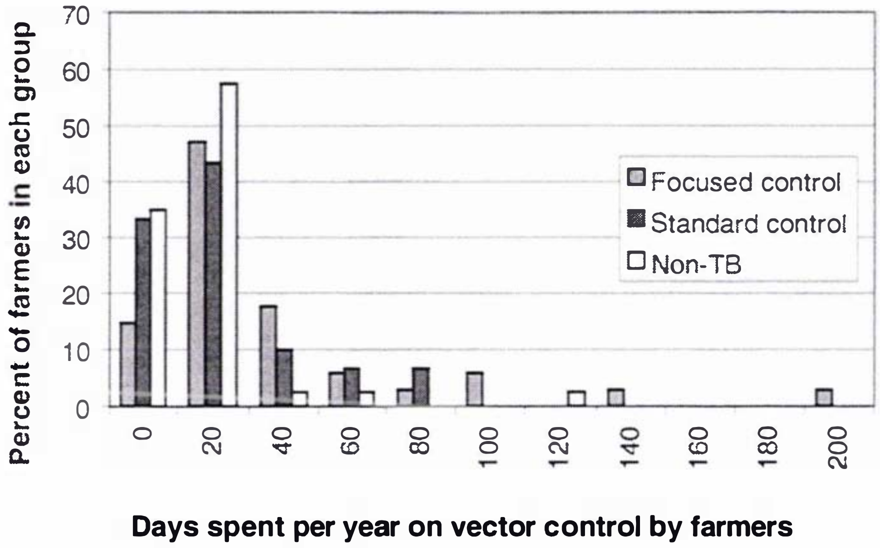



**Figure 29. Time spent per year on vector control by focused control, standard control, and non-TB farmers.**

Of the farms that conducted vector control on their properties the focused control farmers had the lowest average percentage of their land area being controlled by themselves. Standard control farmers indicated that they controlled on average 65% of their farms, and non-TB farmers indicated that they on average controlled 83% of their farms, whereas on average the focused control farmers estimated that 40% of their farms was controlled by themselves (Kruskal-Wallis test $\chi^2$=14.27, 2 df, p=0.0008). This might reflect different perceptions of control effort. Figure 30 presents a box and whisker plot for the area controlled by focused control, standard control and non-TB farmers.

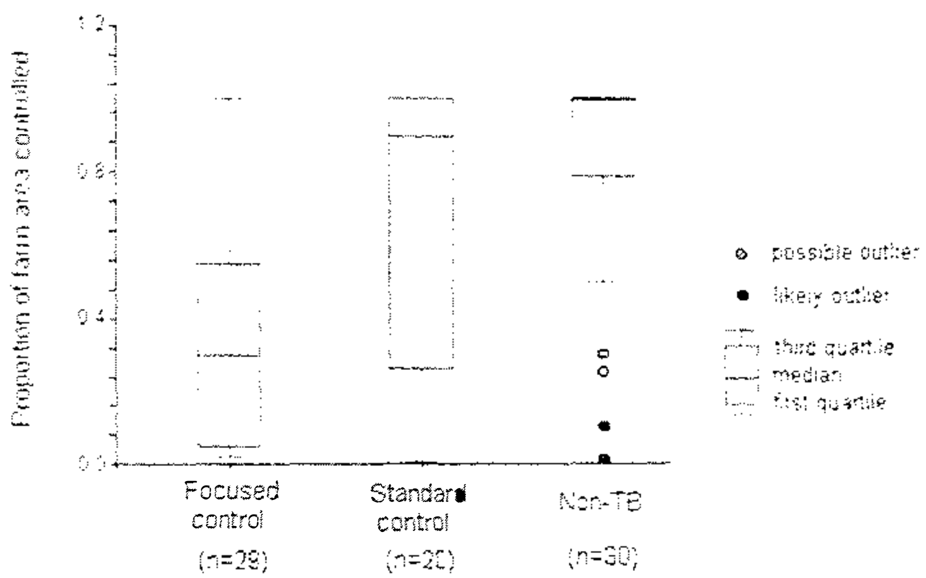



**Figure 30. Box and Whisker plot of the proportion of farm area controlled by focused control, standard control, and non-TB farmers.**

The proportion of farmers controlling vectors on their properties themselves was greatest for focused control farms with 85% of farmers controlling possums, yet this difference was not statistically significant ($\chi^2$=5.56, 2 df, p=0.062). Also the time spent on vector control by farmers themselves was greater for focused control farmers than for standard control farmers. However, the average was influenced by a few focused control farms which spent a high number of days on vector control, whereas the medians for the focused and standard control farms were similar. The difference seen in the average time spent across all farms in the three farm groups was not statistically significant (Kruskal-Wallis test $\chi^2$=10.88, 2 df, p=0.004).

## Attitudes towards TB and its control

The relevant information on focused control farms was collected in the second part of the questionnaire, which was conducted during the fourth farm visit, early 1998, about half way through the project. For two of the standard control farms it was not possible to obtain information on attitudes, as the herd managers had deceased.

Figure 31 presents the importance that was placed on TB eradication by focused control, standard control, and non-TB farmers. Thirty (88.2%) of the 34 focused control farmers considered the eradication of TB as crucial, two as important, and one each as moderately important or of minor importance. Of the 31 standard control farmers with relevant information, 23 (74.2%) considered TB eradication as crucial, six as important and two as minor. Of the 39 non-TB farms with relevant information, 35 (89.7%) considered TB eradication as crucial, three as important, and one as moderately important. This difference was not significant (Chi-squared test for crucial, combining all other categories due to small numbers: $\chi^2$=3.72, 2 df, p=0.156).

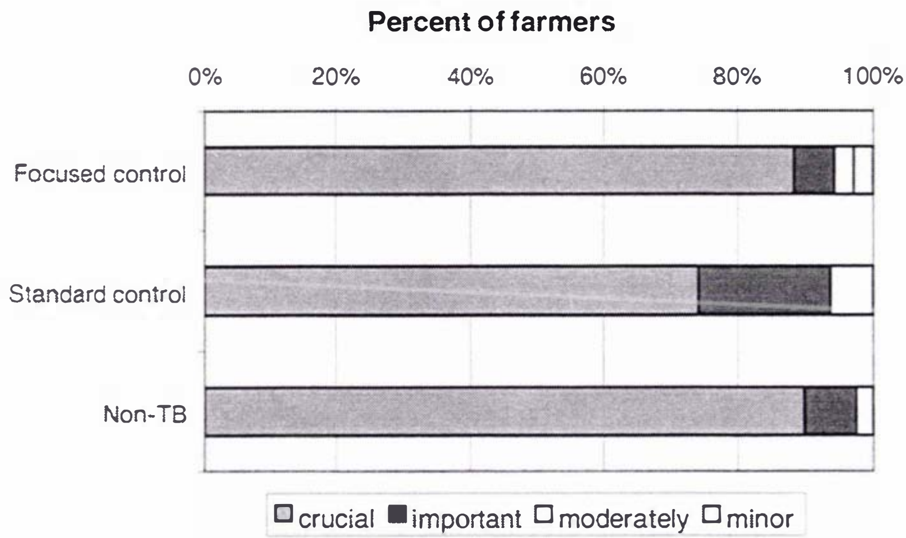



**Figure 31. Importance of TB eradication as considered by Wairarapa focused control, standard control and non-TB farmers.**

Most farmers thought TB eradication was possible on their farms (73.5% (n=25) focused control farmers, 74.2% (n=23) standard control farmers). Only six focused control farmers and five standard control farmers considered TB eradication on their properties impossible due to vegetation and habitat factors. Three farmers in each group answered 'unknown' to this question. This question was not asked in the questionnaire with the non-TB farmers, as they did not have TB on their property.

When farmers were asked if Movement Control should be made stricter, what the effect of having to pay their own TB testing costs directly would be, and what the effect of removal of compensation would be, there were slight differences between the three farm groups (Table 30). While farmers were also asked for the reasons for their responses, not all farmers gave specific reasons to this question.

**Table 30. Attitudes towards TB control by Wairarapa focused control, standard control, and non-TB farmers (percentages of farm group in brackets).**

| | | Focused control (n=34) | Standard control (n=31) | Non-TB (n=42) |
|---|---|---|---|---|
| Movement Control | stricter | 10 (29.4%) | 9 (29.0%) | 20 (47.6%) |
| | Less strict | 23 (67.6%) | 18 (58.1%) | 15 (35.7%) |
| | Unknown[a] | 1 (3.0%) | 4 (12.9%) | 7 (16.7%) |
| Effect of directly paying TB testing | positive | 6 (17.6%) | 5 (16.1%) | 6 (14.3%) |
| | negative | 25 (73.5%) | 23 (74.2%) | 25 (59.5%) |
| | Unknown | 3 (8.8%) | 3 (9.7%) | 11 (26.2%) |
| Effect of removal of compensation | Positive | 5 (14.7%) | 7 (22.6%) | 13 (31.0%) |
| | Negative | 21 (61.8%) | 15 (48.4%) | 18 (42.9%) |
| | NoChange[b] | 8 (23.5%) | 9 (29.0%) | 11 (26.2%) |

[a] includes 1 Wairarapa non-TB with no response to this question
[b] includes 4 Wairarapa non-TB with no response to this question

Nearly half the farmers with TB free herds were in favour of stricter Movement Control, whereas less than a third of the focused and standard control farms shared this opinion. However, across the three farm groups there was no statistically significant difference ($\chi^2$=9.57, 4 df, p=0.046). Figure 32 presents the percentage of answers given by the farmers to this question.

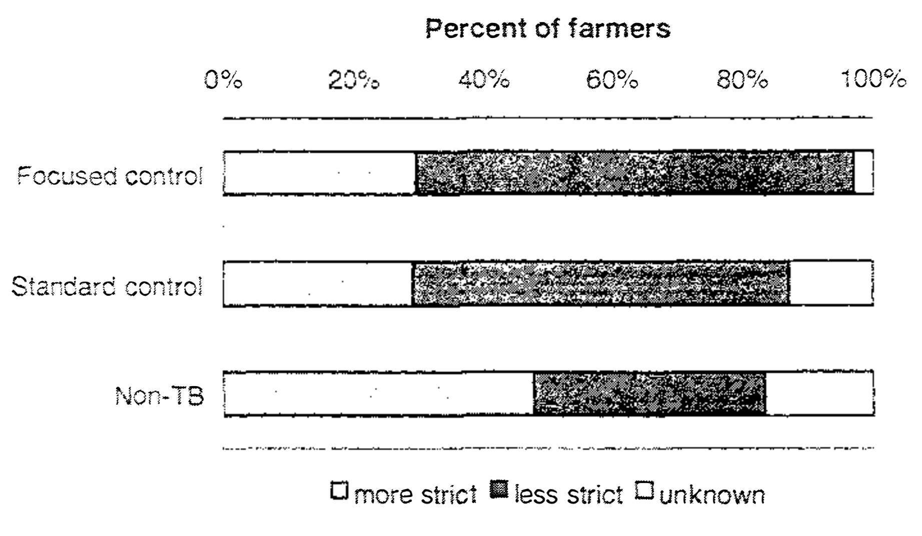



**Figure 32. Attitudes of farmers towards Movement Control restrictions, if they should be stricter or less strict, stratified by Wairarapa focused control, standard control, and non-TB farmers.**

Twenty-four of 39 farmers (61.5%) who indicated that MC should be stricter, argued that the risk of spreading TB could be reduced by this measure. Of the 56 farmers that were in favour of less strict MC regulations, 17 (33.9%) believed that the penalty was already high enough and that any further restrictions would impede the financial situation of the farm and therefore the likelihood of vector control being performed on the farm.

There were no differences in the proportion of farmers in each group associated with the effects which they believed paying TB testing costs directly would have. Between 14% to 17% of the farmers believed in a positive effect of paying TB testing costs directly. Of a total of 17 farmers with this opinion 15 argued that this would give farmers financial incentives to pursue TB control more effectively. Of the 73 farmers who believed in a negative effect of having to pay TB testing costs directly, the main arguments were lost co-operation by farmers (n=19), the reasoning that TB is a national problem not a problem of individual farmers (n=6), and that this would result in less available resources for TB control on farms (n=6).

With regards to the effect of removing compensation for TB reactor cattle, there were no differences between the three farm groups (Figure 33). The non-TB farmers had the highest percentage of farmers believing in a positive effect of removing compensation. Of 25 farmers who believed in a positive effect of removal of compensation, 21 used the argument of additional financial incentive for this effect. Lost co-operation, e.g. farmers testing less frequently, or not presenting all animals for testing, was the main argument for the negative effect of removal of compensation (n=42 of 54 farmers).

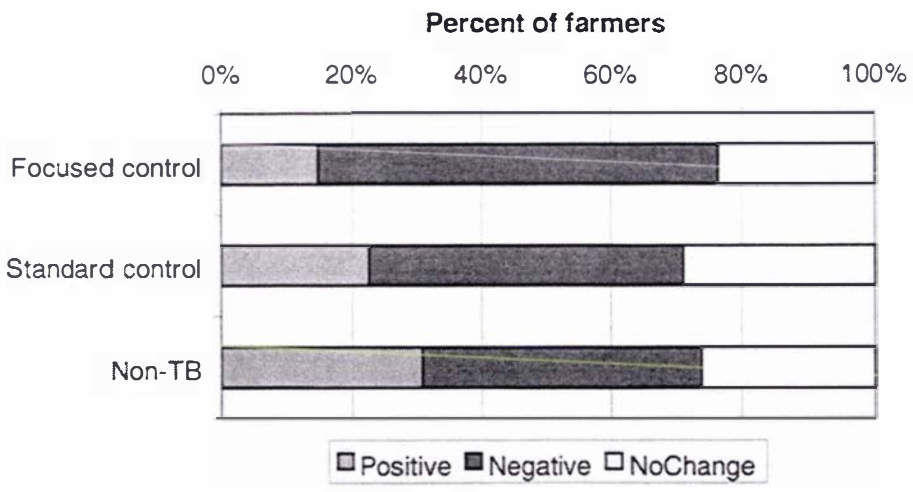



**Figure 33. Farmers' belief regarding the effect of removing compensation for TB reactor cattle, stratified by Wairarapa focused control, standard control, and non-TB farmers.**

When farmers were asked whether they could see any value in vector control or other forms of TB control being conducted by farmers themselves, four main answer categories were found. Some farmers believed that farmers should/could help the Regional Council and continue their work once a main vector control programme had been conducted. Other farmers thought it reasonable that farmers look after their own properties, whereas others did not see any importance or responsibility for vector control by farmers or argued that this would not be effective as not all farmers would participate. Table 31 gives the distribution of these four categories amongst the answers of the three farm groups.

**Table 31. Importance of farmer conducted vector control as seen by the three farm groups – focused control, standard control, and non-TB farmers.**

| | Focused control farmers (n=34) | Standard control farmers (n=31) | Non-TB farmers (n-42) |
|---|---|---|---|
| Help RC/ continue | 8 (23.5%) | 13 (41.9%) | 18 (42.9%) |
| Responsible for own farm | 8 (23.5%) | 6 (19.4%) | 3 (7.1%) |
| Not effective / responsibility of RC | 3 (8.8%) | 4 (12.9%) | 5 (11.9%) |
| No importance seen in conducting own vector control on farm | 9 (26.5%) | 8 (25.8%) | 15 (35.7%) |
| Other answers or no answer | 6 (8.7%) | 0 | 1 (2.4%) |

The focused control farmers had the largest proportion of farmers believing that farmers are 'responsible for their own farm', while the non-TB farmers had the highest proportion of farmers that did not see any importance in conducting their own vector control on their farms. Statistically there was no difference between the farm groups with respect to the answer categories after applying the correction term ($\chi^2$=16.49, 8 df, p=0.030).

Farmers were asked whom they thought responsible for the eradication of TB, whereby they could nominate more than one institution/organisation. They were also asked to give priorities to these organisations. Table 32 gives the seven most nominated organisations and the number of farms that ranked the organisations with highest priority. Figure 34 presents the percentage of all farmers considering the different organisations as being responsible for TB eradication and the number of times, the different organisations were given highest priority in being responsible.

The nominations were similar across the three farm groups. A wide range of organisations/ institutions was mentioned by the farmers, with Government and AHB/AgriQuality receiving most frequently receiving highest priority. A slightly higher percentage of non-TB farmers voted 'only farmers with the problem' (19.0 %) as the highest priority compared with focused and standard control farmers (8.8 %, respectively 6.5 %). However, there was no statistical significant difference between the answer groups across the three farm groups ($\chi^2$=14.40, 14 df, p=0.431).

**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.**

| | Focused control farmers | Standard control farmers | Non-TB farmers | % of all farmers (n=107)[a] |
|---|---|---|---|---|
| Government | 23 (19) | 26 (11) | 27 (12) | 71.0 % |
| Regional Council | 23 (5) | 24 (4) | 28 (9) | 70.1 % |
| All farmers | 25 (10) | 23 (7) | 26 (6) | 69.2 % |
| AgriQuality and Animal Health Board | 17 (7) | 20 (4) | 34 (29) | 66.4 % |
| All landowners | 19 (9) | 20 (7) | 22 (7) | 57.0 % |
| Only farmers with the problem | 3 (3) | 6 (2) | 14 (8) | 21.5 % |
| Other organisations/groups | 7 (2) | 10 (0) | 5 (1) | 20.6 % |
| Local farming group | 6 (1) | 3 (0) | 3 (0) | 11.2 % |

[a] on two standard control farms this information could not be obtained

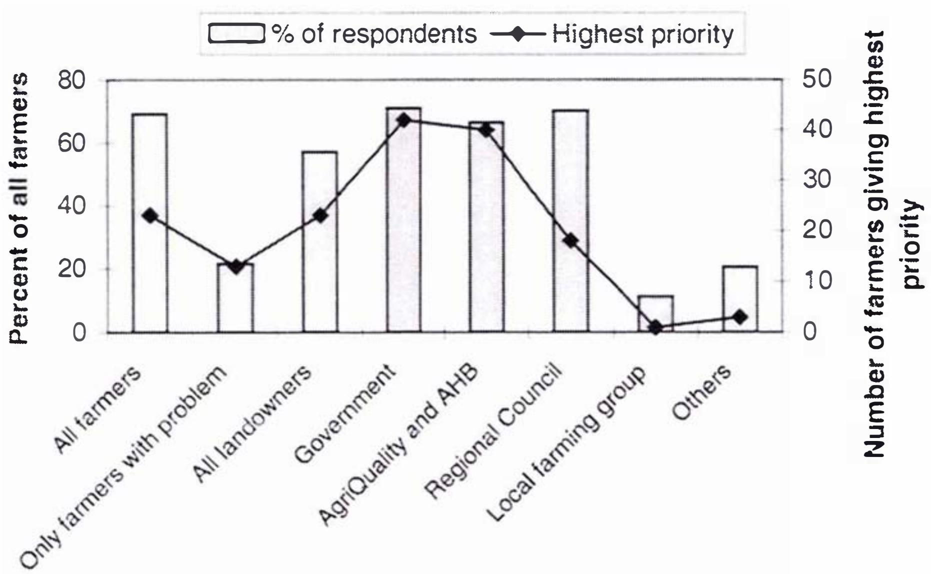



**Figure 34. Organisations/institutions perceived as being responsible for TB eradication.**

Table 33 gives a similar presentation of organisations that were held responsible by the farmers for actually doing the work required to eradicate TB.

**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.**

| | Focused control farmers | Standard control farmers | Non-TB farmers | % of all farmers (n=107)[a] |
|---|---|---|---|---|
| Regional Council | 31 (15) | 26 (12) | 28 (17) | 79.4 % |
| All farmers | 17 (5) | 17 (3) | 20 (6) | 50.5 % |
| AgriQuality and Animal Health Board | 13 (4) | 17 (2) | 24 (10) | 50.5 % |
| All landowners | 15 (5) | 12 (1) | 20 (10) | 43.9 % |
| Government | 12 (5) | 16 (5) | 18 (8) | 43.0 % |
| Only farmers with the problem | 5 (4) | 14 (7) | 14 (7) | 30.8 % |
| Other organisations/groups | 5 (2) | 8 (0) | 3(1) | 14.9 % |
| Local farming group | 5 (2) | 2 (0) | 3 (0) | 9.3 % |

[a] on two standard control farms this information could not be obtained

The Regional Council was the most frequently nominated organisation, followed by AgriQuality/ Animal Health Board and 'all farmers'. Around one third of farmers nominated 'only farmers with the problem' as being responsible for actually doing the work required to eradicate TB.

Farmers were asked where they would expect help from if they had to do their own vector control on their farms, and what expectations of help they would have from these organisations. The most sought-after organisation was the Regional Council. Twenty-eight (82.4%) focused control, 24 (77.4%) standard control and 31 (73.8%) non-TB farmers expected help from the Regional Council. The main help expected from Regional Council was subsidised poison, traps and bait stations (n=33), advice (n=28), actual work (n=18) and funding (n=15).

The second most frequently mentioned organisation from which farmers expected help if they had to conduct their own vector control was AgriQuality/Animal Health Board. Nineteen (55.9%) focused control, 22 (71.0%) standard control and 16 (38.1%) non-TB farmers would expect help from AgriQuality/AHB. Advice (n=20), funding (n=7) and co-ordination (n=4) was the main help expected from these organisations.

Eleven (32.4%) focused control, 11 (35.5%) standard control farmers and 12 (28.6%) non-TB farmers expected help from Government, whereby financial help was mostly expected (n=23). Thirteen (38.2%) focused control, six (19.4%) standard control and four (9.5%) non-TB farmers would also have expected co-operation of their neighbours if they had to control vectors themselves.

## Perceived cost of TB and its control by farmers

Farmers were also asked what their perception was of the costs of TB and its control to their farms. Information for the focused control farms regarding this was collected in the first part of the questionnaire in 1997. For two of the standard control farms this information could not be collected and this question was not asked in the questionnaires for the non-TB farmers. Table 34 gives the distribution for the focused and standard control farms.

**Table 34. Estimated costs of TB and its control to Wairarapa focused and standard control farms.**

| | | Focused control farmers | Standard control farmers |
|---|---|---|---|
| Cost of TB to the farm | = 0 | 12 | 14 |
| | > 0 | 17 (avg $11,214, range $650 - $50,000) | 17 (avg $9,759, range $150 - $75,000) |
| | Unknown | 5 | 0 |
| Cost of poison | = 0 | 11 | 15 |
| | > 0 | 21 (avg $562, range $45 - $2,500) | 16 (avg $952, range $30 - $4,200) |
| | Unknown | 2 | 0 |
| Cost of labour | = 0 | 29 | 21 |
| | > 0 | 4 (avg $1,288, range $50 - $2,000) | 7 (avg $792, range $150 - $2,000) |
| | Unknown | 1 | 3 |

Only about half the farmers put a cost greater than zero on the effect of TB on their farms, with a wide range of estimates. The reasons given for the costs focused on lost opportunities (14 focused control farmers, 7 standard control farmers), lost reactor value (2 focused control farmers, 7 standard control farmers), and inconvenience and time involved in TB testing (7 focused control and two standard control farmers). Other reasons given were costs due to levies and rates (n=2), lost production (n=3) and cost due to potential export threats (n=1).

Most farmers (n=50; 76.9%) did not put any cost on their own labour, they argued that they do it as part of their normal management.

### Multivariate analysis between Wairarapa focused and standard control farms

In order to assist the interpretation of the Bonferroni correction, an uncorrected univariate analysis was followed by a logistic regression comparing focused control with standard control farms. Five variables had p-values of less than 0.10 in the univariate analysis: buying frequency, the likelihood of contact between livestock and possums, the likelihood of contact between livestock and ferrets, the total number of days spent by farmers on vector control and the variable sociable in the self-concept. A logistic regression was conducted with these five variables. Only one variable was significant (buying frequency with Wald statistic 7.08, p=0.029), which was less than expected by chance.

## ***National study farms***

### General farm characteristics

The questionnaires were used to compare general farm characteristics for the two farm groups. Although the farmers were interviewed in 2000, they were asked to give stock numbers as they had been in June 1998. This way the stock numbers related more closely to the time period when the project was actively conducted. One farmer was unable to provide stock numbers as he had left the farm and could not remember.

Table 35 shows some of the general farm characteristics on income, farm size and labour units for the two farm groups. In total 16% (n=15) of the national farms used off-farm grazing. Around 50% of the farm income is generated through sheep and less than 40% through cattle.

**Table 35. General farm characteristics of National focused and standard control farms.**

| | Focused control (n=33)[a] | Standard control (n=63) |
|---|---|---|
| Farmed area (ha) [b] | 1570.7 | 1915.3 |
| Number of farms using off-farm grazing | 7 (21.2 %) | 8 (12.7 %) |
| Self-concept average value [c] | 3.22 (n=30) | 3.24 (n=58) |
| Income from cattle (% of total income) | 37.55 | 37.95 |
| Income from sheep (% of total income) | 46.53 | 50.48 |
| Income from deer (% of total income) | 14.27 | 9.84 |
| Full time labour units on farm | 2.18 | 1.99 |

[a] gives the sample size for each farm group, unless otherwise stated
[b] is the total number of effective hectares on the home property, plus other owned land if less than 100km away, plus leased land if less than 100km away
[c] from Seabrook (1984)

The average size of all farms in the National project was 1796.9 ha of effective land (s.e.=313.3, n=96, median 650 ha). A frequency distribution of farm size for all farms is shown in Figure 35.

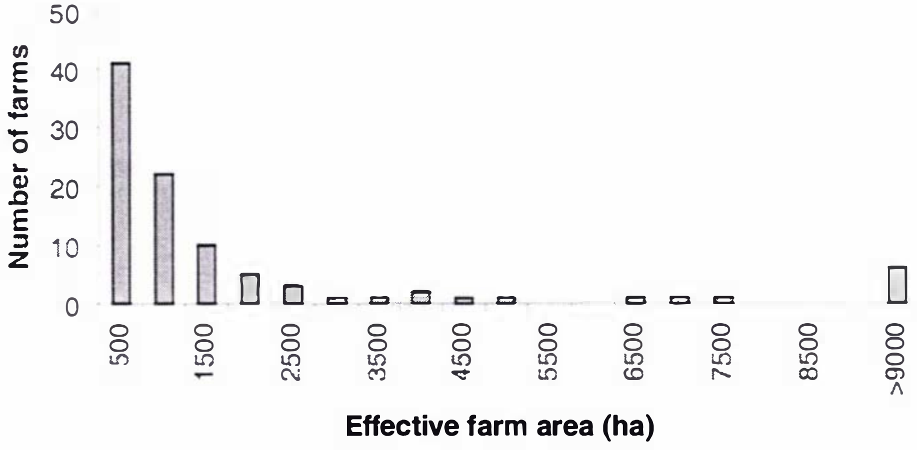



**Figure 35. Effective farm size distribution of all farms included in the national study.**

The size of focused control farms did not differ significantly from standard control farms, as shown in (Figure 36).

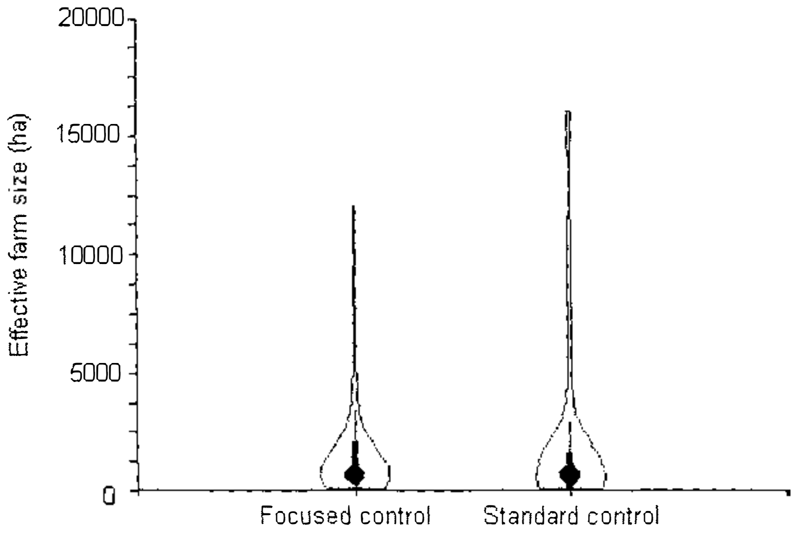



**Figure 36. Violin plots for effective farmed area of national focused and standard control farms.**

Table 36 presents the average effective farm size for the different enterprise types. As there were only three beef finishing farms within the national farm group, these were combined with the beef breeding farms to make 'beef' farms.

**Table 36. Average farmed area stratified by herd type and national farm group (with range in brackets).**

| | Focused control farms | | Standard control farms | |
|---|---|---|---|---|
| Beef | 1994.5 (62 - 7500) | n=24 | 2422.0 (126 - 14560) | n=46 |
| DH | 338.8 (342 - 12000) | n=4 | 132.9 (80 -16121) | n=7 |
| Deer | 525.2 (197 - 500) | n=5 | 832.2 (100 - 185) | n=10 |

On average the farms comprised a total of 6924 livestock units (n=95 herds; s.e.=990.19; median 4411, n=95). This was made up of 2807 cattle SU (s.e.=861.31; median 1365.5), 3733 sheep SU (s.e.=413.35; median 2630) and 328 deer SU (s.e.=84.16; median 0). Only 90 farms had cattle, 78 had sheep and 29 had deer on the property. Cattle and deer comprised an average proportion of 0.49 (s.e.=0.032; median 0.38) of the total number of livestock units kept on the farms. The average cattle/deer density on the national farms was 3.8 SU per effective hectare of land (s.e.=0.36; median 2.70). Table 37 presents this information for the focused and standard control farms.

**Table 37. Livestock units and stock densities of cattle and deer on national focused and standard control farms.**

| | Focused control farms (n=33) | Standard control farms (n=63) |
|---|---|---|
| Average livestock units on farm | 6944 (s.e.=1238, median 5141) | 6913 (s.e.=1361; median 4256) |
| Cattle and deer proportion of total SU[a] | 0.53 (s.e.=0.055; median 0.41) | 0.47 (s.e.=0.039; median 0.37) |
| Cattle and deer density (CSU + DSU)/ha | 3.80 (s.e.=0.523; median 3.19) | 3.73 (s.e.=0.484; median 2.36) |

[a] SU = livestock units

## Herd manager

One of the standard control farmers did not respond to this part of the questionnaire, resulting in a total number of 95 farms.

The median age of herd managers of focused and standard control farms was 40-50 years (Figure 37). The age distributions were bell curve shaped with smaller numbers of farmers in the extremities and the majority of farmers in the central age groups.

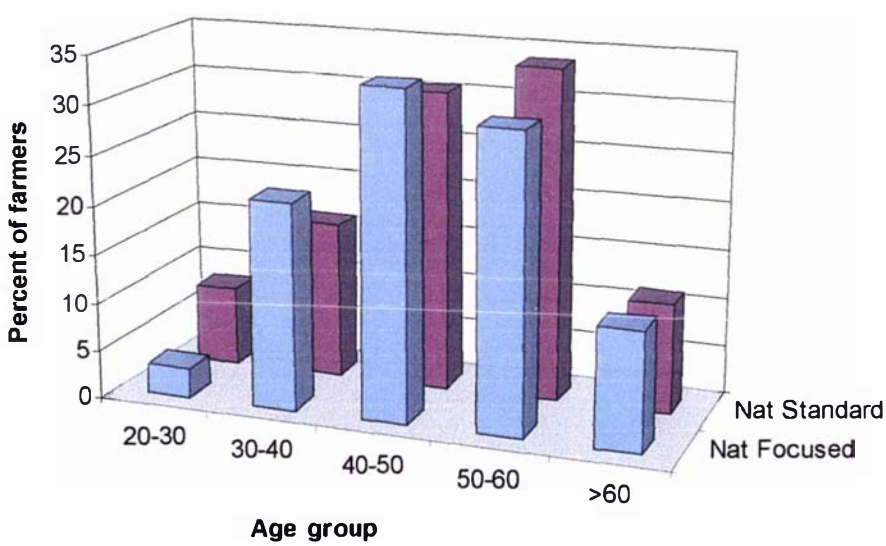



**Figure 37. Distribution of age groups for herd managers of national focused and standard control farms.**

Table 38 presents some of the information on herd managers for focused and standard control farms. There were no obvious differences in these characteristics between the focused and standard control farms. The majority of herd managers, 96.8% (n=92), lived on the farm; 21.1% (n=20) had additional employment; and 80.0% (n=76) farmers covered their living expenses through the farm income. Only one of the 95 farmers was female.

Eighty percent (n=76) of interviewees owned the farm, one farmer was a share milker and 16.8% (n=16) were managers of the farm, two were associated in other ways with the farm they worked on. Fifty-nine percent (n=56) of all farmers considered themselves to be the main decision makers for the farm. Farmers had worked an average of 18.6 years (s.e.=1.23, median=18) on their current farms, while they had worked in farming an average of 29.6 years (s.e.=1.27, median=30).

Nineteen percent of herd managers (n=18) started their farming job without a farming background, whereas 81.1% (n=77) were brought up on a farm. Sixty-six percent (n=63) of herd managers had no formal farming-specific qualification. A higher percentage of herd managers of focused control farms than of standard control farms had a formal qualification (42.4% (n=14) herd managers of focused control farms versus 30.6% (n=19) herd managers of standard control farms, however, this difference was not significant, $\chi^2$=1.30, 1 df, p=0.253).

**Table 38. Information on herd managers for national focused and standard control farms.**

| | Focused control farmers (n=33) | Standard control farmers (n=62) |
|---|---|---|
| Live on farm | 30 (90.9%) | 61 (98.4%) |
| Cover living expenses from farm income | 27 (81.8%) | 49 (79.0%) |
| Owner of farm | 26 (78.8%) | 50 (80.6%) |
| Major decision maker | 22 (66.7%) | 34 (54.8%) |
| Average working time on current farm | 18.79 (s.e.=2.20; median 20) | 18.23 (s.e.=1.51, median 16, n=61) |
| Average working time on farms | 29.94 (s.e.=2.19; median 34) | 29.23 (s.e.=1.58, median 30) |
| Farming background | 26 (78.8%) | 50 (80.6%) |
| Formal qualification | 14 (42.4%) | 19 (30.6%) |

Interviewees were also asked to fill in a self-concept form, which was adapted from Seabrook (1984). In total 88 farmers responded to this part of the questionnaire. Figure 38 shows the arithmetic means of personality traits for the focused and standard control farmers.

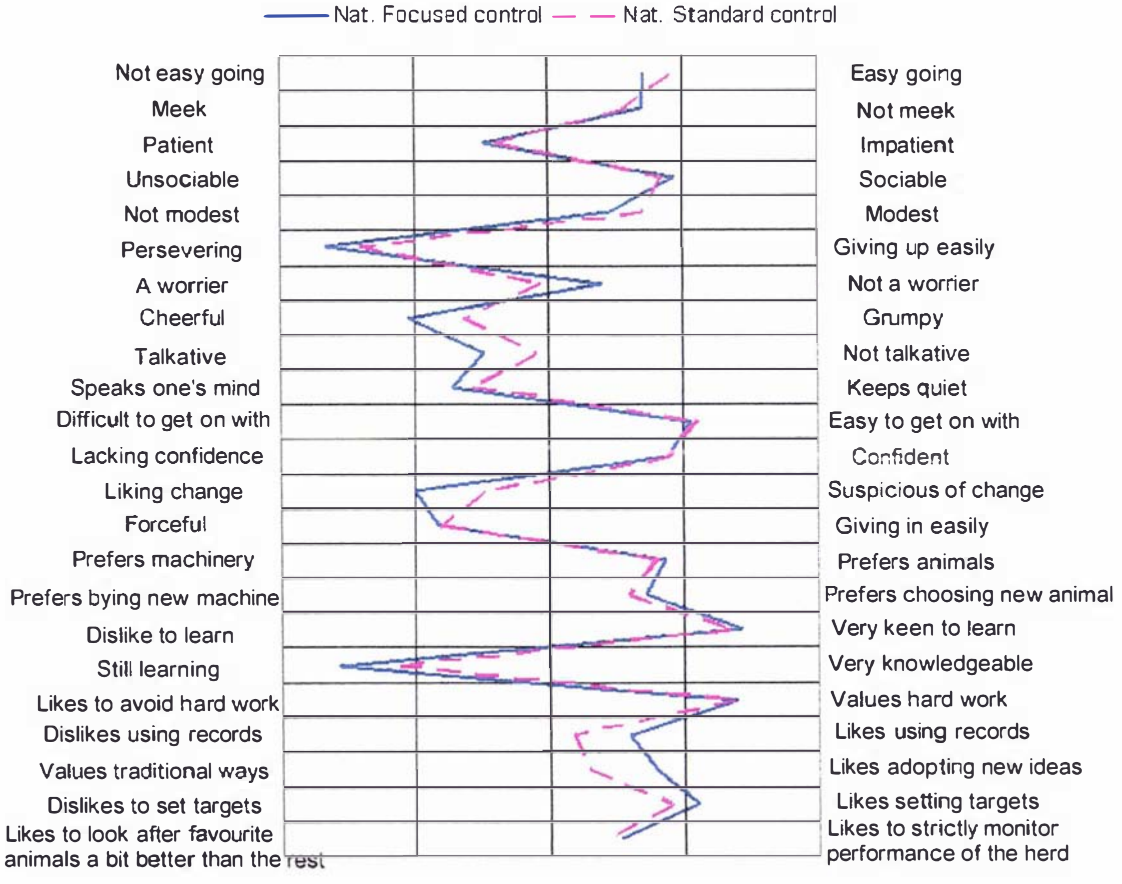



**Figure 38. Personality trait means for national focused and standard control farms (adapted from Seabrook, 1984).**

Differences were found between herd managers in the focused and standard control farm groups. Herd managers of focused control farms tended to be less worrying (Mann-Whitney U test, $Z=1.90$, $p=0.057$), more cheerful ($Z=-2.24$, $p=0.015$), more talkative ($Z=-1.62$, $p=0.106$), more open to change ($Z=-2.51$, $p=0.012$) and new ideas ($Z=1.80$, $p=0.071$), considered themselves much more as still learning ($Z=-2.50$, $p=0.012$) and preferred using records ($Z=1.68$, $p=0.092$) more than herd managers of standard control farms. However, after applying the correction term as numerous tests were conducted, these differences were not statistically significant.

## Stock management

Farmers were also asked about their stock movements on and off the farm. Table 39 presents the results for the two national farm groups. There were no significant differences in the frequency of buying white-tagged cattle, nor the frequency of buying any cattle, nor the importance of trading between the two farm groups (p uncorrected > 0.10).

**Table 39. Information on stock movements on and off farms for national focused and standard control farms.**

| | | Focused Control (n=33) | Standard Control (n=63) |
|---|---|---|---|
| White Tagged cattle bought | Yes | 5 (15.2%) | 4 (6.3%) |
| | No | 28 (84.8%) | 59 (93.7%) |
| Buying frequency | Every year | 9 (27.3%) | 25 (39.7%) |
| | Now and again | 9 (27.3%) | 14 (22.2%) |
| | Other/never[a] | 15 (45.4%) | 24 (38.1%) |
| Trading importance | Crucial | 5 (15.2%) | 11 (17.5%) |
| | Important | 5 (15.2%) | 18 (28.6%) |
| | Moderately | 9 (27.3%) | 6 (9.5%) |
| | Minor/unimport. | 14 (42.4%) | 28 (44.4%) |
| | Not stated | | |

[a] farms that only bought in single bulls for breeding purposes were classified under 'other'

Eighteen (54.5%) national focused control and 34 (54.0%) national standard control farmers indicated that they had changed their stock selling policies due to having TB in their herds. Eight (24.2%) national focused control and 16 (25.4%) national standard control farmers also indicated that they had changed their mix of stock classes as a result of TB. Most farmers changed from selling weaners to finishing more stock themselves.

## TB risk assessment

Table 40 presents information on the reasons farmers suspect to be the cause of TB infection in their herd, about high TB risk areas, neighbouring herds and TB reactor numbers, stratified for national focused and standard control farms.

**Table 40. Information on the TB situation and perception of national focused and standard control farms.**

| | | Focused control (n=33) | Standard control (n=63) |
|---|---|---|---|
| TB problem classification | Continuous | 14 (42.4%) | 15 (23.8%) |
| | On and off | 12 (36.4%) | 25 (39.7%) |
| | Seldom | 4 (12.1%) | 14 (22.2%) |
| | No problem anymore | 3 (9.1%) | 9 (14.3%) |
| Reason for TB infection[a] | TB feral animals | 31 (93.9%) | 55 (87.3%) |
| | Neighbouring herds | 13 (39.4%) | 24 (38.1%) |
| | Stock movements | 1 (3.0%) | 12 (19.0%) |
| High risk areas for TB suspected on farm | Yes | 22 (66.7%) | 25 (39.7%) |
| | No | 8 (24.2%) | 19 (30.2%) |
| | Unknown/not stated | 3 (9.1%) | 19 (30.2%) |
| Graze cattle in high risk areas | Yes | 18 (81.8%) | 20 (80%) |
| | No | 4 (18.2%) | 5 (20%) |
| Any neighbouring farms infected with TB | Yes | 32 (97.0%) | 55 (87.3%) |
| | No | 0 | 2 (3.2%) |
| | Unknown | 1 (3.0%) | 6 (9.5%) |
| Reactor numbers over last three years | Increased | 4 (12.1%) | 6 (9.5%) |
| | Decreased | 24 (72.7%) | 43 (68.3%) |
| | No change/not stated | 5 (15.2%) | 14 (22.2%) |

[a] multiple answers were possible

The national focused control farms had a higher proportion of farmers who believed that the TB problem in their herd was continuous, compared with the standard control far ers ($\chi^2$=3.56, 1df, p=0.059). However, after applying the correction term for numerous tests, this difference was not statistically significant.

Most farmers regarded infected wildlife as the source of TB infection in their herds, around 40% of farmers believed that the neighbouring herds could have been a source, whereas stock movements on and off far s were only mentioned by a minority of farmers.

A higher proportion of focused control far ers knew or suspected high risk areas for TB on their far s, whereas a higher proportion of the standard control far ers were unsure about such risk areas (Chi-squared test over the three categories and the two farm groups $\chi^2$=7.68, 2 df, p=0.021; which was not significant after the correction ter was applied).

## Vectors and vector control on farms

Farmers provided information on how likely they thought it was that there was contact between their livestock and feral animals. Table 41 presents the data for possums and ferrets stratified for focused and standard control farms. Slightly more than half the focused and standard control farmers believed that contact with possums was very likely, while between 35% and 42% believed that contact between livestock and ferrets was very likely.

**Table 41. Assumed likelihood of contact between possums/ferrets and livestock, as indicated by national focused and standard control farmers.**

| | | Focused control farms | Standard control farms |
|---|---|---|---|
| Likelihood of contact with possums | Very likely | 18 (54.5%) | 34 (54.0%) |
| | Possible | 11 (33.3%) | 25 (39.7%) |
| | Unlikely | 4 (12.2%) | 0 |
| | Unknown / not stated | 0 | 4 (6.3%) |
| Likelihood of contact with ferrets | Very likely | 14 (42.4%) | 22 (34.9%) |
| | Possible | 10 (30.3%) | 22 (34.9%) |
| | Unlikely | 3 (9.1%) | 3 (4.8%) |
| | Unknown / not stated | 6 (18.2%) | 16 (25.4%) |

Farmers were also asked about vector control on their properties, what percentage of land was controlled by themselves and/or by the Regional Council and how much time was spent on these controls (see Table 42 and Figure 39).

**Table 42. Vector control by Regional Council and farmers as stated by national focused and standard control farmers.**

| | | Focused control | Standard control |
|---|---|---|---|
| Avg % of farm controlled by RC[a] | | 82.1% (n=31) | 78.6% (n=49) |
| Avg % of farm controlled by farmer[a] | | 68.6% (n=32) | 62.0% (n=45) |
| Regional Council control | Increased | 10 (30.3%) | 17 (27.0%) |
| | Decreased | 6 (18.2%) | 21 (33.3%) |
| Farmer Control | Increased | 13 (39.4%) | 18 (28.6%) |
| | Decreased | 9 (27.3%) | 18 (28.6%) |
| Farmer Control (days/year) | = 0 | 1 (3.0%) | 14 (22.2%) |
| | > 0 | 32 (97.0%) | 49 (77.8%)[b] |
| | | (median 20, avg 34.3, range 1 – 275) | (median 13, avg 28.4, range 2.5 – 365) |
| Regional Council (days/year) | = 0 | 5 (15.2%) | 25 (39.7%) |
| | > 0 | 28 (84.8%) | 38 (60.3%) |
| | | (median 10, avg 12.7, range 1 – 40) | (median 10, avg 14.2, range 2 – 80) |
| Farmer Control | Regularly | 6 (18.2%) | 18 (28.6%) |

[a] according to the farmer
[b] four farmers conducted vector control, but considered the area controlled by themselves as being zero

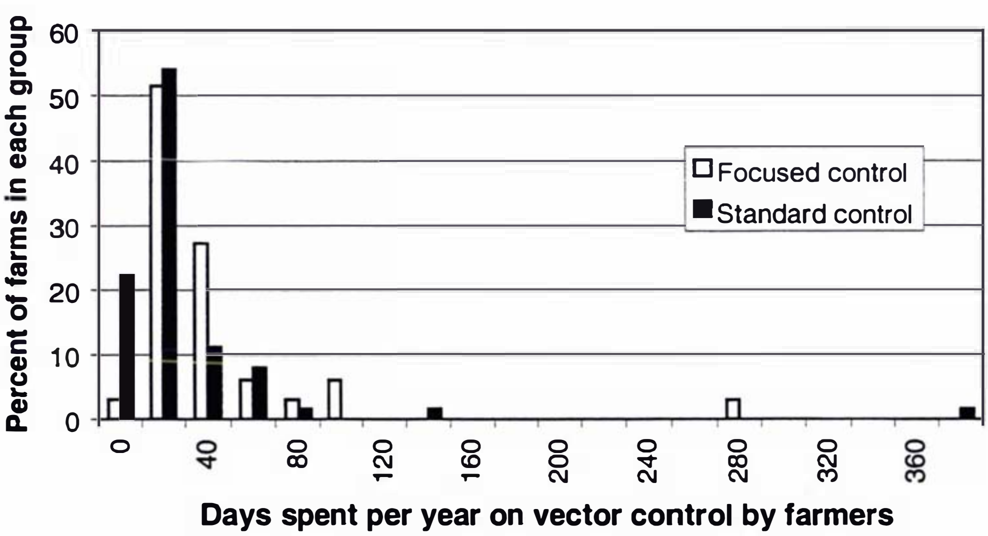



**Figure 39. Days spent per year on vector control by national focused control and standard control farmers.**

While a higher proportion of focused control farmers than standard control farmers conducted their own vector control, this difference was not significant after applying the correction term (Mann-Whitney U test Z=2.64, p=0.008). The time spent on vector control by farmers themselves was greater for focused control than for standard control farmers, but this difference was also not statistically significant after correction for numerous tests (Mann-Whitney U test Z=2.33, p=0.020).

## Attitudes towards TB and its control

Farmers were asked about their attitudes towards TB control and possible changes in the future. For most the farmers eradication of TB was crucial (Figure 40). Twenty-seven (81.8%) of the 33 national focused control farmers and 34 (54.0%) of the 62 national standard control farmers with relevant information, considered TB eradication as crucial. Although this difference was statistically significant in the test (Chi-squared test for crucial, all other categories were combined $\chi^2$=6.75, 1 df, p=0.009) it was not considered significant after the application of the correction term.

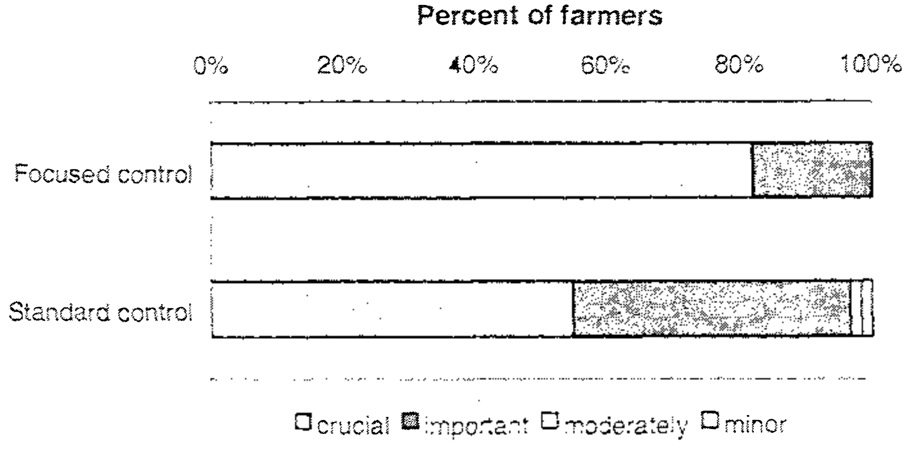



**Figure 40. Importance of TB eradication as considered by national focused and standard control farmers.**

Most farmers thought TB eradication was possible on their farms (75.8% (n=25) focused control farmers and 71.4% (n=45) standard control farmers). Six focused control and nine standard control farmers considered TB eradication on their properties impossible due to vegetation and habitat factors. Two focused control farmers and nine standard control farmers answered 'unknown' to the question about whether or not it is possible to eradicate TB on their properties.

Answers obtained by focused and standard control farmers regarding their attitude to stricter Movement Control restrictions, having to pay their own TB testing costs directly and about the effect of removing compensation for reactor cattle are presented in Table 43. The farmers were also asked for their reasons why they chose the responses, but not all farmers gave specific reasons to this question.

**Table 43. Attitudes towards TB control by national focused and standard control farmers (percentages of farm group in brackets).**

| | | Focused control farmers | Standard control farmers |
|---|---|---|---|
| Movement Control | stricter | 21 (63.6%) | 28 (44.4%) |
| | Less strict | 12 (36.4%) | 24 (38.1%) |
| | Unknown[a] | 0 | 11 (17.5%) |
| Effect of directly paying TB testing | positive | 6 (18.2%) | 11 (17.5%) |
| | negative | 25 (75.8%) | 41 (65.0%) |
| | Unknown[b] | 2 (6.0%) | 11 (17.5%) |
| Effect of removal of compensation | Positive | 6 (18.2%) | 12 (19.0%) |
| | Negative | 21 (63.6%) | 35 (55.5%) |
| | NoChange[b] | 6 (18.2%) | 16 (25.4%) |

[a] includes 3 national standard control farmers with no response to this question
[b] includes 1 national standard control farmers with no response to this question

A higher proportion of focused control farmers were in favour of stricter MC regulations (Figure 41). Thirteen focused control and 19 standard control farmers that where in favour of stricter MC regulations gave the reason that it would result in a reduced risk of spreading TB. Of the 36 farmers that were in favour of less strict MC regulations, five in each group (15.2% focused control farmers, 7.9% standard control farmers) believed that the penalty is already high enough.

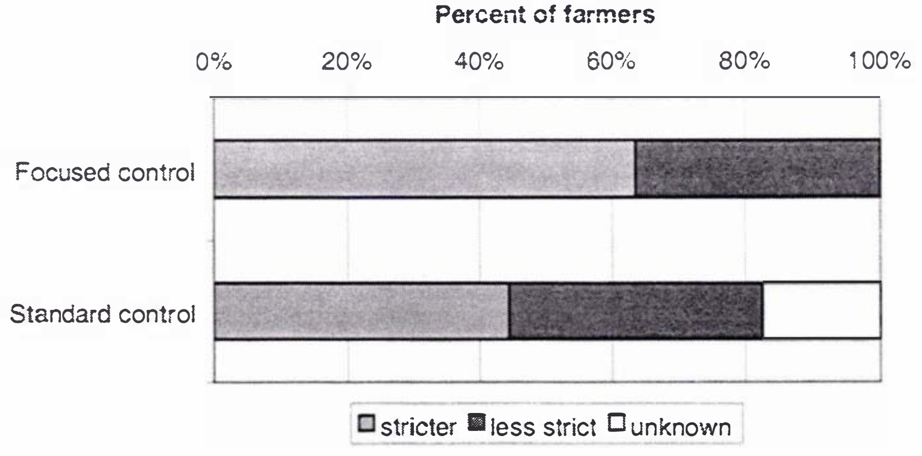



**Figure 41. Percent of national focused and standard control farmers who believed Movement Control restrictions should be more or less strict.**

There was no difference in the proportion of farmers per group who judged the effect of having to pay TB testing costs directly as being positive or negative (see Table 43). Around 18% (n=17) of farmers believed in a positive effect of paying directly, reasoning that this would increase the financial incentive for farmers to control TB (n=1 focused and n=4 standard control farmers). The main arguments for the 66 farmers who believed in a negative effect of having to pay TB testing costs directly were lost co-operation of farmers (n=27), TB is a national problem not a problem of individual farmers (n=5), and that this would result in less available resources for TB control on farms (n=5).

Most farmers (64% of focused control farmers and 56% of standard control farmers) were not in favour of removing compensation for reactor cattle. Of the 56 farmers who believed in a negative effect of removing compensation, 46 argued that it would result in lost co-operation, e.g. farmers testing less frequently, or not presenting all animals for testing. Eighteen to 19% of farmers believed in a positive effect, associated with increased financial incentive (n=11).

The reasons given by farmers in relation to their response to the question about conducting their own vector control or other TB control programmes, are given in Table 44.

**Table 44. Importance of farmer conducted vector control as seen by focused and standard control farmers.**

| | Focused control farmers | Standard control farmers |
|---|---|---|
| Help RC/ continue | 17 (51.5%) | 31 (49.2%) |
| Responsible for own farm | 4 (12.1%) | 4 (6.3%) |
| Not effective / responsibility of RC | 8 (24.2%) | 5 (7.9%) |
| No importance seen in conducting own vector control on farm | 0 | 19 (30.2%) |
| Other answers or no answer | 4 (12.1%) | 4 (6.3%) |

There was a significant difference in the answers given by focused and standard control farmers ($\chi^2$=15.96, 4 df, p=0.003). None of the focused control farmers answered 'no importance seen for conducting own vector control', whereas 30% of the standard control farmers did not see any importance in conducting their own vector control on their farms. However, a higher proportion of focused control farmers believed that farmer conducted vector control would not be effective or that the control should be left to the Regional Council.

Table 45 gives the seven most frequently nominated organisations and the number of farmers that ranked the organisations with highest priority in response to the question about whom they thought responsible for TB eradication. Figure 42 presents the percentage of all farmers considering the different organisations as being responsible for TB eradication, and the number of times the different organisations were given highest priority in being responsible. No individual organisation/ institution was standing out as being nominated most frequently, however, Government was mentioned most frequently with the highest priority.

**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.**

| | Focused control farmers | Standard control farmers | % of all farmers (n=96) |
|---|---|---|---|
| All farmers | 26 (12) | 47 (15) | 76.0 % |
| Regional Council | 24 (5) | 46 (12) | 72.9 % |
| All landowners | 20 (4) | 45 (15) | 67.7 % |
| Government | 24 (14) | 41 (18) | 67.7 % |
| AgriQuality and Animal Health Board | 21 (7) | 42 (12) | 65.6 % |
| Other organisations/groups | 16(4) | 20 (4) | 37.5 % |
| Only farmers with the problem | 7 (3) | 18 (6) | 26.0 % |
| Local farming group | 2 (1) | 18 (1) | 20.8 % |

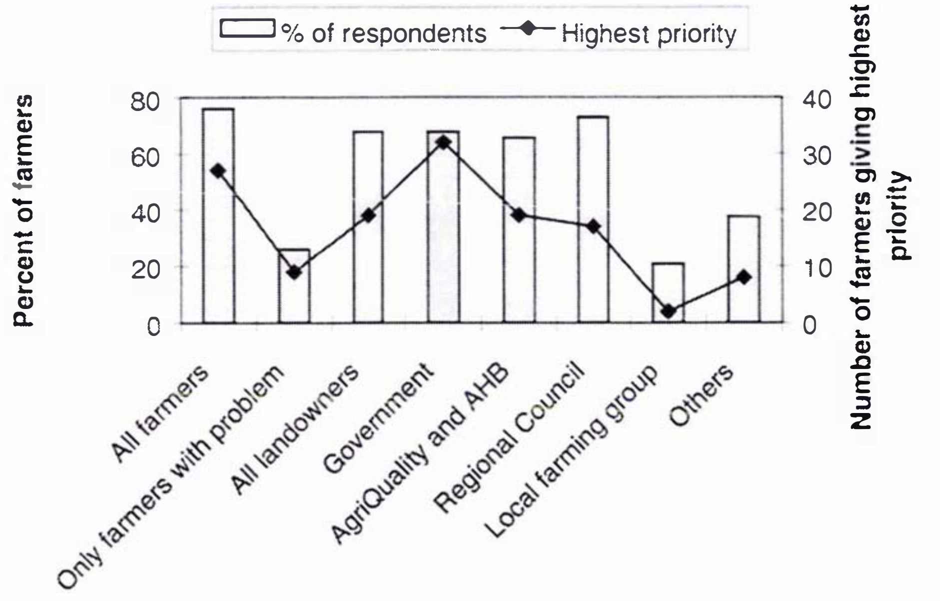



**Figure 42. Organisations/institutions perceived as being responsible for TB eradication.**

Table 46 gives a similar presentation of organisations that were considered by the farmers to be responsible for actually doing the work required to eradicate TB.

**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.**

| | Focused control farmers | Standard control farmers | % of all farmers (n=96) |
|---|---|---|---|
| Regional Council | 24 (12) | 39 (12) | 65.6 % |
| All landowners | 15 (4) | 38 (8) | 55.2 % |
| All farmers | 15 (6) | 37 (10) | 54.2 % |
| AgriQuality and Animal Health Board | 12 (4) | 37 (13) | 51.0 % |
| Government | 11 (7) | 31 (10) | 43.8 % |
| Only farmers with the problem | 6 (5) | 17 (6) | 24.0 % |
| Other organisations/groups | 12 (7) | 11 (3) | 24.0 % |
| Local farming group | 4 (2) | 11 (1) | 15.6 % |

The Regional Council was the most frequently nominated organisation, followed by 'all landowners', 'all farmers' and 'AgriQuality/ Animal Health Board'. Around one quarter of all farmers nominated 'only farmers with the problem' as being responsible for actually doing the work required to eradicate TB.

In another question, farmers were asked where they would expect help from, if they had to do their own vector control on their farms, and what expectations of help they would have. Nineteen (57.5%) focused control and 35 (55.6%) standard control farmers expected help from the Regional Council; 18 (54.5%) focused control and 38 (60.3%) standard control farmers from AgriQuality/AHB, 11 (33.3%) focused control and 30 (47.6%) standard control farmers from Government. Thirteen (39.4%) focused control and 22 (34.9%) standard control farmers also expected the co-operation of their neighbours. The main help expected from Regional Council was advice (n=13), actual work (n= 11), funding (n=9) and subsidised poison (n=7). From AgriQuality/AHB the main help expected was advice (n=19), funding (n=13) and co-ordination (n=4). From Government financial help was mostly expected (n=27).

## Perceived cost of TB and its control by farmers

Table 47 gives the cost distributions for TB and its control for focused and standard control farms.

**Table 47. Estimated costs of TB and its control to national focused control and standard control farms.**

| | | Focused control farmers | Standard control farmers |
|---|---|---|---|
| Cost of TB to the farm | = 0 | 3 | 20 |
| | > 0 | 25<br>(avg $8,650, range $500 - $22,500) | 37<br>(avg $16,452, range $300 - $180,000) |
| | Unknown | 5 | 6 |
| Cost of poison | = 0 | 9 | 27 |
| | > 0 | 24<br>(avg $745, range $100 - $2,500) | 29<br>(avg $552, range $50 - $2,500) |
| | Unknown | 0 | 7 |
| Cost of labour | = 0 | 18 | 32 |
| | > 0 | 15<br>(avg $1,963, range $100 - $5,000) | 25<br>(avg $2,656, range $100 - $25,000) |
| | Unknown | 0 | 6 |

Most of the focused control farmers put a cost greater than zero on the effect of TB on their farms, with a wide range of estimates. The difference between the focused and standard control farms was not significant after the application of the correction factor ($\chi 2$=6.21, 2 df, p=0.045).

The reasons given for the costs of TB focused on lost opportunities (14 focused control farmers, 27 standard control farmers), lost reactor value (four focused control farmers, 12 standard control farmers), and inconvenience, direct costs and time involved TB testing (seven focused control and three standard control farmers). Other reasons given were costs due to levies and rates (n=4), lost production (n=5) and capital loss (n=4).

Slightly more than half the farmers (n=50, 52.1%) did not put any cost on their own labour, as control work is being done as part of their routine management.

## Multivariate analysis between national focused and standard control farms

In comparing focused control with standard control farms twelve variables had p-values of less than 0.10 in the uncorrected univariate analysis: trading importance, areas with high TB risk, graze in high risk areas, TB infection contributed to animals on and off farm, the likelihood of contact between livestock and possums, the proportion of farm being controlled by Regional Council, the proportion of farm being controlled by farmer, the presumed effect of stricter movement control, and four variables within the self-concept (talkative, difficult to get on with, likes changes, knowledge). A logistic regression was conducted with these five variables. The only variable significant was the knowledge variable with Wald statistic 4.17, p=0.041, which was less than expected by chance.

## Discussion

This study looked in detail at the farm and management characteristics of all farms involved in the two intervention projects described in Chapters 3 and 4. Apart from providing the data for comparing focused control with standard control farms, the study provided useful insights into the way farms operated, which was particularly helpful in the Wairarapa project (see Chapter 3).

### *Comparing focused control farms with standard control farms*

In order to identify differences between the farms the projects worked actively with (focused control farms), and the farms which were used for comparison (standard control farms), non-parametric tests were employed, as most variables were not normally distributed. As there were many different variables (over 80) it was not possible to compute test statistics for each individual variable, without increasing Type I and Type II errors. This would have meant that some variables would have shown significance in the test, although there was no real difference between the farm groups. Therefore the variables were first screened visually and subjective comparisons were made between the groups. In the second step only those variables that showed differences in the visual comparison were tested statistically. In the third step the critical p-value for each test was set to 0.0025, which resulted from a Bonferroni correction factor of 20 (Ott, 1988). This way it could be ensured that differences found to be significant in the study had a high likelihood of being real differences.

In the Wairarapa project none of the general farm variables nor the herd manager variables were significantly different between the focused control and the standard control farms. In general the focused control and standard control farms were more similar to each other in terms of general farm characteristics than the non-TB farms. The similarity of the Wairarapa focused control and standard control farms is an indication that the random allocation of farms to these two groups was effective. Therefore any differences found in the intervention study cannot be attributed to differences between the two farm groups, but are most likely due to the interventions conducted on these farms.

Although in the National project no significant differences were found after the application of the correction term, there were more differences seen in the visual assessment than in the Wairarapa farm group. Farmers had to assess their own personality traits and whereas the values in most variables for this self-concept (Seabrook, 1984) were very close for Wairarapa focused and standard control farmers, these values differed more between national focused and standard control farmers. The visual assessment of the national farmers suggested that the focused control farmers were more cheerful, more open to change and considered themselves more as 'still learning'. This is in agreement with the biased selection of focused control farmers, who were selected specifically on their positive motivation, positive outlook and their TB herd history (for more details see Chapter 4). In studies with dairy and pig farmers it was found that differences in the self-concept could also reflect differences in farm management (Seabrook, 1984; Ravel *et al.*, 1996). These differences found between the national focused and standard control farms would suggest that retrospective sampling was not optimal, but there was no scope to influence the selection process.

### *Attitudes towards TB and its control*

In the Wairarapa study group the only significant difference between the focused and standard control farm groups was the proportion of farm area being controlled for vectors by farmers themselves. Of the farmers that performed vector control, the focused control farmers indicated that on average only 40% of their farm area was being controlled by themselves, while the standard control farmers controlled on average 65% of their farm and the non-TB farms 83%. However, these focused control farmers spent on average more days per year on vector control than the farmers of he other two groups. Although this difference was no longer significant after the application of the correction term, it could still indicate different perceptions of vector control. If the focused control farmers spent the same or even more time on less area, several explanations are possible. Firstly, the standard control farms needed less time input for control than the focused control farms, due to already reduced possum numbers on their farms, or secondly focused control farmers focused their effort and intensified their control on specific areas of their farms, while the farmers of the other two farm groups tried to cover the whole of their property. In 1998, when this information was collected from focused control farmers, most farmers already had a good idea of high risk areas for tuberculosis through interactions with the research team. The 1998 figures were judged to be more conservative for the analysis than the 1999 figures, when the farmers themselves had the responsibility for maintaining the bait stations set up by the research team. The 1999 figures might have been an overestimation of the actual time spent on control which can be expected of farmers. It might be expected that the control effort by farmers in the third year of the project would decrease over time to the level of 1998, as the number of possums decreased, the number of reactors decreased or the perceived importance of vector control decreased.

With respect to the attitudes of farmers towards the eradication of TB, an overall positive attitude existed among farmers, with around three quarters of all interviewees considering the eradication of TB as crucial and possible. Yet, nearly half of the farmers were in favour of less strict MC restrictions. Around 70% considered the effect of having to pay TB testing costs directly as having negative consequences, and over 50% considered the effect of removing compensation for reactor cattle as being negative. These results are similar to those found in a study of farmers' attitudes in four additional regions of New Zealand, where 20% to 30% of the beef farmers believed in a positive effect of removal of compensation (Cowan and Clout, 2000). The negative consequences were mainly believed to be the loss of co-operation by farmers, e.g. farmers testing less frequently, or not presenting all animals for testing. Farmers believed this would have an overall negative effect on the TB eradication scheme.

At the current stage of the control strategy farmer co-operation is crucial. If it is not possible to continue current levels of funding farmers will then have to play an increasing role in TB control (Animal Health Board, 2000). Therefore, it has to be evaluated whether the disadvantages outweigh the advantages, such as an increased incentive for farmers (Animal Health Board, 1995; Cullen and Bicknell, 2000). It is proposed that compensation should be kept at current levels for the next few years. With increasing numbers of farmers being aware of and using on-farm control methods, it will be possible to reduce compensation, in order to create a greater incentive for farmers currently not willing to employ on-farm control methods.

Another potentially negative consequence of removing compensation could be that more and more farmers would cease farming cattle and deer. Although this would mean a lower number of herds being on MC, it would also mean that an important indicator of infection in feral animals would be removed.

Many organisations and institutions were mentioned by farmers as being responsible for eradicating TB, whereby no single organisation was mentioned most frequently. This indicates that farmers do not have a clear idea of who is in fact responsible for the eradication of TB. It is noticeable, that on average less than a quarter of all farmers considered that only those farmers with the TB problem should be responsible for its control. Within the non-TB farm group in the Wairarapa only a third were of this opinion. Therefore the TB problem was considered by most farmers as a national problem, not an individual's problem. This is supported by the high proportion of farmers considering 'all farmers' and Government as being responsible for eradicating TB.

While farmers were considered equally responsible for the eradication of TB as were Regional Council, AgriQuality/AHB and Government, farmers were nominated less frequently in answer to the question of who is responsible for actually doing the control work. Over 70% of the farmers indicated that the RC was responsible for this, while only 50% of the farmers considered themselves as being responsible. The same attitude was found when farmers were asked whether they could see any importance in themselves conducting vector control or other means of TB control. Only 12% stated that farmers should be responsible for vector control on their own properties. Forty-three percent of farmers believed that they could assist the RC, but nearly 40% did not see any importance for conducting their own vector control programmes or they believed that such programmes would be ineffective. This indicates that much more emphasis should be placed on motivating farmers and on farmers' awareness of TB and its control. Any future control strategies should include specific extension and education programmes that address these points.

Another point which should be addressed in any future strategies is the cost of TB to the farmers. Only about 60% of the farmers interviewed could put a figure on the cost of TB to the farm. It was noticeable that the national focused control farmers had the lowest percentage of farmers (24%) not able to identify specific costs of TB to the farm. These were the farms with whom a multi-disciplinary team was working, including financial advisors.

## Conclusions

The study showed that the random allocation of farms into focused and standard control farm group was effective in the Wairarapa study and to a lesser degree in the national study.

Overall a positive attitude existed among farmers regarding the importance of TB eradication. 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 did not see themselves, but other organisations, such as Government and Regional Council, as being responsible for eradicating TB and did not see any importance in conducting control programmes themselves.

Therefore, any future eradication strategy should include farmer motivation and some form of extension programme, that addresses specific points, such as the possible control strategies and financial implications of TB.

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**Beef farm in South Wairarapa**

**Sheep**

# Chapter 6

# Economic evaluation of TB control programmes and potential benefits of using incentives or an insurance scheme for different farm types

## Abstract

In New Zealand bovine tuberculosis is of major concern with potential consequences in the trade environment. The Australian brushtail possum is a wildlife reservoir and the main vector for transmitting the disease to livestock. Control and eradication of TB therefore has to involve livestock and wildlife, resulting in expensive control programmes. As a result of these programmes the herd incidence of TB has been reduced, however, more emphasis will have to be put on farms with persistent TB problems. Increasing expectations are put on farmers to take more responsibility for the TB control on their own properties. However, the adoption of available on-farm control measures will depend on their economic viability, and incentives or compliance auditing.

Economic analyses were conducted using deterministic, stochastic and decision analyses methods to evaluate the economic outcomes for an average dairy, an average beef breeding and an average beef finishing farm. From the analyses it was concluded that 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. For beef farms it was only economically beneficial 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 hardly at all and on beef finishing farms the adoption of control programmes became beneficial if the number of TB animals was reduced at least by two. Thus, the reduction of compensation does not create a significant incentive for beef farmers to adopt on-farm control measures. Other forms of incentives might have to be put in place, such as provision of vouchers for vector control or payments for achieving a TB free herd status.

## Definitions

AgriQuality: the national veterinary service, contracted by the AHB to manage and conduct TB testing of all herds, was until recently part of MAF.

Animal Health Board (AHB): the national organisation in charge of TB control.

Herd types were abbreviated using 'BB' for beef breeding farms, 'BD' for beef dry stock farms, also termed beef finishing farms, and 'DH' for dairy herds

MAF: Ministry of Agriculture and Forestry

Movement Control (MC): restrictions put on herds that limit the cattle and deer movements of herds that are suspected or known to be infected with TB

Reactor: an animal that reacted positively to the caudal fold intradermal tuberculin test.

TB animal: any animal that was found with lesions at slaughter (with or without previous positive skin test), whose lesions were found to be typical of TB by histology or culture.

SD: standard deviation

TB status: a herd is classified as 'Infected' if there is known TB infection in the herd, and 'Clear' if the herd had at least two whole-herd tests, in which none of the animals showed positive skin-test results.

White-tagged animal: an animal identified with an official AHB Movement Control tag, to indicate that this animal comes from a herd that is infected with TB

Whole-herd test: using the intradermal tuberculin test on all animals older than 3 months

## Introduction

The Australian brushtail possum (*Trichosurus vulpecula*) was introduced to New Zealand from Australia from 1840 to establish a fur trade. Since then the number has increased to a peak of 60-70 million. As a consequence possums have become a national pest, impacting on native flora and fauna (Howard, 1964), and acting as a reservoir and vector of bovine tuberculosis (Morris *et al.*, 1994; Jackson, 1995). Consequently TB eradication programmes in many areas have been unsuccessful and expensive, necessitating control of infected feral animals as well as tuberculous cattle and deer on farms. In 1996/97 $26 million were spent on possum control, with an expected $30 million by the year 2000 (O'Neil and Pharo, 1995). The funding for TB management and associated vector control programmes are obtained through levies and grants from the farming industries, regional and district councils, and Government (Coleman and Livingstone, 2000). As a result of these programmes the number of cattle and deer herds under movement control for TB has decreased (Pannett, 1995; Livingstone, 1997). However, in many areas tuberculosis is endemic in feral possum populations and requires continuous control efforts to keep tuberculosis incidence in livestock animals at low levels. These areas where TB has been identified in feral vector populations, are termed Vector Control areas, for which stringent TB control regulations are in place, such as annual TB testing of all animals. All animals suspect of being infected with tuberculosis have to be removed to slaughter. While a herd is classified as being Infected with TB, it remains under Movement control (MC), and all animals sold to market from these herds have to be identified with an official AgriQuality Movement Control Tag ('white-tagged' animals). These white-tagged animals can often only be sold at a discount, as their market is limited and farmers from Vector Free Areas are reluctant to take the risk. For more detailed information on MC restrictions and TB related regulations see Appendix III (p. 334).

### *Need for Economic Analysis*

As more herds come off MC, emphasis has to be put on the remaining infected farms. Control of TB on these farms will most likely involve a combination of available measures. The marginal revenue for each dollar spent in large-scale possum control operations will decrease with decreasing number of herds on MC in that area. Therefore, it will be more difficult to expect substantial Government funding and farmers increasingly will be expected to assist more in TB control, or else pay increasingly for control work through rates.

At farm level, grazing management and localised possum control are the two main control measures currently available for farmers to implement on their own. Their effectiveness has been evaluated in Chapters 3 and 4 of this thesis. Management that avoids grazing TB hot-spot areas with cattle and deer at certain times of the year, together with localised possum control before livestock are put into these paddocks, are expected to reduce the direct contact between infected, moribund possums and livestock. This contact was found to be the most likely way of transmitting the disease from infected possums to livestock (Sauter and Morris, 1995). By preventing this direct contact from happening, the risk of direct transmission of *M.bovis* from possums to cattle and deer was expected to be reduced and farms were more likely to get off MC. However, current farming is very economics-orientated, and therefore it was necessary to evaluate the profitability of such control measures on various types of farms. It was found that the decision to change or adopt certain measures was strongly dependent on the financial pay-off (Morris *et al.*, 1995; Cullen and Bicknell, 2000).

The needs of the farmers have to be met through planned disease prevention and control programmes, involving a range of measures, each of them offering a different degree of protection and requiring a different level of investment. Determining the optimum input and control level, therefore, is to a large extent a matter of economic decision making. This applies not only to the individual livestock owner, but also to national Government (Dijkhuizen and Morris, 1997).

## *Techniques available for analysis*

Partial budgeting is one technique available for economic analysis. It is a quantification of the economic consequences of a specific change in farm procedure, e.g., a herd health programme. It is particularly useful for analysing relatively small changes in the business. Partial budgeting only considers those items of returns and costs that change as a consequence and estimates the difference in profit expected from the alternative option versus the base situation. It does not calculate the total income and the total expense for each of the options.

A partial budget is made up of four sections: (1) **additional returns**: a list of items of returns from the alternate plan that will not be received from the base plan, (2) **reduced costs**: a list of items of costs for the base plan that will be avoided with the alternate plan, (3) **returns foregone**: a list of items of returns from the base plan that will not be received from the alternate plan, and (4) **extra costs**: a list of items of costs of the alternate plan that are not required with the base plan (Dijkhuizen and Morris, 1996). All added costs and returns and reduced costs and returns are assumed to be caused by the introduction of the control measures.

## *Aim of this study*

The objective of this analysis was to determine the economic viability of on-farm TB control measures under current policies and to suggest policy changes that might increase the cost-effectiveness of these programmes. If there is an economic benefit, farmers will be interested in adopting on-farm control measures and therefore assisting TB control programmes.

## *Insurance*

Following the economic analysis of different options the possibility of an insurance scheme was discussed. In order to insure against an adverse event, the risk of this event occurring has to be measurable. An insurance company is making a prediction about losses that are expected to occur and will estimate the range of error; that way the risk is measurable. The risk for the insurance company is that the prediction is not accurate (Vaughan and Vaughan, 1999). The probability of losses occurring is one part in the measurement of risk, the potential severity and size of the loss is the other part. Both can be taken into account when using the concept of expected values. An expected value is calculated by multiplying the probability of the event happening by the amount of the potential loss (Vaughan and Vaughan, 1999). Other terms used in the insurance business include 'peril' and 'hazard'. A peril is the actual cause of the loss, e.g. peril of hail, whereas a hazard is a situation that creates or increases the chance of a loss, resulting from a given peril. There are some situations that are both peril and hazard, such as disease. A disease is a peril causing direct economic loss, but it also is a hazard for premature culling because disease-affected animals may no longer justify their place in the herd.

There are several ways to deal with risks: Some fundamental risks are dealt with through society and Government (e.g. police), whereas individuals deal with some particular risks by avoiding them, retaining, transferring, sharing and reducing the risk (Vaughan and Vaughan, 1999). For our case with tuberculosis, risk sharing (e.g. within an insurance group) and risk reduction (e.g. prevention of loss or controlling the severity of it, such as possum control) are most important.

Insurance creates security, it does not remove or reduce the risk, but it reduces the probability of severe financial loss for the individual. Insurance has two main characteristics, the first is transferring/shifting risk from an individual to a group and the second is the sharing of losses amongst all group members, whereby the burden of financial loss is spread amongst the group. This method of loss distribution is the basis on which insurance can exist (Vaughan and Vaughan, 1999).

Insurance agreements can work in two ways, either where the members of the group share the loss after it has occurred or on advance premium basis, whereby the members of the group pay their share in advance. For the second method, probability theory and predictions are of importance. By agglomerating a large number of homogeneous individuals/units that are exposed to the same risk, the insurance company can predict (using probability theory) the amount of losses that will occur in the group, something an individual is not realistically able to do. To achieve this prediction the insurance company is using past experience and establishes empirical probabilities (*a posteriori* probability). However, as these empirical probabilities will not be exactly accurate, a margin for error is allowed (e.g. on the basis of standard deviation of the past experiences). The more past events are investigated to obtain the prediction, the more accurate this prediction is. Equally, the more subjects are included in the group, the better the prediction fits to this population (due to the law of large numbers).

In order for a risk to be insurable some prerequisites should be met: There should be a large enough number of homogeneous exposed units (important for prediction); the loss should be measurable in terms of finances; there should be an uncertainty to whether the loss occurs or not; and the loss should not be catastrophic (affecting a very large percentage of insured subjects at any one time) (Vaughan and Vaughan, 1999). Additionally, an insurable risk should also fulfil criteria with regards to moral hazard and adverse selection. Moral hazard results from dishonest characteristics of an insured person, such as would be the case if an individual buys an insurance policy and then deliberately changes behaviour to increase the magnitude or the probability of a loss. Deductibles, co-payment and checking the insured's behaviour are some ways of dealing with moral hazard.

Adverse selection occurs if individuals have a better knowledge about the magnitude or probability of their losses than the insurer, e.g. farmers who have an above average risk are more likely to obtain insurance. The way to deal with this problem is by classifying the insured persons/farms into different risk categories based on detailed information on magnitude and probability of loss (Meuwissen *et al.*, 1997).

An insurance rate is charged on a per unit basis. Insurance premiums are calculated by multiplying the rate by the number of units insured. The rate is usually determined from the cost of production, but as these are unknown the rates must be based on an estimation of future losses and costs, which is called rate-making (Vaughan and Vaughan, 1999). The premium can be divided into pure premium, which is intended to cover the losses, and the loading, which covers the expenses of operating the system.

There are different types of rates: Class rates are most common in the insurance business, they are applied to all subjects that have the same set of features/qualities. Individual rates are used when the features of the subjects differ too much and the loss of production has to be calculated on an individual basis.

Most insurance schemes available for agriculture deal with the property, crop, natural risks such as flood or hail, or social risks (e.g. burglary, accidents) (Ray, 1981). There are no examples of using insurance in animal production in New Zealand, and only limited examples from overseas with regard to the management of a contagious disease in animals. In Germany livestock insurance and State animal disease insurance are available to farmers (Siemienkowicz, 1984). In the Netherlands studies were conducted on providing insurance for classical swine fever (Meuwissen *et al.*, 1997).

## Materials and Methods

In the partial budgeting a farm without an on-farm TB control programme and with a TB problem was taken as the baseline for comparison. Farming with an on-farm TB control programme (as described in Chapter 3) and consequently a reduction of the TB problem was used as the alternative. The different costs and revenues were determined in consultation with experts from AgriQuality and experts from the farm consulting company Baker & Associates, Masterton.

### *Representative farms included in the study*

Three representative farm types were used in the analysis: dairy farms, sheep and beef breeding, and sheep and beef finishing farms, the three types most common in the Wairarapa, a TB Vector

Control Area (VRA). It was assumed that possums were the main vector species on these farms, and that the role of ferrets or other infected wildlife species was of minor importance.

Some characteristics of the typical farms used in the economic analysis are presented in Table 48 (Ministry of Agriculture and Forestry, 1998). More details on farming operations in New Zealand can be found in Parker (1997) and in publications from Livestock Improvement Corporation Limited (1998).

**Table 48. Some characteristics of farms in the Hawke's Bay-Wairarapa District (from Ministry of Agriculture and Forestry, 1998).**

| | Dairy herds | Beef breeding herds | Beef finishing herds |
|---|---|---|---|
| Total herds | 226 | 680 | 570 |
| Average herd size | 243 cows/herd | 2625 sheep stock units | 1682 sheep stock units |
| | | 664 cattle stock units | 684 cattle stock units |
| Stocking rate (in Stock Units/ha) | | 7.68 | 9.86 |
| Replacement rate | 20 | 20 | -- |
| Average effective hectares | 98 | 428 | 240 |
| Average kg milksolids produced/ farm | 71,407 | -- | -- |
| Average Dairy company payout ($/kg milksolids) | 3.63 | -- | -- |

Revenues for a sheep and beef breeding farm was generated from sheep through wool production and lamb sales and from cattle through sales of cull cows, weaner steers and weaner heifers (rising one-year old animals). Revenues for sheep and beef finishing farm through cattle consisted of selling the fattened animals to the slaughterhouses. Sheep provided often 50% or more of the total farm income (Parker, 1997).

### *Tuberculous animals*

For the purpose of the economic analyses it was assumed that all tuberculous animals were identified through on-farm TB testing. It was assumed that no animals were found tuberculous at slaughter that had tested negatively in the previous test or were not tested at all. It was assumed that beef finishing farms tested all their cattle before sending them to slaughter. None of these herds was assumed to have the herd status 'Works monitored', which can be obtained if over 90% of the herd is slaughtered annually. In herds with this status, no on-farm TB testing is required (see Appendix III for more details, p. 334).

All animals reacting positively to the skin test are eligible for compensation, which is currently set at 65% of the 'fair market value'. Animals that had not been TB skin tested prior to slaughter, but were found to be TB lesion positive at slaughter are not eligible for compensation. The farmer receives the slaughter value of that animal (which can only be sold for local trade, not for the export market). If the animal is condemned due to extensive lesions, the farmer does not receive any revenue from that cattle beast. Most farmers in the Wairarapa TB test their animals regularly and almost all tuberculous animals are identified by TB skin testing. Therefore the analysis assumed that all infected animals were found by TB testing.

### *Details of costs and revenues used in the partial budgeting*

A summary of the assumptions and data used in the partial budgeting for the different herd types is presented in Table 49.

On sheep and beef farms TB had only implications for cattle, not sheep. TB in sheep has only been recorded very seldom (Davidson *et al.*, 1981; Cordes *et al.*, 1981). Furthermore they did not expose themselves to 'infection' by close contact with possums to the same degree as cattle (Sauter and Morris, 1995), which means that sheep can be used to graze the TB hot-spot areas, thus utilising grass production in these areas.

#### Additional returns resulting from the implementation of control measures

*Increased animal value (live animals)*

All animals sold live from a TB infected herd, have to be identified with white tags and can often only be sold at an estimated discount of 10% for dairy herds and 15% for beef herds from 'fair market price' (Pannett pers. comm., 1999). This increased animal value only applied if the herd achieved an off-MC status.

*Increased milk production*

This additional return was only applicable to dairy herds. Tuberculous cows had to be slaughtered as soon as possible after the positive reaction to the intradermal tuberculin test. Consequently milk production was lost if the animals were removed during lactation. If the on-farm control measures reduced reactor numbers, this increased milk production. It was assumed that whenever 5 reactors were removed from the average farm (243 milking cows) this caused a 1% reduction on the overall milk yield for the current season (Pannett pers. comm., 1999).

## Reduced costs resulting from the implementation of control measures

*Premature disposal due to TB*

All cattle suspected to be tuberculous, based on the national TB testing programme, must be slaughtered. Currently farmers are compensated for reactor cattle at 65% of 'fair market value' (determined by AgriQuality), irrespective of the 'true' TB status of the animal, determined at slaughter. Therefore a cost of 35% per reactor animal could be saved if the number of reactors was reduced due to the implementation of control programmes. Under current control policies it was considered unlikely that any cattle would die of TB, although in the absence of control measures this would occur.

## Additional costs resulting from the implementation of control measures

*Localised possum control*

Localised possum control was concentrated on five months per year (October to December plus March and April) and on areas with known or potential TB hot-spots. It can be done by using bait stations or traps. Poison and labour needed for possum control were additional costs.

Due to larger farm sizes and rougher vegetation, these cost drivers were expected to be higher for beef farms than for dairy farms. On an average dairy farm it was estimated that 15 bait stations ($10 each) were needed. Depreciation of bait stations was attained in five years, resulting in a cost of $30 per year. About $150 will be spend annually on poison on an average dairy farm.

On an average sheep and beef breeding farm the localised possum control was expected to require an investment of $1,250 for bait stations and traps, assuming that 16% of the total farm area was possum-denning habitat, and 50% of this area was classified as hot-spots area (McKenzie, 1999). Therefore, 34 hectares had to be covered in the localised possum control programme. For an effective possum control it was estimated that 50 bait stations at $10 each and 10 Timms-traps (killing traps) at $35 each had to be purchased (Pannett pers. comm., 1999). With a depreciation period of five years, this resulted in an annual cost of $170. Furthermore, it was estimated that $700 will be spent annually on purchasing bait and poison. For a beef finishing farm the costs were about half of the costs for beef breeding farms, due to their farm size. A total cost of $430 a year was estimated.

The additional labour needed for possum control was included in the additional management needed for the grazing management strategies.

*Additional management*

The localisation of TB hot-spots on the farm for targeted control measures, managing the grazing strategies (using grazing records) and localised possum control all require additional management. Once TB hot-spot areas are identified on a farm, this part requires only limited time input. Keeping grazing records, setting up strategies, and conducting localised possum control once or twice a year, required the main time input.

Most dairy farmers already have detailed grazing strategies in place. Therefore, exclusion of hot-spots during certain times of the year could easily be incorporated into their existing farm management. Possum control was expected to take four hours per month. The adjustment of the grazing strategy was expected to involve one hour per week (Pannett pers. comm., 1999). It was expected that 100 hours of additional labour per year were sufficient to cover the time requirements for on-farm control programmes on an average dairy farm.

On a beef breeding farm it was estimated that a farmer had to spend 60 hours annually on poisoning and trapping possums (twice a year three weeks trapping/poisoning, with 3 hrs every second day = 54 hr/annum). The additional labour needed for the grazing management was expected to be 50 hours annually, focusing on fencing and shifting cattle. The total time spent on a beef finishing farm (about half the size of a beef breeding farm) was estimated to be 55 hrs a year.

*Additional fencing*

On dairy farms no additional fencing was required to implement the strategy.

Paddock sizes on beef farms are generally significantly bigger than on dairy farms. In order to minimise the area to be excluded from grazing, additional fencing is required around TB hot-spot areas. The main costs involved are fencing material and labour; the equipment needed for fencing is already available on most farms. Fencing expenses for a beef breeding farm were estimated at a total of $5,000, excluding the labour involved, which was accounted for in the management costs. As the fencing costs only incur once, an annual cost of $1,000 was obtained with a depreciation period of five years. The costs for a beef finishing farm were estimated at $500 per year ($2,500 investment, depreciated in five years).

### Returns foregone as a result of the introduction of control measures

No returns foregone were identified in the analysis.

### *Parameters used in the economic analysis*

#### Deterministic model

A deterministic partial budget model was built in Microsoft Excel (Microsoft Excel for Windows 97, Version 8.0, Microsoft Corporation, Redmond, WA). Table 49 provides a summary of the input variables as detailed in the previous section and used in the analyses for the three different farm types.

**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.**

| | Dairy farm | Beef breeding | Beef finishing |
|---|---|---|---|
| Increased milk production (kg milksolids/ cow not having to be slaughtered) | 142.8 | -- | -- |
| Discount TB reactors (slaughter) | 35% | 35% | 35% |
| Annual cattle sales | 50 cows | 17 cows | 70 slaughter beef |
| | 6 R2yr heifers | 42 weaner steers | |
| | 10 R1yr heifers | 21 weaner heifers | |
| Discount 'white tagged' (live animals) | 10% | 15% | -- |
| Animal value > 2yrs | $ 850 | $ 695 | $ 970 |
| Animal value 1 – 2 yrs | $ 750 | $ 695 | $ 695 |
| Animal value 6wks – 1 yr | $ 375 | $ 315 | |
| | | steers to 18mths $ 495 | |
| Additional labour cost | 100 hrs/yr | 110 hrs/yr | 55 hrs/yr |
| Additional fencing cost | -- | $1,000/yr | $500/yr |
| Trapping/poisoning cost | $180/yr | $870/yr | $430/yr |

In estimating the annual cattle sales a 20% replacement rate was assumed. To keep the results of the economic analyses comparable it was assumed that the TB reactors were dairy cows older than two years, beef breeding cattle older than one year of age, and beef finishing steers and non-breeding bulls older than 18 months. The market value of the reactor animals was determined from the payout scheme of AgriQuality, paid for reactor animals. For each animal class a maximum value is set for the amount which AgriQuality will be able to value the animal for compensation. This maximum value was used in the deterministic model.

The spreadsheets used for the analysis in these three farm types are shown in Appendix V (p. 351).

In the economic analysis six scenarios, regarding the reduction in reactor numbers, achieved by the implementation of on-farm control measures, were considered for the three farm types separately (Table 50).

**Table 50. The six scenarios analysed in the study.**

| | Number of reactors in previous year | Number of reactors in following year | Achieve Off-Movement Control status |
|---|---|---|---|
| Scenario 1 | 5 | 2 | No |
| Scenario 2 | 5 | 0.5[a] | No |
| Scenario 3 | 5 | 0 | Yes |
| Scenario 4 | 2 | 0.5[a] | No |
| Scenario 5 | 2 | 0 | Yes |
| Scenario 6 | 1 | 0 | Yes |

[a]one reactor every second year

The goal of implementing the two control measures (grazing management system and localised possum control) was to reduce the incidence of TB in livestock on farms, with a final goal of the herd achieving a TB free herd status. The analysis was therefore intended to examine the different scenarios described above and show their economic consequences.

In addition the economic consequences were also evaluated under a range of different reactor cattle compensation levels, ranging from the current 65% to zero.

## Stochastic model

In addition to the deterministic spreadsheet model, a stochastic economic analysis was performed using a risk analysis and simulation add-in for Microsoft Excel (@RISK, Version 3.5.2, Palisade Corporation, Newfield, New York, USA). This Monte-Carlo simulation package allowed input variables (costs and returns) to be modelled as distributions rather than deterministic fixed values. Input distributions such as price of animals were sampled at each iteration. These sampled values were then used in the economic analysis to calculate the economic benefit for each iteration. The outputs were summarised across iterations at the end of the simulation and could be presented as histograms of expected economic returns. The simulation was conducted using 1000 iterations generated by Latin hyper-cube sampling, a sampling method that selects random numbers from the specified distributions (Vose, 1996).

Table 51 provides a summary of the input variables, their distributions and parameters, as used in the stochastic model for the three farm types.

Cattle prices were determined from the maximum payout scheme for reactor cattle used by AgriQuality. This group of variables was assumed to be normally distributed with a maximum value, therefore a truncated normal distribution was used in the model (Table 51).

Discount percentage on white-tagged animals was elaborated with representatives from AgriQuality and Animal Health Board. As the value of 10% for dairy and 15% for beef farms was considered the best estimate, a truncated normal distribution with a very small standard deviation was used in the model (Table 51).

For dairy farms the total milk yield in kg milksolids was estimated from the published average milk yield per farm in the Wairarapa. This variable was assumed to be normally distributed with a maximum and minimum cut-off value, therefore indicating a truncated normal distribution (Table 51).

The price per kg milksolids for dairy farms was estimated from published data and modelled with a truncated normal distribution with the mean of $3.63, paid out in the financial year 1998/99 (Table 51).

The hourly cost of labour was modelled as a truncated normal distribution with the mean expected value of $12 (Table 51).

For the amount of time spent on grazing management and possum control, the number elaborated for the deterministic model was assumed to be the most commonly observed one. On this basis, a triangular distribution with maximum, minimum and mode parameters was used (Table 51).

The distribution for the cost of fencing for beef breeding and beef finishing farms was assumed to be triangular with minimum, maximum and mode parameters specified as presented in Table 51.

The cost of poison and bait stations for each of the three farm types was elaborated with representatives of AgriQuality and farm consultants and was modelled as a triangular distribution, as it was reasonable to assume minimum and maximum values and assign the mode to the amount specified by the experts (Table 51).

**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.**

| Herd[a] | Variable | Distribution | Mode | Min | Max | Mean | SD |
|---|---|---|---|---|---|---|---|
| DH | Animal value >2yr ($) | Truncated normal | | 750 | 850 | 800 | 40 |
| DH | Animal value 1-2 yr ($) | Truncated normal | | 450 | 750 | 700 | 40 |
| DH | Animal value 6wks – 1 yr ($) | Truncated normal | | 200 | 375 | 325 | 25 |
| DH | % discount white-tag | Truncated normal | | 8 | 15 | 10 | 2 |
| DH | Milk yield (kg MS) | Truncated normal | | 65,000 | 78,000 | 71,407 | 7000 |
| DH | Price /kg MS ($) | Truncated normal | | 3.4 | 3.8 | 3.63 | 0.4 |
| DH | Additional time required (hrs) | Triangular | 100 | 80 | 120 | | |
| DH | Cost of Poison/Traps ($) | Triangular | 180 | 150 | 200 | | |
| | | | | | | | |
| BB | Animal value breeding > 1yr | Truncated normal | | 500 | 695 | 650 | 40 |
| BB | Animal value breeding 6wks – 1yr | Truncated normal | | 200 | 315 | 270 | 40 |
| BB | Animal value steers 6wks – 18 mths | Truncated normal | | 350 | 495 | 450 | 25 |
| BB | % discount (white-tag) | Truncated normal | | 10 | 18 | 15 | 2 |
| BB | Additional time required (hrs) | Triangular | 110 | 90 | 130 | | |
| BB | Additional fencing cost ($) | Triangular | 1000 | 500 | 1200 | | |
| BB | Cost of Poison/Traps ($) | Triangular | 870 | 650 | 1100 | | |
| | | | | | | | |
| BD | Steers > 18mths | Truncated normal | | 750 | 970 | 900 | 50 |
| BD | Additional time required (hrs) | Triangular | 55 | 45 | 65 | | |
| BD | Additional fencing cost ($) | Triangular | 500 | 250 | 650 | | |
| BD | Cost of Poison/Traps ($) | Triangular | 430 | 350 | 550 | | |
| | | | | | | | |
| DH/BB /BD | Labour / hr | Truncated normal | | 7 | 20 | 12 | 2 |

[a]Herd type: DH: dairy herd; BB: beef breeding herd; BD: beef finishing herd

Output variables included return minus costs for each of the six scenarios described above. The spreadsheets used in the analysis were the same as for the deterministic model (Appendix V, p. 351). Sensitivity analyses were performed for each output in order to determine the most important input variables. The rank correlation coefficient was used to measure sensitivity in an output to variation in the individual input distributions.

## Decision analysis

As a third step in the economic analysis, decision tree analysis was performed. For each of the three farm types decision trees were constructed, using an add-in for Microsoft Excel (PrecisionTree, Version 1.0a, Palisade Corporation, Newfield, New York, USA). The expected economic outcomes of the deterministic model and a range of probabilities for achieving the different scenarios (Table 52) were used in the decision tree analysis. The estimates for the probabilities where on-farm control has been adopted were taken (as far as possible) from the actual data obtained in the 'focused control' farms of the study described in Chapter 3. However, especially for the scenarios starting with five reactors the actual data was less extensive than for the other scenarios (only five farms had five or more reactors). For the situation where no on-farm control programme was adopted, estimates for the probabilities were taken and adjusted from the 'standard control' farms in Chapter 3. The actual probabilities found in the intervention study could not be taken unadjusted, as some standard control farms also had their own on-farm control programmes in place. The probability of having the same number of reactors the following year could not be assumed to be 1.0 for the situation where farmers do not adopt the control measures, as most areas of the Wairarapa are subject to regional possum control. The costs of the current slaughter-levy for adult cattle was included in this part of the analysis in order to compare the current levy ($7.20) with the increased one ($13.00), suggested in the new pest management strategy of the AHB.

**Table 52. Assumed probabilities of reducing reactor numbers per farm if conducting on-farm TB control or not.**

| Reactor numbers in two consecutive years | Probability if adopting on-farm control | Probability if not adopting on-farm control | |
|---|---|---|---|
| | | Original | Adjusted[a] |
| 5 reactors to 6 reactors/yr | 0.08 | 0.10 | 0.15 |
| 5 reactors to 5 reactors/yr | 0.15 | 0.40 | 0.45 |
| 5 reactors to 2 reactors/yr | 0.31 | 0.10 | 0.20 |
| 5 reactors/yr to 1 every 2nd yr | 0.31 | 0.20 | 0.10 |
| 5 reactors to 0/yr | 0.15 | 0.20 | 0.10 |
| 2 reactors to 5 reactors/yr | 0.0 | 0.21 | 0.25 |
| 2 reactors to 2 reactors/yr | 0.12 | 0.21 | 0.25 |
| 2 reactors/yr to 1 every 2nd yr | 0.50 | 0.36 | 0.35 |
| 2 reactors to 0/yr | 0.38 | 0.21 | 0.15 |
| 1 reactor to 2 reactors/yr | 0.12 | 0.28 | 0.30 |
| 1 reactor to 1 reactor/yr | 0.23 | 0.25 | 0.30 |
| 1 reactor to 0/yr | 0.65 | 0.47 | 0.40 |

[a] To take account of standard control farms which undertook on-farm control by farmer choice.

## Results

In the following 'net gain' or 'net loss' are terms used for the monetary value, resulting from adding the costs and returns incurred from the implementation of on-farm control measures for TB.

### *Deterministic model*

#### Current situation (65% compensation)

All three types of farms were analysed and the economic consequences are presented in Table 53. For example the benefit of reducing the number of reactors from five per year to two per year is described in the first row.

**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%).**

| | Dairy | Beef breeding | Beef finishing |
|---|---|---|---|
| From 5/yr to 2/yr | $ 1,068 | - $ 2,460 | - $ 572 |
| From 5/yr to 1/2$^{nd}$ yr | $ 2,292 | - $ 2,095 | - $ 62 |
| From 5/yr to off MC[a] | $ 7,775 | $ 3,805 | $ 108 |
| From 2/yr to 1/2$^{nd}$ yr | - $ 156 | - $ 2,825 | - $ 1,081 |
| From 2/yr to off MC[a] | $ 5,327 | $ 3,075 | - $ 911 |
| From 1/yr to off MC[a] | $ 4,511 | $ 2,832 | - $ 1,251 |

[a]MC = Movement Control

The economic outcomes show that the implementation of on-farm control measures on a dairy farm resulted mostly in a net gain under the current compensation scheme (65%). Only in the scenario where the herd started with two reactors a year and reduced the reactor number to one every second year, did the implementation result in a net loss. The herd still incurred the discount of white-tagged animals, and the reduction in reactor number was not sufficiently large to equal the costs of the programme. If the herd came off MC the prices for cull cows and other cattle sales increased, causing relatively large benefits in the economic outcomes (Table 53).

Another return was the increased overall milk yield, as the cows did not have to be removed from the farm in the middle of their lactation any more. The influence of a milk production increase was considerable, especially when a farm managed to reduce its number of reactors from five per year to zero and get off MC. The increase of 1% in milk production calculated to result from this reduction in reactor numbers resulted in additional revenue of almost $2,600.

The introduction of an on-farm TB control programme on a sheep and beef breeding farm under the current compensation scheme (65%) resulted in an economic advantage in those situations where the herd got off MC, irrespective of the number of reactors it had previously. If the herd did not get off MC, then only if it had a reduction of at least 14 reactors, was the break-even point reached – with an expected net benefit of +$216.

In contrast to dairy and sheep and beef breeding farms, the introduction of an on-farm TB control programme under current policies (65% compensation) on to a sheep and beef finishing farm resulted generally in a net loss. It was only economically beneficial if the herd reduced its reactor numbers by at least 5 reactors per year (break-even point) (Table 53).

### Alternative situations with reduced or no compensation for reactor animals

A significant source of controversy is whether or not the level of compensation for reactor animals should be reduced from 65%. The deterministic analysis model was run for different levels of reduced compensation, ranging from 60% to 0%, keeping all other variables equal to the original analysis. Figure 43, Figure 44, and Figure 45 show the expected net returns for each of the compensation levels for the three herd types; the scale of the y-axis (expected net return) was kept the same in all three figures, in order to facilitate comparison between the three herd types. From Figure 43, Figure 44, and Figure 45 it can be seen that the beef finishing farms have a lower expected net return than beef breeding and dairy farms. The expected net return for beef breeding farms is on average $3,274 lower than for dairy farms, and the expected net return for beef finishing farms is on average $4,030 lower than for dairy farms. Table 54 provides the outcomes of the analysis for zero compensation.

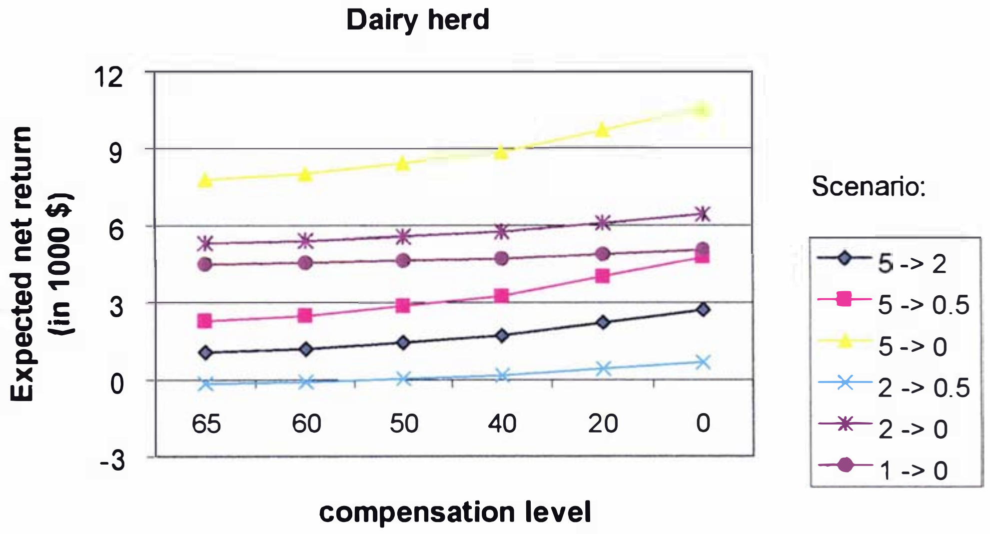


**Figure 43. Expected net returns on dairy farms for different reductions in reactor numbers using different compensation levels for reactor animals.**

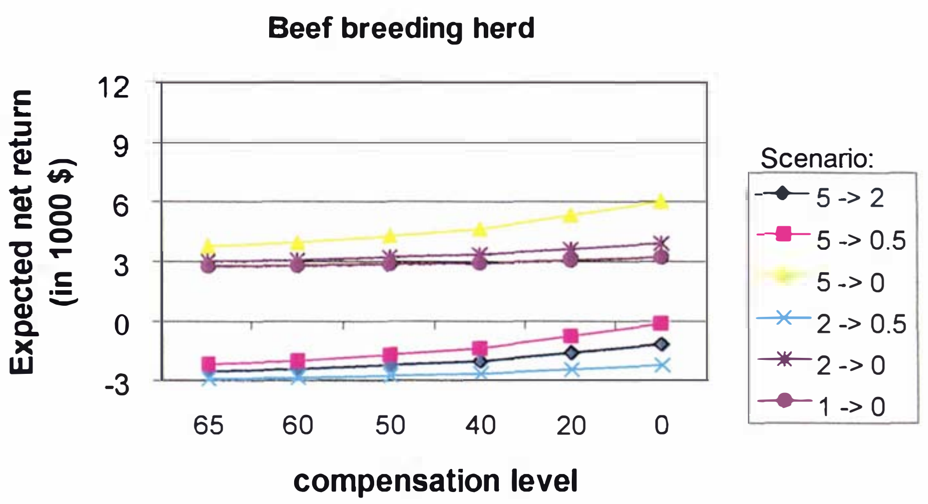


**Figure 44. Expected net returns on beef breeding farms for different reductions in reactor numbers using different compensation levels for reactor animals.**

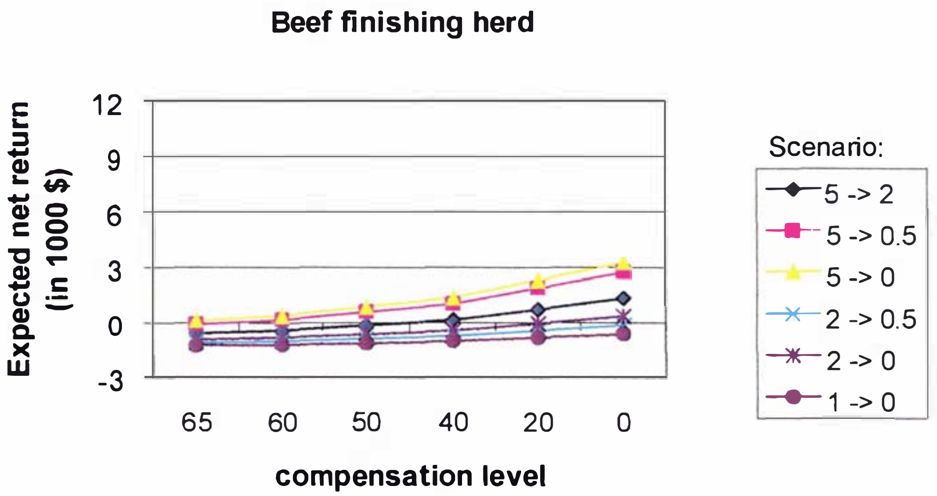


**Figure 45. Expected net returns on beef finishing farms for different reductions in reactor numbers using different compensation levels for reactor animals.**

**Table 54. Expected economic outcomes in partial budgeting of reducing the number of reactors in the three different farm types with zero compensation**

| | Dairy | Beef breeding | Beef finishing |
|---|---|---|---|
| From 5/yr to 2/yr | $ 2,725 | - $ 1,105 | $ 1,320 |
| From 5/yr to 1/2$^{nd}$ yr | $ 4,778 | - $ 63 | $ 2,775 |
| From 5/yr to off MC | $10,537 | $ 6,064 | $ 3,260 |
| From 2/yr to 1/2$^{nd}$ yr | $ 673 | - $ 2,147 | - $ 135 |
| From 2/yr to off MC | $ 6,432 | $ 3,979 | $ 350 |
| From 1/yr to off MC | $ 5,063 | $ 3,284 | - $ 620 |

The reduction of compensation level from 65% to zero compensation resulted in an increased net gain or at least a reduced net loss for some situations for all scenarios and farm types. For dairy farmers it was always economically beneficial to implement on-farm control measures, for beef breeding farms it was beneficial if the herd came off MC, but not beneficial if the herd still stayed under MC. For beef finishing farms the carrying out of on-farm control measures was beneficial if their reduction of reactor animals was at least two animals per year.

### Alternative situation with subsidies on control costs

In the following, a situation was modelled where a subsidy was paid to cover the costs of poison and bait stations. The costs of labour and fencing were still incurring. The expected net returns were calculated for three different compensation levels (65%, 40%, and 0%). Table 55, Table 56, and Table 57 present the expected net returns for the three farm types for the different scenarios under these circumstances. As many of these expected net returns are still net losses for beef farmers, one can calculate the additional subsidy necessary to achieve net gains in all, or almost all situations.

**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.**

| Beef breeding with a subsidy of $950/yr | 65% comp. | 40% comp. | Zero comp. |
|---|---|---|---|
| Scenario 1 (5 -> 2) | - $ 1,590 | - $ 1,069 | - $ 235 |
| Scenario 2 (5 -> 0.5) | - $ 1,225 | - $ 444 | $ 808 |
| Scenario 3 (5 -> 0) | $ 4,675 | $ 5,544 | $ 6,934 |
| Scenario 4 (2 -> 0.5) | - $ 1,955 | - $ 1,695 | - $ 1,278 |
| Scenario 5 (2 -> 0) | $ 3,945 | $ 4,293 | $ 4,849 |
| Scenario 6 (1 -> 0) | $ 3,702 | $ 3,876 | $ 4,154 |
| Additional subsidy necessary for all scenarios resulting in net gains | **$ 1,960** | **$ 1,700** | **$ 1,280** |
| Additional subsidy necessary for all except one scenario resulting in net gains | **$ 1,600** | **$ 1,070** | **$ 240** |

**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.**

| Beef finishing with a subsidy of $450/yr | 65% comp. | 40% comp. | Zero comp. |
|---|---|---|---|
| Scenario 1 (5 -> 2) | - $ 142 | $ 586 | $ 1,750 |
| Scenario 2 (5 -> 0.5) | $ 368 | $ 1,459 | $ 3,205 |
| Scenario 3 (5 -> 0) | $ 538 | $ 1,750 | $ 3,690 |
| Scenario 4 (2 -> 0.5) | - $ 651 | - $ 287 | $ 295 |
| Scenario 5 (2 -> 0) | - $ 481 | $ 4 | $ 780 |
| Scenario 6 (1 -> 0) | - $ 821 | - $ 578 | - $ 190 |
| Additional subsidy necessary for all scenarios resulting in net gains | **$ 820** | **$ 580** | **$ 190** |
| Additional subsidy necessary for all except one scenario resulting in net gains | **$ 480** | **$ 290** | **$ 0** |

**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.**

| **Dairy herds with a subsidy of $180/yr** | **65% comp.** | **40% comp.** | **Zero comp.** |
|---|---|---|---|
| Scenario 1 (5 -> 2) | $ 1,248 | $ 1,885 | $ 2,905 |
| Scenario 2 (5 -> 0.5) | $ 2,472 | $ 3,428 | $ 4,958 |
| Scenario 3 (5 -> 0) | $ 7,955 | $ 9,017 | $ 10,717 |
| Scenario 4 (2 -> 0.5) | $ 24 | $ 343 | $ 853 |
| Scenario 5 (2 -> 0) | $ 5,507 | $ 5,932 | $ 6,612 |
| Scenario 6 (1 -> 0) | $ 4,691 | $ 4,903 | $ 5,243 |
| Additional subsidy necessary for all scenarios resulting in net gains | **No additional subsidies necessary, all net returns are net gains when cost of poison is covered** | | |
| Additional subsidy necessary for all except one scenario resulting in net gains | **No additional subsidies necessary, all net returns are net gains when cost of poison is covered** | | |

From Table 57 it can be seen that the dairy farms always achieve a net gain if they do not have to pay for poison and bait stations. For the beef farms, especially the beef breeding farms it is more difficult to achieve a net gain, even if the costs of poison and bait stations are covered. The beef breeding farms require additionally between $1,300 and $2,000 to achieve a net gain in the scenario with the worst financial net return, where the farm reduces its reactor numbers from two per year to one every second year. Beef finishing farms only require support of between $200 and $800 to achieve a net gain in all scenarios.

## Break-even points

In order to find the break-even points, at which the amount of money spent on on-farm control measures was equal to the benefits of the programme, the additional revenues were calculated independently of the costs. For dairy herds under the current compensation scheme (65%) the additional revenues were found to be $816 per one animal reduction in reactor numbers plus an additional $5,075 if the herd came off MC. For the beef breeding herds the additional revenues were only $243 per one animal reduction in reactor numbers plus $5,779 if the herd came off MC. The higher value per one animal reduction in dairy herds versus beef herds was due to the increase in milk production. Beef finishing farms received additional revenue of $340 for each reactor less and no additional revenue if the herd came off MC (Figure 46).

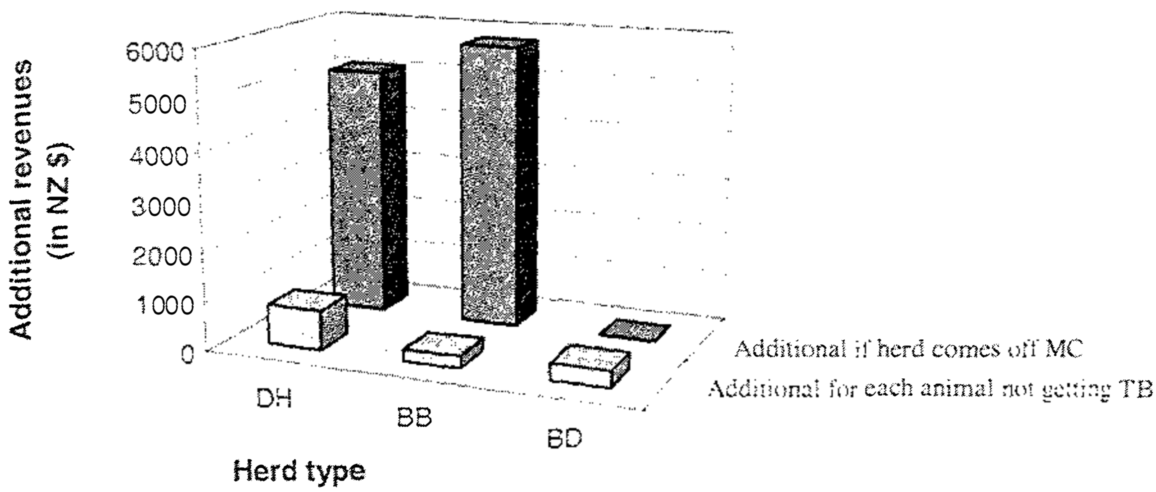


**Figure 46. Additional revenues per animal reduction in reactor numbers and if the herd came off Movement Control.**

The costs of the programme were $1,621 for dairy farms, $2,455 for beef breeding farms, and $2,199 for beef finishing farms. This indicates that for dairy farms and beef breeding farms the programme was economic if the herd came off MC. If the herd did not achieve this off-MC status, a dairy farm needed a reduction of at least two animals in reactor numbers to make the programme financially viable. A beef breeding farm needed a reduction of at least 11 animals and beef finishing farms a reduction of at least 7 animals to obtain a net gain from adopting the control programme if the herd did not get off MC.

If the imposed levy on slaughtered adult cattle is increased to $13 instead of the current $8.41, one suggested element of the new strategy (Animal Health Board, 2000), the costs of the programme increases to $1,850 for dairy farms, $2,533 for beef breeding farms, and $2,520 for beef finishing farms. If the herd did not get off MC dairy farms and beef finishing farms would require a reduction in reactor number of one animal more than under the current levy, whereas beef breeding farms would still require a reduction of at least 11 animals to make the programme financially viable.

### *Stochastic model (@RISK)*

#### Stochastic model on dairy farms

The stochastic model, using the parameters specified, yielded a histogram of expected net benefits obtained with 1000 iterations. Figure 47 presents the histograms of the financial output for the six scenarios (returns minus cost for each of the six scenarios) for a dairy farm. The distribution parameters for the six scenarios are shown in Table 58.

**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.**

| | TB reactor scenario | | | | | |
|---|---|---|---|---|---|---|
| | From 5 to 2 | From 5 to 1/2$^{nd}$ yr | From 5 to 0 | From 2 to 1/2$^{nd}$ yr | From 2 to 0 | From 1 to 0 |
| Mean | 1001.54 | 2194.06 | 7585.82 | -190.98 | 520078 | 4405.77 |
| Maximum | 1678.11 | 2960.91 | 10213.07 | 395.31 | 7843.09 | 7053.10 |
| Minimum | 225.20 | 1296.52 | 5710.26 | -894.34 | 3452.36 | 2699.73 |
| 5$^{th}$ percentile | 601.18 | 1760.04 | 6430.31 | -580.74 | 4073.19 | 3290.12 |
| 95$^{th}$ percentile | 1383.55 | 2615.69 | 8965.76 | 161.42 | 6576.17 | 5764.64 |

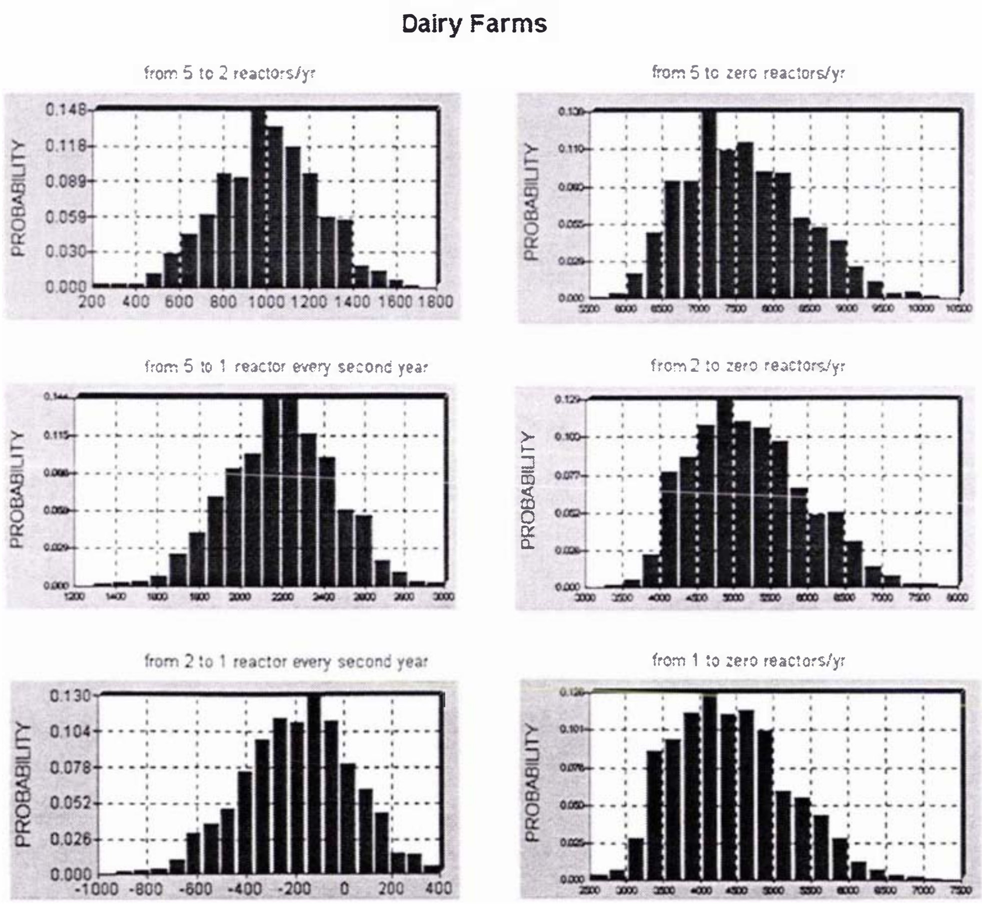


**Figure 47. Economic outcome distributions from @Risk stochastic partial budgeting model for returns minus costs for six scenarios of reductions in reactor numbers for a dairy farm.**

Sensitivity analysis showed that returns minus costs for dairy farms whose herds did not come off MC, were most sensitive to the cost of labour, followed by the time spent in conducting the on-farm control measures and the increased milk production. As an example, Figure 48 shows the tornado graph obtained for scenario 1, where the reactor number changed from five to two reactors per year. For the scenarios where the herd came off MC as a consequence of adopting the control measures, the final economic outcome was most sensitive to the chosen discount percentage (for white-tagged animals), followed by the hourly rate for labour and then the price of dairy cattle older than two years.

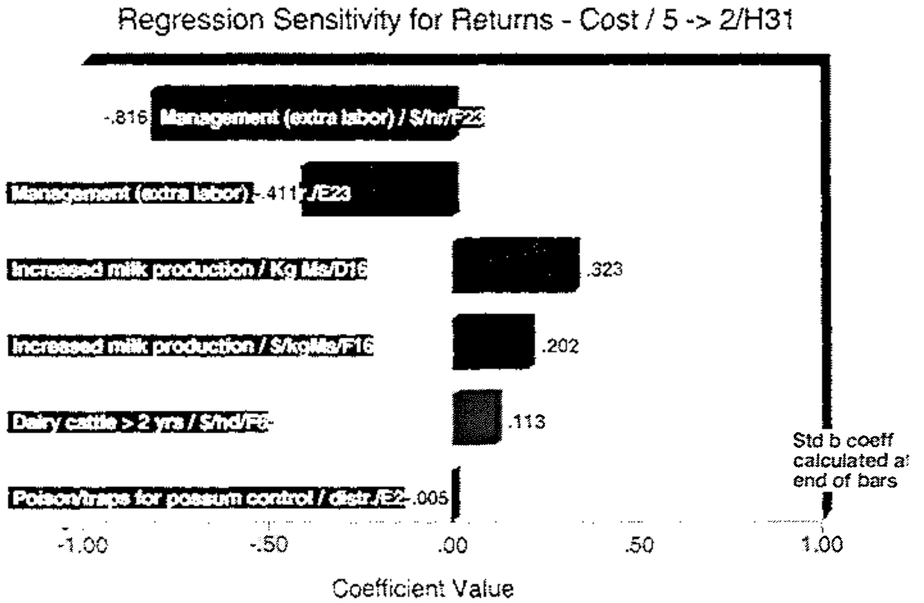


**Figure 48. Tornado graph with results of sensitivity analysis showing the importance of influence of different input variables for the situation where a dairy farm had 5 reactors and reduced it to 2/yr due to the implementation of on-farm control programmes.**

Expected values, 5[th] and 95[th] percentiles obtained from the output distributions were compared graphically in order to determine whether the differences between the farm types were likely to reflect true differences in economic merit or random variation. Figure 49 shows these three estimates for each of the scenarios. The net benefit for the three scenarios where the herd came off MC (number 3, 5 and 6 in the graph) was much greater than for the scenarios where the herd did not come off MC. Scenario 4 (from 2 reactors/yr to 1 every second year) had the least favourable monetary outcome.

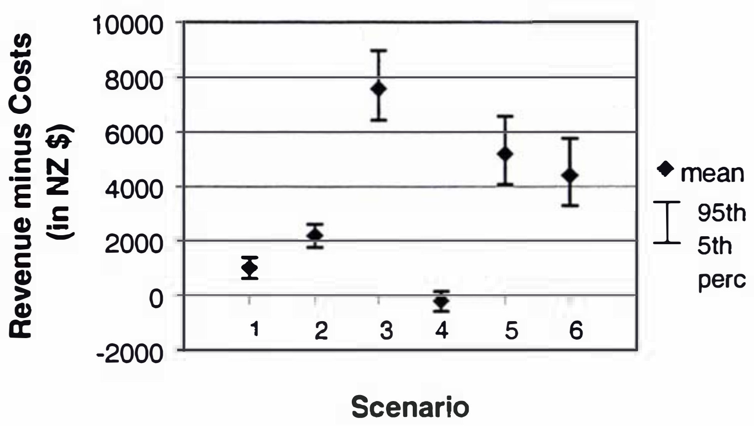


**Figure 49. Comparison of the range of expected returns minus costs from the stochastic @Risk partial budgeting model for the six scenarios of reducing reactor numbers in a dairy farm.**

## Stochastic model on beef breeding and beef finishing farms

The same analyses were conducted for the beef breeding and beef finishing farms. Figure 50 shows the distribution of the expected economic output for the six scenarios in the beef finishing herds, sorted for worst to best case scenario.

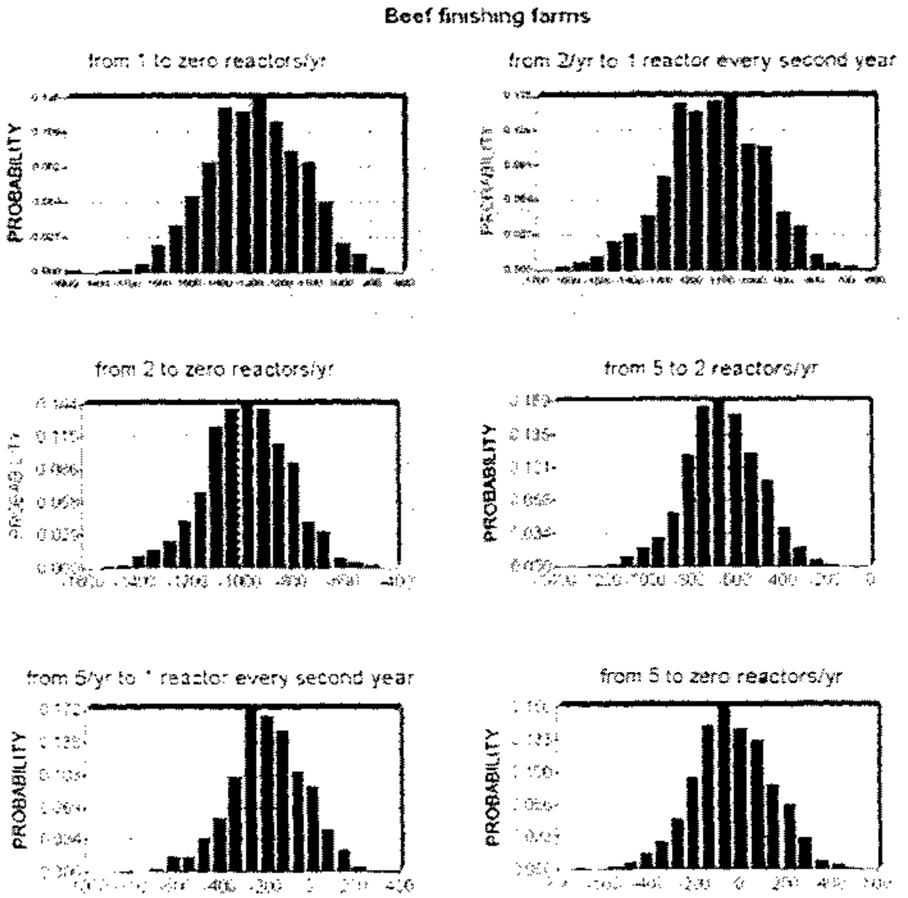


**Figure 50. Economic outcome distributions from @Risk stochastic partial budgeting model for returns minus costs for six scenarios of reductions in reactor numbers for a beef finishing farm (ordered from worst case scenario to best).**

For most scenarios in the beef finishing farms and the ones in the beef breeding farms, where the herd stayed on MC, the cost of labour, followed by the cost of fencing and the cost of poison were the most important input variables in the sensitivity analysis (see Figure 51 as an example for beef finishing farms). In the beef breeding farm scenarios, where the herd came off MC the most influential factors were the discount percentage on white-tagged animals, followed by the hourly costs of labour and the time required for extra management (see Figure 52).

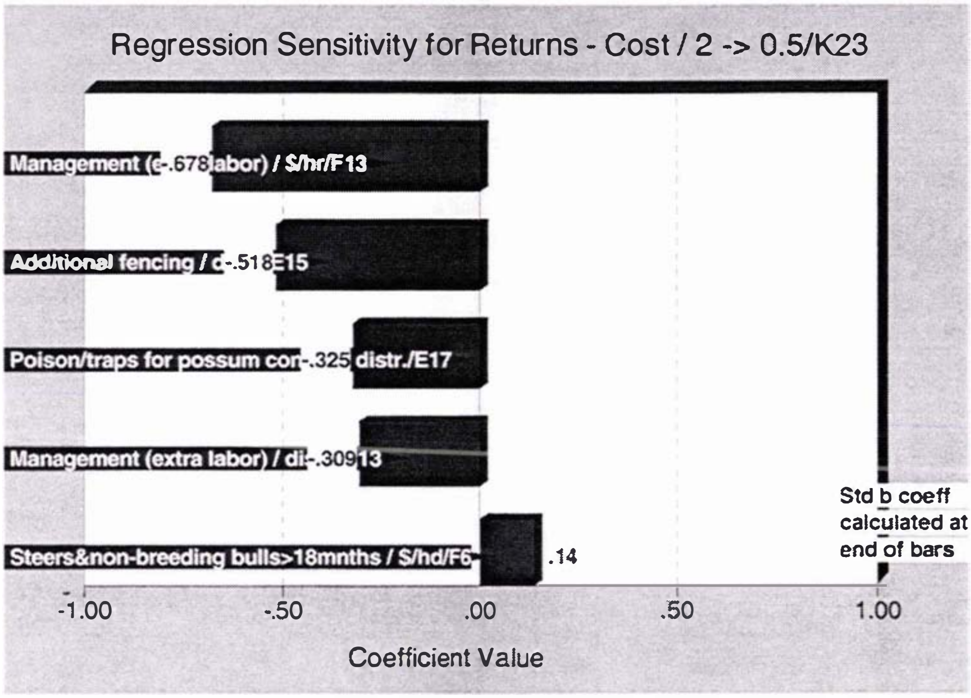


**Figure 51. Tornado graph with results of sensitivity analysis showing the importance of influence of different input variables for the situation where a beef finishing farm had 2 reactors and reduced it to one every 2nd year due to the implementation of on-farm control programmes.**

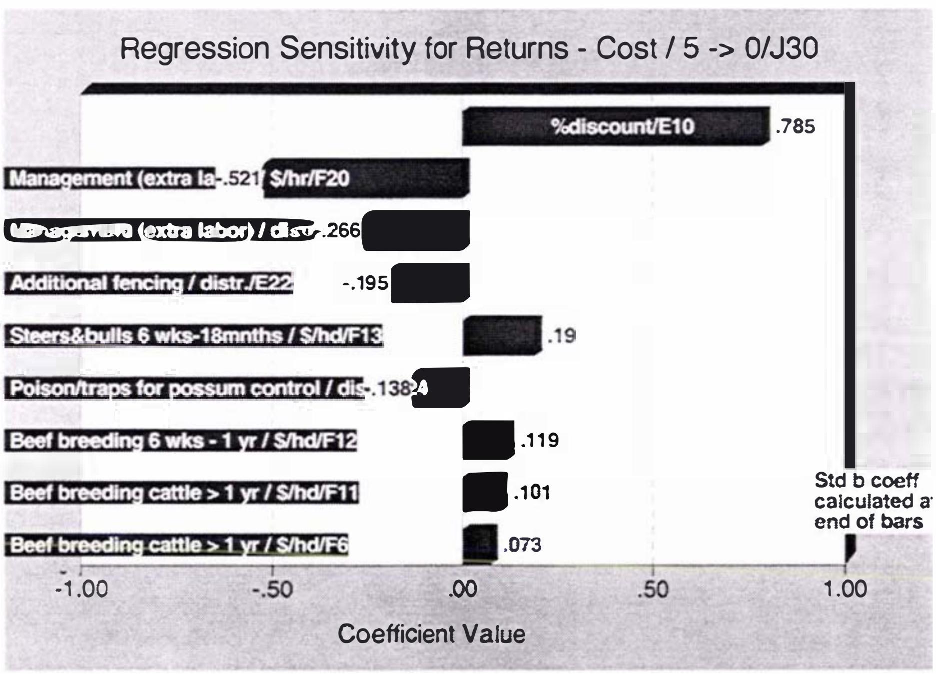


**Figure 52. Tornado graph with results of sensitivity analysis showing the importance of influence of different input variables for the situation where a beef breeding farm had 5 reactors per year and reduced it to zero due to the implementation of on-farm control programmes.**

### Comparing 65% compensation level for reactors with zero compensation

Figure 53 shows the different economic outcomes (revenues minus costs) using current 65% (blue colour) and zero (pink colour) compensation levels. The three different farm types are indicated by their two-letter code, and the six TB reactor scenarios are indicated by the large bold numbers. For both compensation levels, the respective outcomes for each scenario were always higher for dairy than for beef breeding and beef finishing farms. For the three scenarios, where the herd did not get off MC (scenario 1,2, and 4), the revenues minus costs were lowest for beef breeding farms, as the added revenue through increased capital prices did not occur. In the scenarios where the herd came off MC, the beef breeding farms achieved a higher outcome than the beef finishing farms.

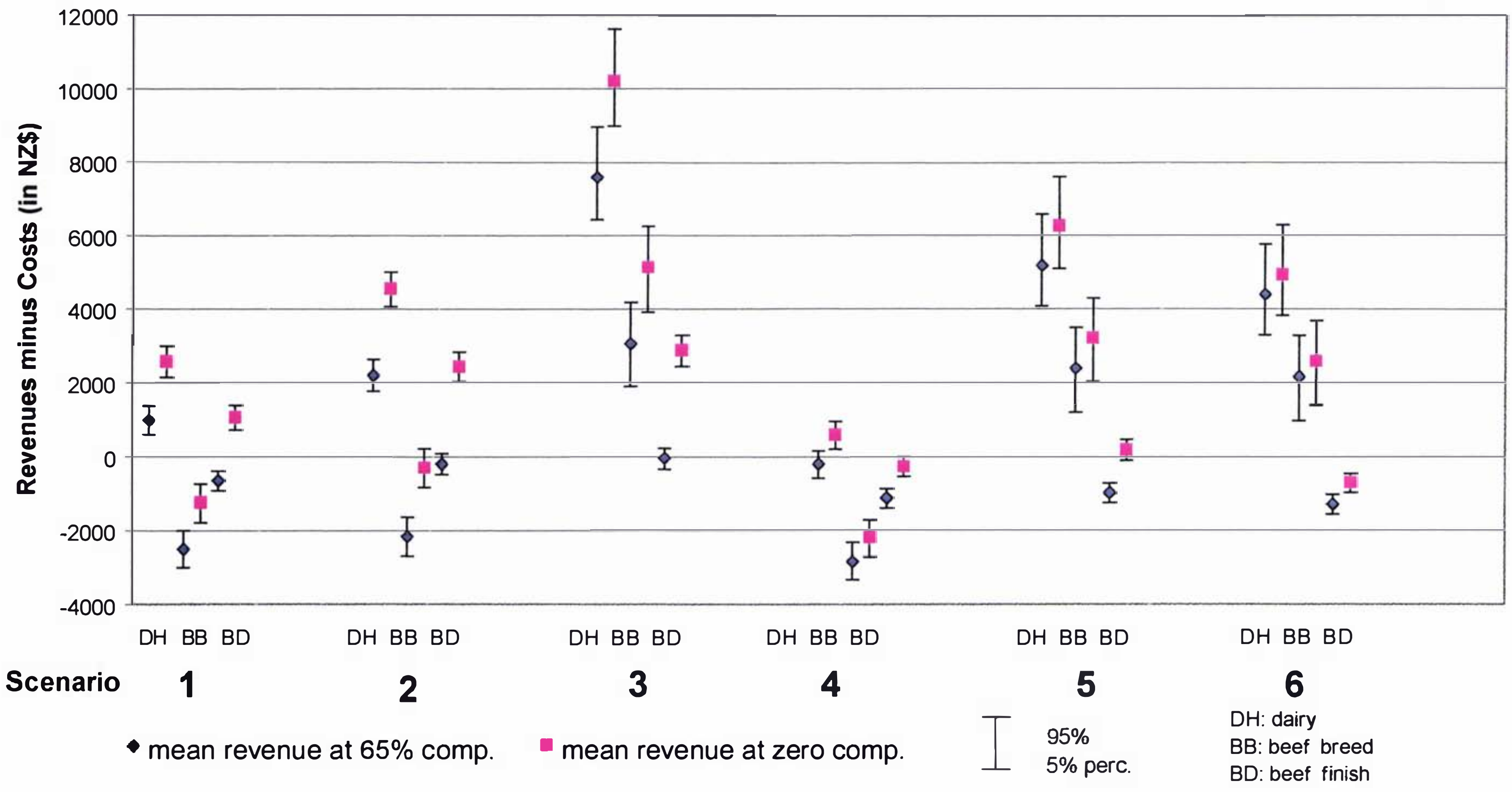


**Figure 53. Expected revenues minus costs from stochastic partial budgeting (@RISK) for all three farm types and all six scenarios of reducing reactor numbers with 65% and zero compensation.**

## *Decision analysis*

Decision analysis was performed for all three farm types, using the expected outcomes of the deterministic models for the decision trees.

### Decision analysis on dairy farms

Decision trees were constructed for the three situations, where the farm has five, two and one, respectively reactors per year and adopts on-farm TB control or not. Assuming the probabilities for reducing reactor rates as noted in Materials and Methods for a dairy farm, the results show that under current 65% and under zero compensation the adoption of the programme on average is the preferred option in all except one situation (see also Table 59).

**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.**

| Starting reactors | Compensation level | Slaughter levy | Expected value of adoption | Expected value of non-adoption | Decision |
|---|---|---|---|---|---|
| 5 | 65% | None | $ 1,825 | $ 1,650 | Adoption |
| 5 | 65% | Current | $ 1,465 | $ 1,643 | Non-adoption |
| 5 | 65% | Increased | $ 1,175 | $ 1,000 | Adoption |
| 5 | 0% | None | $ 3,480 | $ 2,423 | Adoption |
| 5 | 0% | Current | $ 3,120 | $ 2,063 | Adoption |
| 5 | 0% | Increased | $ 2,830 | $ 1,803 | Adoption |
| 2 | 65% | None | $ 1,781 | $ 822 | Adoption |
| 2 | 65% | Current | $ 1,421 | $ 462 | Adoption |
| 2 | 65% | Increased | $ 1,131 | $ 172 | Adoption |
| 2 | 0% | None | $ 2,615 | $ 864 | Adoption |
| 2 | 0% | Current | $ 2,255 | $ 504 | Adoption |
| 2 | 0% | Increased | $ 1,965 | $ 214 | Adoption |
| 1 | 65% | None | $ 2,351 | $ 2,112 | Adoption |
| 1 | 65% | Current | $ 1,991 | $ 1,752 | Adoption |
| 1 | 65% | Increased | $ 1,701 | $ 1,462 | Adoption |
| 1 | 0% | None | $ 2,644 | $ 2,167 | Adoption |
| 1 | 0% | Current | $ 2,284 | $ 1,807 | Adoption |
| 1 | 0% | Increased | $ 1,994 | $ 1,517 | Adoption |

Figure 54 presents the decision tree for the five-reactor situation under the current 65% compensation scheme. Probabilities are presented above the branches and outcomes below the branches coming off the chance nodes. The expected economic value is higher when on-farm control measures are implemented versus situations where no control is conducted ($1,825 versus $1,650). The return on invested funds for this situation is 132% (expected net value of $1,825 on $1,380 invested).

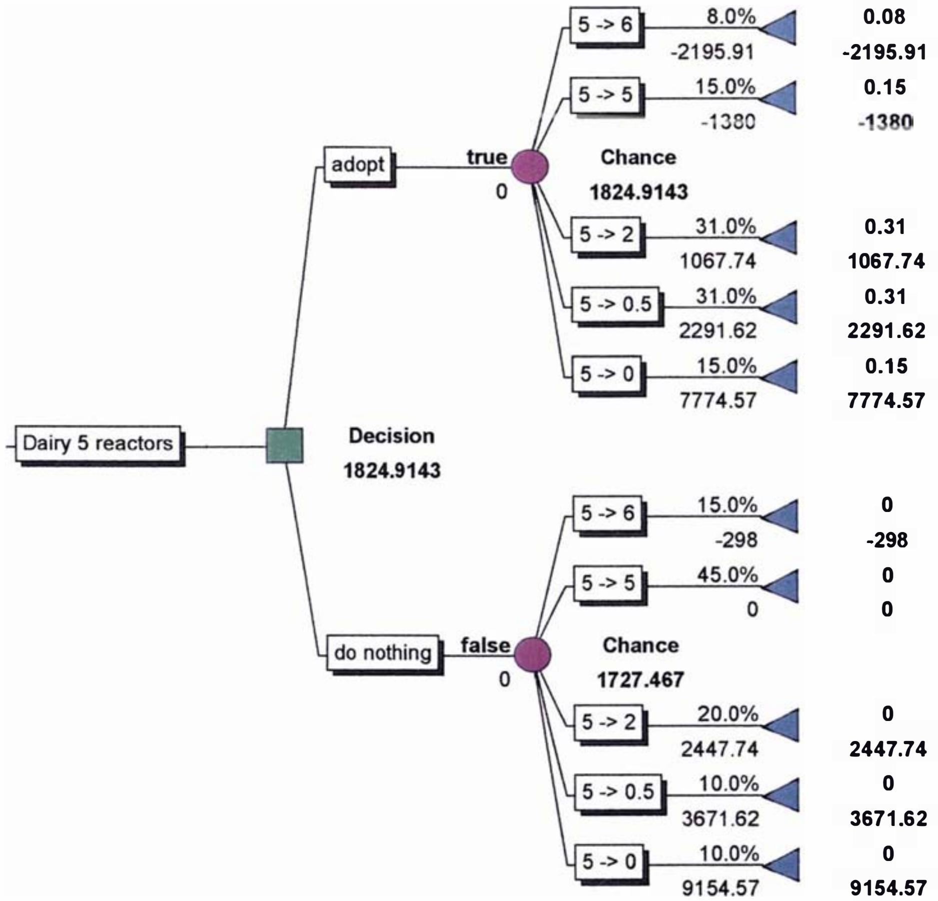


**Figure 54. Decision tree for expected financial outcomes for adoption or non-adoption of on-farm control measures on a dairy farm with five reactors.**

## Decision analysis on beef breeding farms

For the beef breeding farm under 65% compensation the decision tree starting with five reactors is presented in Figure 55. On average it was more economical not to adopt the control measures, as only the increased benefits of getting off MC were captured, but no cost for on-farm control incurred. The expected values for adopting on-farm control programmes versus non-adoption are presented in Table 60, stratified for the two compensation levels (65% and zero) and slaughter levy.

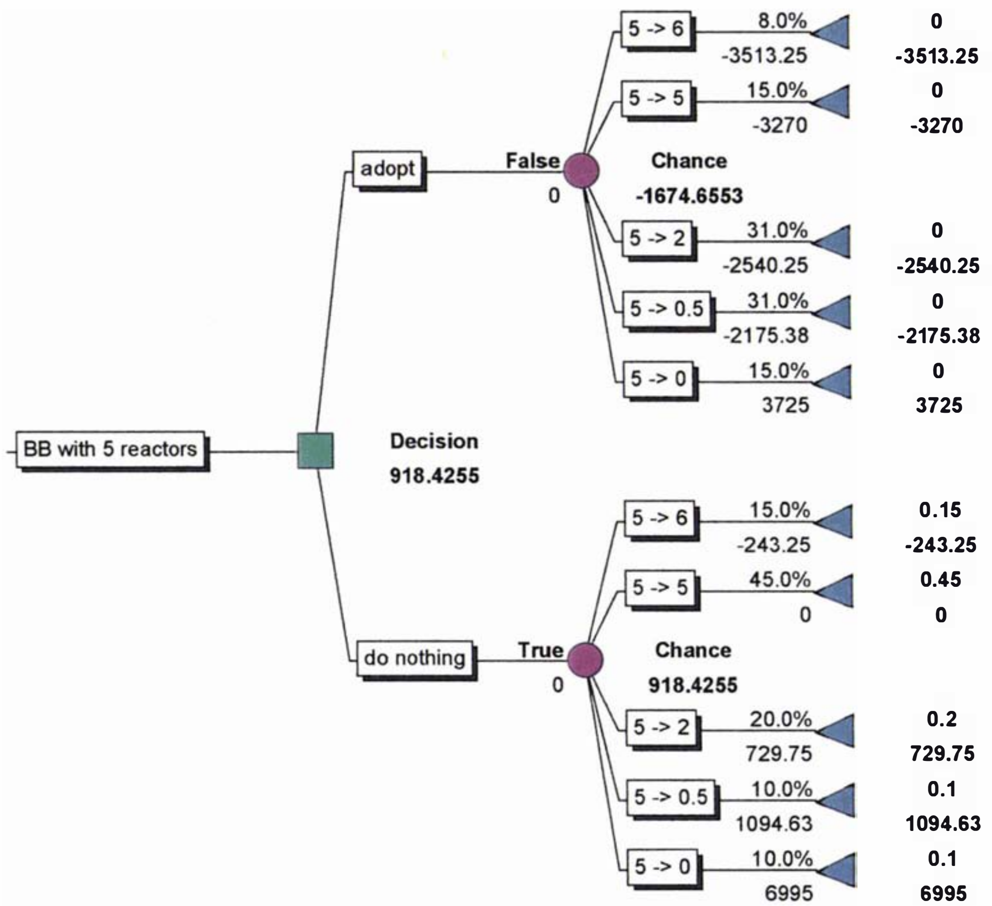


**Figure 55. Decision tree for expected financial outcomes for adoption or non-adoption of on-farm control measures on a beef breeding farm with five reactors.**

**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.**

| Starting reactors | Compensation level | Slaughter levy | Expected value of adoption | Expected value of non-adoption | Decision |
|---|---|---|---|---|---|
| 5 | 65% | None | - $ 1,675 | $ 918 | Non-adoption |
| 5 | 65% | Current | - $ 1,790 | $ 803 | Non-adoption |
| 5 | 65% | Increased | - $ 1,883 | $ 710 | Non-adoption |
| 5 | 0% | None | - $ 322 | $ 1,551 | Non-adoption |
| 5 | 0% | Current | - $ 437 | $ 1,436 | Non-adoption |
| 5 | 0% | Increased | - $ 530 | $ 1,343 | Non-adoption |
| 2 | 65% | None | - $ 707 | $ 885 | Non-adoption |
| 2 | 65% | Current | - $ 822 | $ 770 | Non-adoption |
| 2 | 65% | Increased | - $ 915 | $ 677 | Non-adoption |
| 2 | 0% | None | - $ 25 | $ 919 | Non-adoption |
| 2 | 0% | Current | - $ 140 | $ 804 | Non-adoption |
| 2 | 0% | Increased | - $ 233 | $ 711 | Non-adoption |
| 1 | 65% | None | $ 627 | $ 2,336 | Non-adoption |
| 1 | 65% | Current | $ 500 | $ 2,221 | Non-adoption |
| 1 | 65% | Increased | $ 407 | $ 2,128 | Non-adoption |
| 1 | 0% | None | $ 855 | $ 2,381 | Non-adoption |
| 1 | 0% | Current | $ 739 | $ 2,269 | Non-adoption |
| 1 | 0% | Increased | $ 647 | $ 2,173 | Non-adoption |

From Table 60 it can be seen that under the probabilities chosen the preferred option was always not to adopt the control programme, independent of compensation level or slaughter levy level.

For a starting situation with only two reactors and current compensation level of 65%, the adoption of the programme was the preferred option, if it led to probabilities of 0.35 for getting the reactor rate down to one reactor every second year and 0.55 for getting it down to zero and therefore achieving off MC status and if the non-adopter had only a 5% chance of getting off MC, but a 60% chance of having either an increased or the same number of reactors (see Figure 56).

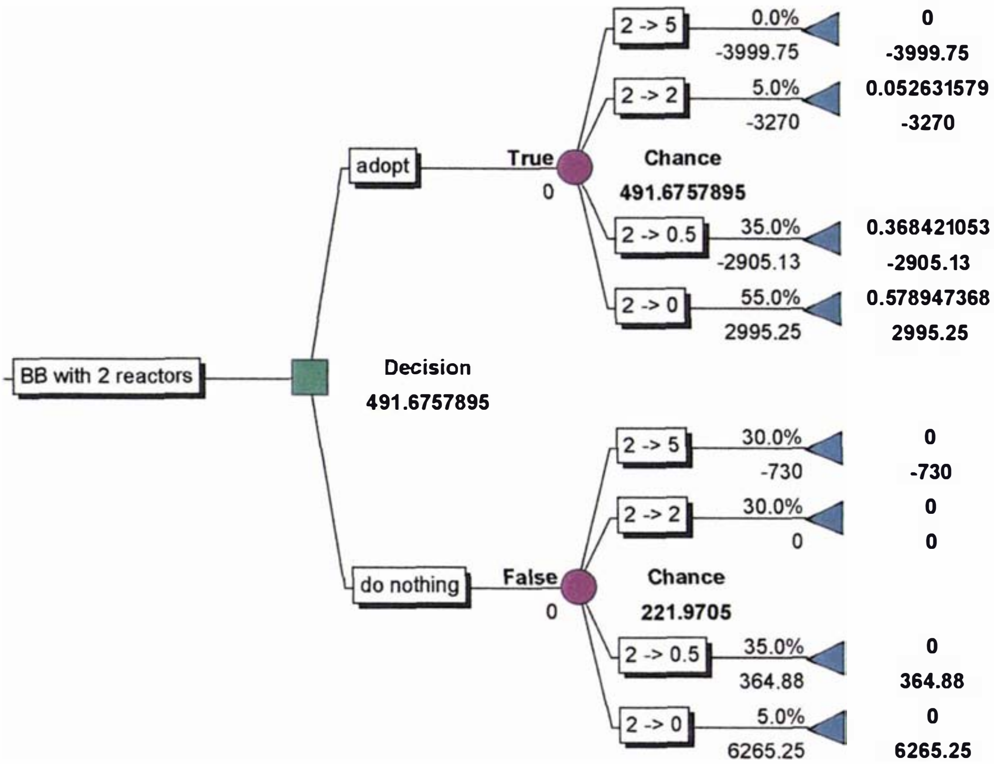


**Figure 56. Decision tree for beef breeding farm starting with two reactors and changed probabilities of reducing reactor numbers after implementing on-farm control programmes.**

*Beef breeding: Including a subsidy for labour and material and payment for off-MC*

The decision tree analysis was also calculated for situations where a subsidy is paid for poison, bait stations and labour (e.g. voucher) as well as a yearly payment to farms that achieve to come off Movement Control (this payment for a maximum of three years within a 10-year period). The subsidies necessary to make the adoption of on-farm control programmes the preferred option in the decision tree analysis, depended on the starting situation of the reactor numbers; with five reactors the probability of getting off MC are lower than with two or one reactor, and therefore a higher subsidy is required. The off-MC payoff was calculated as a yearly payment over a 10-year period, e.g. a payoff of $4,000 for three years if the herd comes off MC equates to $1,200 per year for 10 years. No slaughter levies were included in this analysis. Table 61 presents the minimum amount necessary in relation to the off-MC-amount paid per year, in order to make 'adoption' the preferred option under current compensation level (65%) and zero compensation. For 40% compensation Figure 57 presents the subsidies and payments for the five-, two-, and one-reactor situation.

**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.**

| Beef breeding farm | 5-reactor situation | | 2-reactor situation | | 1-reactor situation | |
|---|---|---|---|---|---|---|
| **Off-MC-payment** | **65% comp.** | **Zero comp.** | **65% comp.** | **Zero comp.** | **65% comp.** | **Zero comp.** |
| $1,000 | $ 2,580 | $ 1,860 | $ 1,530 | $ 880 | $ 1,650 | $ 1,460 |
| $1,500 | $ 2,580 | $ 1,860 | $ 1,490 | $ 850 | $ 1,610 | $ 1,420 |
| $2,000 | $ 2,570 | $ 1,850 | $ 1,460 | $ 810 | $ 1,580 | $ 1,380 |
| $2,500 | $ 2,560 | $ 1,840 | $ 1,420 | $ 780 | $ 1,540 | $ 1,340 |
| $3,000 | $ 2,550 | $ 1,830 | $ 1,390 | $ 740 | $ 1,500 | $ 1,310 |
| $3,500 | $ 2,550 | $ 1,830 | $ 1,360 | $ 710 | $ 1,460 | $ 1,270 |
| $4,000 | $ 2,540 | $ 1,820 | $ 1,320 | $ 670 | $ 1,430 | $ 1,230 |

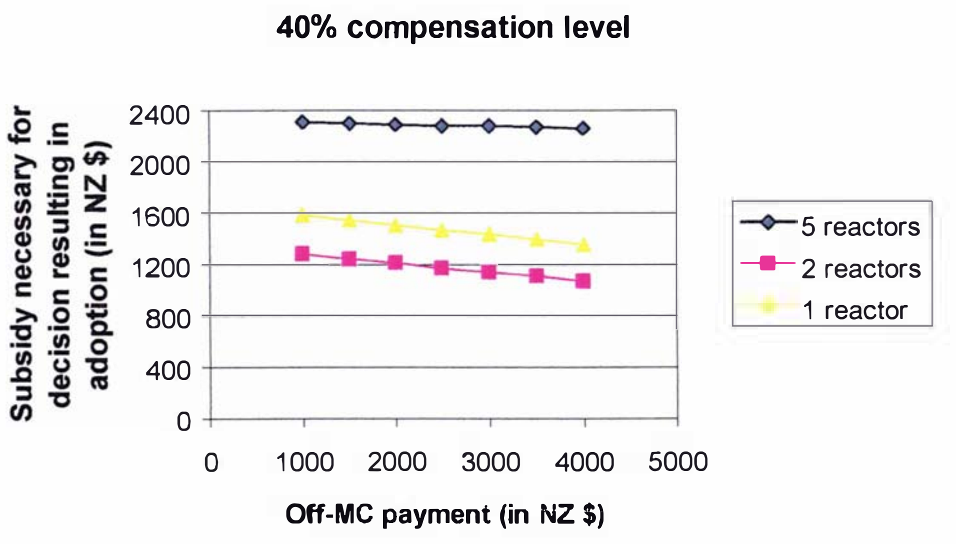


**Figure 57. Subsidies and off-MC-payments for beef breeding farms in order to make adoption of on-farm control programmes the preferred option in the decision analysis for the five-, two, and one-reactor starting situation, under 40% compensation.**

## Decision analysis on beef finishing farms

The decision analysis for the beef finishing farms never resulted in the decision to adopt the control programme. Table 62 presents the expected values for the two different compensation levels (65%

and zero), the different slaughter levies and the different reactor starting situations. In all cases the non-adoption of the on-farm control programme was the preferred option.

**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.**

| Starting reactors | Compensation level | Slaughter levy | Expected value of adoption | Expected value of non-adoption | Decision |
|---|---|---|---|---|---|
| 5 | 65% | None | - $ 593 | $ 475 | Non-adoption |
| 5 | 65% | Current | - $ 1,097 | - $ 29 | Non-adoption |
| 5 | 65% | Increased | - $ 1,503 | - $ 435 | Non-adoption |
| 5 | 0% | None | $ 1,295 | $ 1,358 | Non-adoption |
| 5 | 0% | Current | $ 791 | $ 854 | Non-adoption |
| 5 | 0% | Increased | $ 385 | $ 448 | Non-adoption |
| 2 | 65% | None | - $ 1,097 | $ 25 | Non-adoption |
| 2 | 65% | Current | - $ 1,601 | - $ 479 | Non-adoption |
| 2 | 65% | Increased | - $ 2,007 | - $ 885 | Non-adoption |
| 2 | 0% | None | - $ 145 | $ 73 | Non-adoption |
| 2 | 0% | Current | - $ 649 | - $ 431 | Non-adoption |
| 2 | 0% | Increased | - $ 1,055 | - $ 837 | Non-adoption |
| 1 | 65% | None | - $ 1,430 | $ 34 | Non-adoption |
| 1 | 65% | Current | - $ 1,934 | - $ 470 | Non-adoption |
| 1 | 65% | Increased | - $ 2,340 | - $ 876 | Non-adoption |
| 1 | 0% | None | - $ 1,096 | $ 97 | Non-adoption |
| 1 | 0% | Current | - $ 2,320 | - $ 407 | Non-adoption |
| 1 | 0% | Increased | - $ 2,006 | - $ 813 | Non-adoption |

*Beef finishing: Including a subsidy for labour and material and payment for off-MC*

For the beef finishing farms the decision tree analysis was also calculated for situations where subsidy was paid for poison, bait stations and labour and the yearly payment to farms that achieved off Movement Control status. No slaughter levies were included in this analysis. Table 62 presents the minimum amount necessary in relation to the off-MC-amount paid per year, in order to make 'adoption' the preferred option under current compensation level (65%) and zero compensation. Figure 58 presents the subsidies and payments for the five-, two-, and one-reactor situation under 40% compensation.

**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.**

| Beef finishing farm | 5-reactor situation | | 2-reactor situation | | 1-reactor situation | |
|---|---|---|---|---|---|---|
| Off-MC-payment | 65% comp. | Zero comp. | 65% comp. | Zero comp. | 65% comp. | Zero comp. |
| $1,000 | $ 1,060 | $ 10 | $ 1,060 | $ 150 | $ 1,390 | $ 1,120 |
| $1,500 | $ 1,050 | $ 20 | $ 1,020 | $ 120 | $ 1,360 | $ 1,090 |
| $2,000 | $ 1,040 | $ 20 | $ 990 | $ 90 | $ 1,320 | $ 1,050 |
| $2,500 | $ 1,040 | $ 30 | $ 960 | $ 50 | $ 1,280 | $ 1,010 |
| $3,000 | $ 1,030 | $ 40 | $ 920 | $ 20 | $ 1,240 | $ 970 |
| $3,500 | $ 1,020 | $ 50 | $ 890 | $ 0 | $ 1,210 | $ 940 |
| $4,000 | $ 1,010 | $ 50 | $ 850 | $ 0 | $ 1,170 | $ 900 |

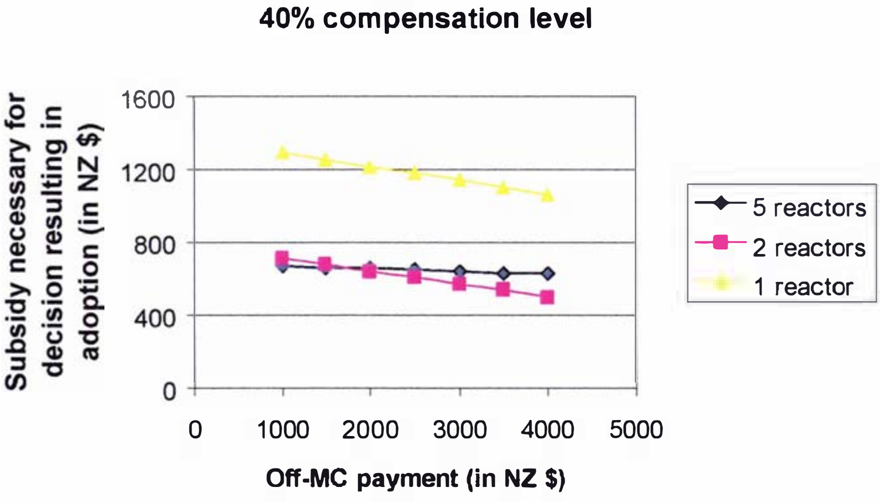


**Figure 58. Subsidies and off-MC-payments for beef finishing farms in order to make adoption of on-farm control programmes the preferred option in the decision analysis for the five-, two, and one-reactor starting situation, under 40% compensation.**

### *Provision of voucher for control and off-MC-payment for the Wairarapa region*

Using the level of subsidies described in the previous section for beef farms, which would make the adoption of on-farm control programmes financially beneficial, the total cost for the Wairarapa was calculated. Currently there are 80 farms on MC (AgriQuality, pers. comm. 2000). Forty-five (45) of these farms are beef breeding, 17 beef finishing, 15 dairy herds and three miscellaneous herds. As these miscellaneous herds are very small, they are grouped together with the dairy farms.

Two situations were calculated; in the first situation an off-MC payment of $2,500 was made for three years and in the second situation this payment was only $1,000. Table 64 presents the amount necessary for each of the herd types and the number of reactors currently on the farm, whereby the two categories one or two reactors were combined.

**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.**

| | | Dairy | | Beef breeding | | Beef finishing | |
|---|---|---|---|---|---|---|---|
| Reactor numbers | | 5 | 1 or 2 | 5 | 1 or 2 | 5 | 1 or 2 |
| $2,500 off-MC-pay | 40% comp. | $ 0 | $ 0 | $ 2,280 | $ 1,460 | $ 650 | $ 1,180 |
| | 65% comp. | $ 0 | $ 0 | $ 2,560 | $ 1,540 | $ 1,040 | $ 1,280 |
| $1,000 off-MC-pay | 40% comp. | $ 0 | $ 0 | $ 2,310 | $ 1,580 | $ 670 | $ 1,290 |
| | 65% comp. | $ 0 | $ 0 | $ 2,580 | $ 1,650 | $ 1,060 | $ 1,390 |

Assuming that 10% of MC-herds have five or more reactors, 70% have 2 to 5 reactors, 20% of MC-herds have one reactor per year and that 80% of the MC-herds come off MC within 5 years, the regional costs to the Wairarapa can be calculated. The total costs to the region from providing vouchers as indicated in Table 64 and two different levels off-MC-payments ($2,500 and $1,000) are detailed in Table 65. The off-MC-payments are paid for three years within a 10-year period.

**Table 65. Regional cost for providing vouchers for control work and two different off-MC-payments under two different compensation levels for reactor animals.**

| | Dairy | Beef breeding | Beef finishing | Total |
|---|---|---|---|---|
| **$2,500 off-MC-payment for three years and 40% reactor compensation** | | | | |
| Vouchers over 5 yrs | $ 0 | $ 344,900 | $ 95,000 | $ 439,900 |
| Off-MC-payments over 5 yrs | $ 105,000 | $ 270,000 | $ 105,000 | $ 480,000 |
| Total cost over 5 yrs | $ 105,000 | $ 614,900 | $ 200,000 | $ 919,900 |
| **Avg. annual cost** | **$ 21,000** | **$ 122,980** | **$ 40,000** | **$ 183,980** |
| **$2,500 off-MC-payment for three years and 65% reactor compensation** | | | | |
| Vouchers over 5 yrs | $ 0 | $ 366,900 | $ 106,400 | $ 473,300 |
| Off-MC-payments over 5 yrs | $ 105,000 | $ 270,000 | $ 105,000 | $ 480,000 |
| Total cost over 5 yrs | $ 105,000 | $ 636,900 | $ 211,400 | $ 953,300 |
| **Avg. annual cost** | **$ 21,000** | **$ 127,380** | **$ 42,280** | **$ 190,660** |
| **$1,000 off-MC-payment for three years and 40% reactor compensation** | | | | |
| Vouchers over 5 yrs | $ 0 | $ 370,100 | $ 103,450 | $ 473,550 |
| Off-MC-payments over 5 yrs | $ 42,000 | $ 108,000 | $ 42,000 | $ 192,000 |
| Total cost over 5 yrs | $ 42,000 | $ 478,100 | $ 145,450 | $ 665,550 |
| **Avg. annual cost** | **$ 8,400** | **$ 95,620** | **$ 29,090** | **$ 133,110** |
| **$1,000 off-MC-payment for three years and 65% reactor compensation** | | | | |
| Vouchers over 5 yrs | $ 0 | $ 389,850 | $ 114,850 | $ 504,700 |
| Off-MC-payments over 5 yrs | $ 42,000 | $ 108,000 | $ 42,000 | $ 192,000 |
| Total cost over 5 yrs | $ 42,000 | $ 497,850 | $ 156,850 | $ 696,700 |
| **Avg. annual cost** | **$ 8,400** | **$ 99,570** | **$ 31,370** | **$ 139,340** |

The total cost for the region is less if only a $1,000 off-MC-payment is paid instead of $2,500. The amount paid for vouchers is very similar in both situations.

The amount for the vouchers could also be calculated on a per hectare basis, as the amount of vector control work is dependent on the farm size. For the situation with $1,000 off-MC-payment and 40% reactor compensation the vouchers amount to $5.40/ha for BB with 5 reactors, $3.70/ha for BB with 1 or 2 reactors, $2.80/ha for BD with 5 reactors, and $5.38/ha for BD with 1 or 2 reactors. Under 65% reactor compensation, the vouchers amounts to $6.03/ha for BB with 5 reactors, $3.86/ha for BB with 1 or 2 reactors, $4.42/ha for BD with 5 reactors, and $5,79/ha for BD with 1 or 2 reactors.

## Discussion

### *Factors considered and omitted in the partial budget*

The acquisition and organisation of data for the economic analysis was the most difficult aspect, as found in most agricultural economic decision-making (Marsh, 1999). Data about consequences of the implementation of on-farm TB control measures were obtained by visiting some farms, which were part of the intervention study that evaluated these measures (see Chapter 3). Discussions with experts from AgriQuality and experts from the farm consulting company 'Baker & Associates' were another important source of information. They provided the best available information to calculate or estimate data that are influenced by the implementation of on-farm control measures. To facilitate the comparison between the three different types of farms, equal values were assumed across farms for the costs of one hour of labour, costs of fencing and depreciation period. The time horizon (the period for which the economic analysis was undertaken) was kept to one year, as the costs were fixed and of short-term effect. Consideration of the time value of money (discounting) was therefore not necessary (Marsh, 1999).

In the present model two factors were included in the additional returns accrued from the implementation of the control strategies: (1) increased animal value, which only applied if the herd came off MC and (2) increased milk production, which only applied to dairy farms. It is generally known and accepted that white-tagged animals can often only be sold at a discount. However, the estimation of these discounts proved difficult, as no published information was available. The values used in the analysis were based on discussions with AgriQuality and experts from the AHB. However, we realise that these percentages chosen can be debated, and that they might need adjustment in further research, as more detailed information becomes available.

The increased milk production on dairy farms was due to the reduction of the number of reactors. If this number is reduced as a consequence of adopting on-farm control measures, these animals do not have to be removed in mid-lactation.

Only one factor was included in the reduced costs section of the present model: premature disposal due to TB, not as a consequence of the animal dying from TB, which is in the long run fatal, but because under the official control regulations the animal has to be slaughtered once suspected of being tuberculous. Three other factors were considered for inclusion in the 'reduced costs' section, but were either regarded as unimportant or un-quantifiable in the present context: (1) Altered feed conversion efficiency, which occurs if the disease affects animal productivity by altering the metabolic processes for protein and other nutrients (Dijkhuizen and Morris, 1997). However, under current TB testing schemes, TB is unlikely to have a subclinical effect on milk production and live weight gain of the animals, because generally it is diagnosed very early. (2) Increased live weight gain; generally diseased animals gain weight more slowly than equivalent disease-free animals (Dijkhuizen and Morris, 1997). In New Zealand the existing TB control practices ensure animals are identified and slaughtered before clinical signs of TB show. Therefore, the increase of live weight was considered to be minimal and was left 'un-quantified'. (3) More accurate genetic selection. If cows have to be removed from the herd due to being considered tuberculous, this means that more replacements have to be chosen from the available heifers, leaving fewer options and fewer animals for sale. Thus not only will livestock sale income be reduced, but also management flexibility for herd improvement will be curtailed (Dijkhuizen and Morris, 1997). TB infection might contribute to the loss of genetically superior animals. However, this effect was considered un-quantifiable in the present study.

Quantifying the cost and time needed for implementing an on-farm control programme, involving vector control and altered grazing management strategy, was complicated through the fact that grazing management was already incorporated in any existing farm system. Additionally the revenues and investments that resulted from implementing such specific on-farm control measures were influenced by farm characteristics, such as vegetation, location of the farm and especially the commitment of the farmer.

A potential additional cost-contributing factor was the purchase of supplements. Excluding TB hot-spot areas from grazing could mean less available feed for cattle, thus necessitating supplementary feeding. However, dairy farms could use hot-spot areas for part of the day if necessary and beef farms could use sheep in these areas. Furthermore beef farmers are more likely to sell their cattle in times of pasture shortage, than to buy in supplements. Therefore this factor was excluded from the analysis.

In the present study no returns foregone were included. A drop in milk production as a result of not using TB hot-spot areas, thus sub-optimal use of grazing possibilities, could have been a possible return foregone. Chapter 7 considers this issue, and concludes it is not important. The increase in milk production, due to not having to remove animals in mid-lactation, was expected to be much higher and as a result the overall milk production will increase.

For the sheep and beef farms the effects of adopting grazing strategies on the sheep production was left un-quantified. Sheep can be used to graze TB hot-spot areas, as they will not expose themselves readily to moribund possums (Sauter and Morris, 1995). As a consequence of this and the introduction of a detailed grazing strategy, the live weight gain in sheep might be increased. However, these influences were difficult to measure and were left un-quantified in this analysis, but were considered in the whole-farm simulation model (Chapter 7).

In the present analysis only direct impacts were taken into account. Other benefits associated with the eradication of tuberculosis from herds, such as the achievement of the international status of TB freedom, with its effects on export and trade, implications for human health and animal welfare have not been quantified in the study. These items can far exceed those at the farm level, but the analysis has been restricted to farm decisions. Macro-economic effects would require a more complex economic evaluation for which data availability would be a major issue (McInerney *et al.*, 1992). Additionally the analysis only took into account the monetary values of costs and benefits. However, for farmers to decide whether or not to implement any TB control, they may also be influenced by non-monetary considerations - the perception of TB, its threat, and social effects. D. Maling (1993), a deer-farmer in Hawke's Bay described a range of feelings, from anger to despair, as a consequence of a TB outbreak. These emotions cannot be put into monetary values and yet, they might have a far greater impact on the farmer and his decisions regarding TB control, than any expected financial outcomes of implementing control programmes. For the farmer mentioned above the only goal was to eradicate TB from his farm and he consequently spent $14,500 on blood tests alone, regardless of economic implications of this course of action.

### *Farms used in the study and TB reactor scenarios analysed*

Using 'typical' or 'representative' farms was one way of dealing with the variety of farm practices and farm management systems. Management on dairy farms does not differ substantially between farms; however, differences might exist in replacement rates and calving percentages, which influence the number of cattle being sold annually. In contrast, beef breeding and beef finishing farms show great variety. These farms adjust their management continuously, depending on market prices and available feed supplies. Therefore, the number of cattle on the farm and the type of cattle differ considerably from year to year. In addition many farms in the Wairarapa have changed their stock selling policies as a result of having TB in their herd. Farms that had the grass growth potential moved from selling weaners to keeping less breeding stock and finishing all offspring. Hence, they could avoid selling white-tagged weaners at a discount of about $30 to $40 a head. These farms can be regarded as a combination of breeding and finishing enterprises. However, in the present study they were not considered as a farm type on their own, as all their stock leaves for slaughter, therefore showing high similarities with beef finishing farms. However, the revenues would be slightly less as female young stock would not achieve the same weight and hence price as male young stock, which mostly are held on pure beef finishing farms. On beef breeding farms the costs of the programme would be higher than on beef finishing farms, as beef breeding farms usually comprise a larger area. However, the larger number of cattle sold would compensate this.

In the present study it was assumed that all beef finishing farms tested their cattle prior to sending them to slaughter and that all tuberculous cattle were identified through the test, rather than being found lesioned at slaughter without testing positive first in the TB test. Beef finishing farms have the option to obtain the herd status 'Works monitored' if over 90% of the herd get slaughtered annually. In herds with this herd status, no on-farm TB testing is required – all animals are subject to the routine slaughterhouse inspection. If a small lesion is found in such animals, the farmer receives the revenue of the carcass, which is downgraded to local trade price instead of possible export price. If the lesions found are extensive, the carcass may be condemned and the animal does not generate any revenue for the farmer. However, these condemned cases occur very seldom with current TB testing policy. As the number of farms with herd status 'Works monitored' in the Wairarapa was very low, the present analysis did not take this farm type into consideration.

The six different reactor number scenarios modelled in the study, starting with five, two, one, respective reactor per year were intended to cover the range of observed situations in the Wairarapa. Three scenarios covered the situation, where the farm remained under MC and the other three where the herd was classified as TB free ('Clear' Status) as a possible result of implementing the control measures. It was important to evaluate the economic effects for both outcomes regarding MC.

### *Results from the deterministic and stochastic models*

Uncertainties and lack of information about parameter values were incorporated into the spreadsheets by using the stochastic modelling approach, which did not assume fixed values but rather a range of values. Sensitivity analysis was used to evaluate the effects of changing parameters. In scenarios where the farm did not come off MC the net benefit was most influenced by the cost of labour, followed by the cost of fencing and poison in beef farms, and the time spent on control measures for dairy farms. In all scenarios where the herd came off MC, the outcome was most severely affected by the discount percentage of white-tagged animals.

### Farm types

Results from the deterministic and stochastic model showed that for dairy and beef breeding farms it was much more beneficial to implement control measures if the herd achieved off-MC status, as this resulted in a higher value for live animals. The farm was able to sell cattle without the discount of white-tags, assumed to be 10% and 15%. Another advantage of being off MC is the higher flexibility in terms of sales policies and grazing policies, such as having the opportunity to graze cattle on TB free farms. This is often critical to dairy farms in order to avoid damage to paddocks during the wet winter months. This higher flexibility was not specifically included in the partial budgeting, but needs to be considered too. The higher value for live animals and the higher flexibility was a considerable advantage for dairy farms and sheep and beef breeding farms, but had no effect on beef finishing farms. As beef finishing farms generally only sell their cattle to slaughter, farmers receive 100% slaughter value for animals with and without white MC tags, if no TB lesions are found. These animals are generally suitable for local and export trade. In the export trade, only a few countries, such as Russia, will not accept cattle from Movement Control herds (Atkinson, pers. comm., 2000). The fact that white-tagged cattle can yield the same revenue at slaughter as non white-tagged cattle, is often used to the advantage of a beef finishing farm when white-tagged animals are bought in at a discount and then sold to slaughter, where no discount applies.

### Compensation level and subsidies

Dropping the compensation level from the current 65% to zero would make it more beneficial for beef finishing farms to implement control measures. If the farm achieved at least two reactors less through the implementation of control measures, the investment was financially worthwhile with an expected net benefit of $350. However, for beef breeding farms the reduction in compensation was still not enough to make adoption of the control measures worthwhile if the herd remained on MC. This was mainly due to the high costs of the programme and the continuous discount in price obtained for animals sold for fattening. If the costs of the programme were reduced through a subsidy of poison, the programme had to achieve a reduction of at least four reactor animals to make it worthwhile.

It was argued that by providing compensation the actual costs associated with TB are masked, which will result in a reduced incentive for farmers to conduct vector control (Animal Health Board, 1995). As the principles of beef finishing farms apply to most mixed farms in the Wairarapa, the abandonment of the compensation could be beneficial on a large number of farms. However, due to the national and regional TB control work being done, it is more likely that the farms with continuing TB problems would have only one or two reactors. If the farm has only one reactor, then the implementation of on-farm control programmes is not even beneficial under zero compensation.

It is therefore concluded that other incentives, apart from reduction of compensation, have to be put in place. One also has to give some consideration to the compliance of farmers if compensation was removed. Many farmers expressed their concern that they or other farmers would not present all animals for testing or would remove possible reactors from the herd before the test is read (see Chapter 5). This therefore would harm the control process very much or would require means of checking the compliance of farmers.

### *Results from the decision analysis*

The financial outcomes in the deterministic and stochastic model for beef breeding farms showed that it was well worth implementing on-farm control programmes if the herd achieved off MC status, but not so if the herd remained under MC. Thus, this would leave it up to the farmer to assess the risk to his farm, how likely he thought it is to achieve zero reactors. The more the compensation level is reduced the higher the expected financial benefit if the farm gets off MC. Decision tree analysis was used to evaluate these situations, taking into account elements of uncertainty. The choice of the preferred option is found through a process called folding back (Marsh, 1999). The result of the decision tree analysis with 65% compensation for the five reactor situation showed that the expected value of implementing control on a beef breeding farm was negative with -$1,675, whereas when no compensation was paid, the expected outcome was -$322.

The decision analysis also showed that for beef finishing farms the adoption of control measures never resulted in a net gain, due to the costs of the programme not being counterbalanced by any additional return if the herd came off MC, only by the difference in value of reactor animals. The expected outcome of non-adoption could never fall below zero, as no additional costs were incurred, but benefits were obtained at zero cost if the herd reduced its reactor numbers. This indicated that beef finishing farmers are probably better off investing their money in other parts of their enterprise rather than TB control with current policies.

Calculating the expected values for the three farm types under a policy where no compensation was paid, showed that there was no change in the preferred option for dairy nor for beef farms; for dairy it was on average more beneficial to implement the control measures than doing nothing, both under the current compensation scheme, and under zero-compensation. For the beef farms it was never the preferred option to implement control measures.

From the decision tree analysis with the two different levels of slaughter levy on adult cattle on beef farms it was seen that the increase of the levy would further add to the costs of TB for the farm, and therefore it would be less likely that farmers adopt on-farm control programmes. The expected value for the adoption of the programme was always less than for the non-adoption in the beef farms. None of the different combinations of levy and compensation resulted in the adoption of the programme as the preferred option. Therefore, other incentives have to be put in place.

### *Insurance as an additional method*

The current policy where all farmers pay a slaughter levy on adult cattle and farmers obtain 65% compensation for any animal reacting positively to the TB test, is a form of insurance. However, this can lead to reduced motivation to do on-farm control, which was found in an outbreak of classical swine fever in Germany (Davies, 1996). Thus it might result in using less preventive measures and increased reliance on large-scale control efforts (Howe and Whittaker, 1997). It also induces situations where farmer 'blame' the national programme for any failures on their property. In New Zealand, the current system of a universal slaughter levy and compensation for reactor cattle has worked well so far, as many herds were affected by tuberculosis or saw themselves at risk.

A more comprehensive insurance scheme could involve rate-making, where farmers pay different insurance rates, depending on area, enterprise type, precautions taken and similar criteria (Howe and Whittaker, 1997). However, traditional rate-making in insurance is subject to criticism that past experience does not fully represent the future. If the deviation from the past is positive, this does not cause a great problem, but if the deviation is negative then the rate calculated will be inadequate (Vaughan and Vaughan, 1999). Differentiating the premiums would also result in more administrative and monitoring costs, therefore necessitating evaluation of whether the efficiency gained through differentiation is more than these additional costs.

Insurance companies are also reluctant to insure events with a high probability of occurrence, and particularly of re-occurrence on the same farm. The probability of an outbreak of an endemic disease is relatively high and several farmers in the same area might be affected. In the case of TB the proportion of farms affected is now low and declining, so companies may be willing to insure farmers. However, many farmers may see the risk as low and hence decline insurance, so the risk would not be adequately shared and premiums for at-risk farms would be unacceptably high.

The biggest problems of an insurance scheme would be those of adverse selection and moral hazards. Producers with good control measures could be less likely to buy insurance than producers with poor control measures, as the probability of getting infected is smaller for the former ones than for the latter (Ekboir, 1999). Furthermore producers with a potentially higher loss could be more likely to take out insurance. For example a stud beef breeding farm that sells cattle nationally will incur very high losses if the herd is diagnosed with tuberculosis and would insure, whereas a beef finishing farm would not. A further problem could be that farmers who are off MC for longer periods underestimate the threat of TB to their farm and are less likely to buy insurance, but also less likely to conduct control measures. The biggest problem of an insurance scheme is moral hazard; if farmers who bought insurance took less care in their control programmes and therefore took more risk of getting infected, than if they had not bought insurance.

Even if a way of insurance for TB is found that works well, the scheme will have high costs in terms of administration and audits. These costs have to be covered in the case of a private insurance market by the farmers choosing to insure their herds, or in the case of a state insurance scheme, by taxpayers' money.

### *Effects for future control of TB*

From the potential problems with an insurance scheme it is suggested that increased emphasis on insurance against TB is not a preferred option in the national control of TB on their own properties. Instead, increased motivation is necessary that encourages farmers to assist the control of TB. Motivation can be increased through market signals. The current policy of slaughter levy and compensation does not give any market signals to encourage personal efforts to control TB on farms. However, if compensation is removed altogether there is the risk that farmers will circumvent the measures and that the co-operation of the farmers in the national control programme is lost.

Reducing, not eliminating, the compensation will increase useful market signals. However from the analysis it can be seen that the increased loss per TB animal is not enough to counterbalance the costs of the programme. Therefore it is concluded that the reduction in compensation is not incentive enough. Furthermore, from the analysis it can be seen that dairy herds gain more financially from on-farm control programmes than beef farms (Table 66).

**Table 66. Expected financial outcome of adopting on-farm control measures for the three herd types and the different reactor scenarios.**

| | Under 65% compensation | | | Under zero compensation | | |
|---|---|---|---|---|---|---|
| | **Dairy** | **Beef breed.** | **Beef fin.** | **Dairy** | **Beef breed.** | **Beef fin.** |
| From 5/yr to 2/yr | $ 1,068 | - $ 2,460 | - $ 572 | $ 2,725 | - $ 1,105 | $ 1,320 |
| From 5/yr to 1/2$^{nd}$ yr | $ 2,292 | - $ 2,095 | - $ 62 | $ 4,778 | - $ 63 | $ 2,775 |
| From 5/yr to off MC* | $ 7,750 | $ 3,805 | $ 108 | $10,537 | $ 6,064 | $ 3,260 |
| From 2/yr to 1/2$^{nd}$ yr | - $ 156 | - $ 2,825 | - $ 1,081 | $ 673 | - $ 2,147 | - $ 135 |
| From 2/yr to off MC* | $ 5,327 | $ 3,075 | - $ 911 | $ 6,432 | $ 3,979 | $ 350 |
| From 1/yr to off MC* | $ 4,511 | $ 2,832 | - $ 1,251 | $ 5,063 | $ 3,284 | - $ 620 |

An additional inequity of costs associated with TB between dairy and beef producers in the Wairarapa are the regional council rates. These are set per hectare, independent of land use, but dependent on the existence of Regional Council vector control programmes (R.Cleary, pers. comm., 2000). However, the properties of beef producers are much larger than those of dairy producers, thus introducing further disadvantage to beef producers. This could also induce an increased reliance on Regional Councils and a tendency to blame them for problems. Beef producers pay proportionally more to RC and therefore 'expect' RC to control possums on their land. However, these rates are not set by the AHB and therefore the option of reducing RC rates for beef producers was not elaborated in this study.

Based on the different gains/losses for dairy- versus beef producers, it is suggested that differential positive and negative signals to different producers should be put in place. A simple reduction in compensation does not provide such a differentiation. The following options are suggested:

- Substantially penalising TB positive animals at slaughter (culls) while leaving compensation for test-positive animals at 65%; for example the introduction of a charge on all TB culls of 70% of value. This step would encourage pre-slaughter testing on farms. The skin test has better sensitivity than detection of TB lesions at routine slaughter (Ryan, 1992; Corner, 1994; Whipple *et al.*, 1995). In the last phase of a disease eradication programme it is important to find all true positive animals, therefore it is important to avoid situations where tuberculous animals go to slaughter and do not get detected. The herd of origin of these animals poses a risk to other herds.

- Introduce a payment per year for herds which get off Movement Control. These payments could be limited to a maximum of three years in a 10-year period. They could be differential, a higher sum for beef producers than for dairy-producers, in order to achieve the same financial gain for both enterprise types. The main advantage of this payment is as an incentive for farmers to assist the control of TB. As the number of farms in this category is small and will further be reduced, this part will not be a major cost to the national programme. From Figure 43 to Figure 45 it can be seen that the expected net return of implementing on-farm control programmes on beef breeding farms is around $3,000 and for beef finishing farms around $4,000 lower than for dairy farms. These differences in the net return could be reflected in the suggested payments for coming off MC.

- In order to make the adoption of on-farm control programmes more attractive, the costs of material and labour have to be reduced to the individual farmer. Therefore, vouchers for additional RC/contractor/own on-farm control efforts or similar systems could be provided. Table 55, Table 56, and Table 57 provide the amount necessary for beef farms to obtain a net gain in all reactor number scenarios. When poison and bait stations are provided for free, dairy farms will always obtain a net gain. This voucher-system in conjunction with the yearly payment if the herd comes off MC provides a big incentive for farmers to do something on their farms.

- Use a phasing of different methods over the next four to five years, with decreasing compensation, higher penalties for tuberculous animals at slaughter (culls) and stricter movement control rules, such as MC farms only permitted to sell to slaughter.

Vaccination could be used for fringe areas, where there is a risk of spreading TB into uninfected area. Funding from different sources could also be focused on different control measures. E.g. focus Government and regional rates money on broad-scale RC control efforts, and the limitation of spread of TB, whereas the industry money could be used for additional on-farm control efforts.

Additionally, a significant share of TB costs at AHB level could be shifted from beef to dairy producers, as they are the ones who benefit most of control programmes.

With these different combinations of penalties and incentives it is possible that the control of TB is achieved quicker than if the sole focus is put on large-scale intensive possum control operations. The intention is that a policy mix is found that provides positive and negative incentives to each enterprise type which will give each an appropriate set of market signals.

The risk that Vector-Risk-Areas are still expanding requires separate methods. Reducing possum numbers on its own might not solve the problem, but vaccination on a broad base could be much more useful.

With ongoing national and regional TB control it will be more likely that farms will have only one or two reactors, rather than five or more. Therefore a change in compensation level from 65% to zero could make a difference for the beef breeding farms. Under current compensation levels, adoption of control measures for a farm with two reactors does not result in a net benefit, but a net benefit would be achieved if no compensation were paid.

From January 2000 new cattle movement policies are in place, whereby cattle can only move to other herds if the herd already had one clear test and the group to be moved has passed a clear test within 60 days of movement. Animals from infected herds without a clear test will have to pass a skin test and a parallel blood test. If these conditions are met, then the animals can move subject to a permit, with white ear tags, and they must be tested a minimum of 90 days after the pre-movement test. In addition the purchaser's herd status will be suspended and only restored to C1 after a clear whole herd test a minimum of six months after the post-movement test.

It is expected that this will constrain cattle sales for beef breeding farms very much if they are still on MC, as not many purchasers will want to lose their status and obtain a status of only C1 (Animal Health Board, 1999). Especially purchasers with herds that have been clear for many years will not buy white-tagged animals any more. The additional requirement of a blood test for cattle from infected herds without a clear herd test, is a further step towards ensuring that no infected animals can go on to other farms.

Another expected consequence of the changed rules is that many beef breeding farmers will change their trading policies towards reducing their number of beef breeding cows and fattening all the offspring (Animal Health Board, 1999). Therefore the same principles would apply to them as for the beef finishing farms, which are not affected by the change of regulation. These farms are still able to buy in white-tagged cattle at a heavily discounted price. If the animals pass the post-movement test, their white tags can be removed and the cattle fattened and sold to slaughter or privately as normal animals. Any purchaser's herd status thereafter would not be affected anymore. This is also the case when farms have two different blocks of land with two separate herd numbers. For example a farm with a herd status of I5 can get their weaned calves tested (skin test plus parallel blood test) and (provided they all pass) move them on to the second block, and test them again within 90 days of the pre-movement test. If the animals pass this test as well, the white ear tags can be removed and the animals sold to any farm (e.g. C6) without affecting the purchaser's herd status. A stricter version of the rules might involve that any purchaser's herd status would obtain the lower status of the herd where the animals came from. For example, if a herd with classification C5 buys in cattle from a herd classified as C3, the herd status will change from C5 to C3.

With the change of policy and its expected impact on the possibilities of being able to sell white-tagged cattle, it might well be that the discount for white-tagged cattle is even greater than assumed in our study (10% for dairy and 15% for beef cattle). As the sensitivity analysis in the stochastic modelling showed, this discount value is of major importance when the herd comes off MC. This means if the discount is even greater, the added benefit of selling non-white tagged cattle is greater. In the decision analysis this higher positive outcome could therefore cause on average a higher expected monetary value for the implementation option than for the option of doing nothing. It remains to be seen if the discount will change very much as a result of the changed rules for movement from infected cattle herds.

## TB and its effect in the wider economy

The part which the public sector has to play in controlling animal diseases is increasingly debated (McInerney, 1996; Sanson and Thornton, 1997). As a result the private sector has to adopt a larger role in planning and implementing animal health policies (Ekboir, 1999). However, with a disease complex such as tuberculosis, which has probably a greater effect on the national export trade than on the individual farm, one could argue about the principle of 'user-pays'. The potential losses in export trade in the worst-case scenario could be worth NZ$5 billion over 10 years (Parliamentary commissioner for the envirionment, 1994). Additionally, at farm level control on one farm will automatically also have effects on the neighbouring farms, termed 'external effects' or 'externalities'. Poor control by neighbours reduces the effectiveness of possum control by any particular farmer, through potential immigration of possums from neighbouring properties. The same applies the other way round, if a farm is surrounded by farms that conduct intensive possum control, then eventually this will also show a positive effect on the farm in the middle, even if that farm does not do any control at all. Therefore this farmer in the middle benefits from the control programmes of the neighbouring farms ('free-riding') (Ekboir, 1999). In order to avoid the problem of 'free-riding' and to make sure that all farmers are participating in the control effort, it might be necessary to impose legal requirements for participation, and compliance monitoring. Alternatively, market signals might be used to induce such producers to participate.

Under the current TB control policies it does not seem to be economically beneficial for beef farms to eliminate TB from their herds, however as the disease does pose a threat to the national economy, it is very important to eradicate TB. If the aim is to put more and more responsibility for TB control on farmers instead of the general tax-paying community, then rules, regulations and/or incentives should be put in place that create positive net-benefits for all farm types.

The need to become free of TB might increase enormously, if the persistence of TB in New Zealand is going to be used as a non-tariff barrier against New Zealand by trading partners. The consequences of TB in a herd would then be much more dramatic than assumed in this study. Therefore, efforts should be made now to reduce the risk of TB spread and to reduce the TB levels on farms. As long as there is no measure available to eradicate TB from possums, or even better to eradicate the possum population itself, on-farm control measures, including targeted vector control and grazing management system, can be a helpful instrument in the fight against TB.

## *Conclusions*

Table 67 and Table 68 show summaries of the results found in the study. In Table 67 the financial outcomes of the deterministic and stochastic partial budget are presented as 'Gain' or 'Loss'. The TB reactor scenarios are as described in the Materials and Methods. In Table 68 the outcomes of the decision tree analysis using the probabilities as stated in Materials and Methods are summarised.

**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.**

| | Scenario 1<br>5 down to 2 reactors | Scenario 2<br>5 down to 0.5 react. | Scenario 3<br>5 down to 0 reactors | Scenario 4<br>2 down to 0.5 react. | Scenario 5<br>2 down to 0 reactors | Scenario 6<br>1 down to 0 reactors |
|---|---|---|---|---|---|---|
| DH with 65% comp. | Gain | Gain | Gain | Loss | Gain | Gain |
| BB with 65% comp. | Loss | Loss | Gain | Loss | Gain | Gain |
| BD with 65% comp. | Loss | Loss | Gain | Loss | Loss | Loss |
| DH with zero comp. | Gain | Gain | Gain | Gain | Gain | Gain |
| BB with zero comp. | Loss | Loss | Gain | Loss | Gain | Gain |
| BD with zero comp. | Gain | Gain | Gain | Loss | Gain | Loss |

**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.**

| | Starting with 5 reactors | Starting with 2 reactors | Starting with 1 reactor |
|---|---|---|---|
| DH with 65% comp. | Adoption | Adoption | Adoption |
| DH with zero comp. | Adoption | Adoption | Adoption |
| BB with 65% comp. | Non-adoption | Non-adoption | Non-adoption |
| BB with zero comp. | Non-adoption | Non-adoption | Non-adoption |
| BD with 65% comp. | Non-adoption | Non-adoption | Non-adoption |
| BD with zero comp. | Non-adoption | Non-adoption | Non-adoption |

From the results presented in Table 67 and Table 68, it is concluded that under the current compensation level of 65% the adoption of on-farm control measures is generally resulting in a net gain for dairy farms, but for beef farms only if they get their reactor number down to zero. If the compensation level is reduced to zero, the situation is not altered significantly. The net gain in the dairy farms increases, the situation in the beef breeding farms changes hardly at all and on beef finishing farms the adoption of control programmes becomes beneficial if at least two reactors can be saved.

Therefore it is concluded that a reduction of compensation level does not create a significant incentive for beef farmers to adopt on-farm control measures for TB. In addition, the removal of compensation could result in less co-operation by farmers, and therefore lead to results contrary to the intended ones. Thus other incentives or stringent rules and regulations, have to be put in place to encourage or force farmers to conduct their own control programmes.

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Beef farm in the Wairarapa (modelled in Chapter 7)

Beef farm in the Wairarapa

# Chapter 7

# FarmORACLE, a farm simulation model

## Abstract

Bovine tuberculosis control in New Zealand is complicated through the existence of wildlife reservoirs. The Australian brushtail possum is the main vector for transmitting the disease to livestock. Control of tuberculosis therefore is two-fold, control of livestock and control of infected wildlife. Large-scale poisoning operations are the main control method. These are expensive and it is not possible to cover all areas with infected wildlife. Thus, progressively greater responsibility will be imposed on farmers to control TB on their own properties. Tuberculous possums are mostly located in specific TB hot-spot areas, not evenly distributed across the farm. On-farm control methods found to be effective (see Chapter 3) included targeted vector control and specific grazing management strategies to exclude cattle and deer from grazing hot-spot areas at high risk times during the year. Grazing routines are often based on past experience and tradition. For adoption of alternative grazing strategies, that take these TB issues into considerations, it is necessary to provide the farmer with likely outcomes of the changed grazing strategy. A computer simulation model for the whole farm and all animals present on the farm, was developed to assist the process of evaluating alternative grazing strategies. Outcomes used for the economic evaluation included liveweight of animals sold, and milk production on dairy farms.

The use of the program is described on four farms in the Wairarapa, two dairy, one beef finishing and one beef breeding farm. In all four farms it was possible to find a grazing strategy that resulted in similar or even better economic outcome than the traditional grazing regime.

## Introduction

Tuberculosis in cattle and deer is a disease of great concern for agriculture in New Zealand. Control of the disease is complicated through the existence of wildlife vectors, such as possums (*Trichosurus vulpecula*) and ferrets (*Mustela furo*). Infected brushtail possum populations are the major source of TB infection for farmed animals (Jackson, 1995; Morris and Pfeiffer, 1995; Livingstone, 1997). The New Zealand cattle and deer industry is based on pastoral production and contact between livestock and feral animals is the most likely transmission pathway for TB (Sauter and Morris, 1995). Tuberculous possums are not evenly distributed across the farm but are localised in clusters, commonly referred to as 'hot-spots' (McKenzie, 1999). Excluding cattle and deer from grazing areas of the farm where hot-spots are located during certain times of the year, was shown to reduce the incidence of disease in livestock (see Chapter 3). Grazing management is thus a useful tool to assist farmers control TB in cattle and deer. These hot-spot paddocks excluded from grazing can be used productively in other ways, such as preserving the pasture in the form of silage or hay, or by grazing them with other stock, such as sheep.

Often, grazing management on farms is based on tradition and many years experience. Therefore, it is necessary to convince farmers that changing their management can result in the same or an even better economic outcome than the traditional grazing plan. A computer model, simulating the individual farm with all its animals and stock numbers could assist the process of evaluating alternative grazing programmes and of convincing farmers to implement these. There are several whole farm or feed budgeting decision support systems available, such as for example FEEDBAL (Lodge and Frecker, 1990), MIDAS, described by Pannell (1996), and PRO Plus (McPhee *et al.*, 2000) all developed for Australian conditions, and 'The Grazing Manager' developed by the Texas A & M University (1997) for beef farmers in the USA. The only whole-farm decision support system for livestock farms in New Zealand is STOCKPOL, developed by the Ministry of Agriculture and Fisheries. It can be used to model different management strategies, long-term policy changes or short-term feed budgets, but it cannot be used for paddock-level feed budgeting (Marshall *et al.*, 1991). All these models focus on maximising animal and farm production, while the present study required a model that had the flexibility to incorporate disease control issues such as managing areas of potential contact between livestock and tuberculous wildlife.

Research has shown that there are many factors influencing the efficiency with which pasture is utilised on a farm. Pastures are dynamic and complex plant communities with new tissue continually being formed through growth and old tissue disappearing through the process of senescence, death and decay (Matthews, 1994). Therefore grazing management is very complex; for example, pasture cannot be carried forward between grazing periods. Residual pasture left after grazing will contribute to initial plant growth following grazing before disappearing through senescence and decay. If pasture is grazed laxly in an attempt to increase animal intake, then over time pasture quality will deteriorate and net herbage production will decrease resulting in reduced production (Matthews, 1994; Matthews, 1995). If the pasture cover was on average down to 1200kg DM per hectare by the end of winter this led to low animal performance in early spring (Coutinho *et al.*, 1998). Therefore it was recommended that grazing management should be changed over the winter period to focus on achieving a desired sward condition for early spring, rather than improving liveweight gains in winter. Following this grazing management could then focus again on both pasture and animal performance (Coutinho *et al.*, 1998).

The manipulation of grazing rotation has more to do with pasture utilisation than with pasture production. It is the grazing rotation that manipulates average pasture cover and allows pasture to be transferred within the system on the short term and determines pasture availability on a day to day basis (Matthews, 1994). Pasture quality is maintained by control of the pre grazing levels rather than those after grazing. If pre grazing levels are too high, there will be increased losses and decreased nutritive value of the sward which will result in reduced intakes of lower quality feed, and reduced pasture growth rates (Matthews, 1995).

Traditionally, grazing management is controlled on New Zealand dairy farms through the control of animal intake. Variations in pasture growth are overcome by adjustments to intake levels and therefore animal liveweight and production. This way, the grazing animal acts as a buffer in the pasture system (Matthews, 1994). However, with the current trend of having higher animal performance, particularly in the dairy industry, cow requirements must be met throughout the year to meet these higher production targets and therefore the grazing animal can no longer act as a buffer. Supplements are one form of replacing the cow as the buffer in the system, which is determined by the post grazing residual (Matthews, 1994; Matthews, 1995).

All these factors mentioned in relation to grazing management indicate that there are many options for a grazing management plan on an individual farms. A whole-farm simulation model, which models pasture growth and animal intake was therefore considered to be of major importance in help farmers determine which grazing strategies would achieve their desired outcomes. These outcomes might be purely financial or they may also be associated with disease control issues, such as reduced exposure of cattle to infectious tuberculous possums. Regardless of the outcome, any grazing management programme may have a positive effect on production (Matthews, 1994). Often farmers are reluctant to try new approaches, due to the uncertainty of the outcome (Morris *et al.*, 1995). If different grazing strategies can be modelled, and the outcomes compared against each other, farmers might be more likely to adopt certain strategies. FarmORACLE was developed as a tool for this purpose.

## Overview of FarmORACLE

FarmORACLE is a whole-farm simulation model, designed to allow veterinarians, farm advisors and herd managers to select grazing management plans that minimise the risk of livestock contact with TB-infected feral animals. It is intended to be a stand-alone system, operating under MS Windows, using data input from any farm recording program. Increasingly farmers are using farm recording programs such as FarmTracker® or Endeveour®, to record stock movements, animal treatments and/or paddock events. The program is written in the programming language Delphi.

The use of FarmORACLE to develop a grazing plan that incorporates TB control as well as production outcomes, involves four main steps:

(i) setting up paddock maps and animal groups (mobs) for the individual farm,

(ii) setting up the base grazing plan, according to the way animals are normally rotated around the paddocks,

(iii) setting up an alternative grazing plan, in which cattle and deer are excluded from known or suspected TB hot-spot areas from November to January and during July and August, the high risk times for livestock coming into contact with moribund tuberculous possums (see Chapter 3),

(iv) comparing the production outcome between the base plan and the alternative plan.

The current model derives its data from the farm recording program, FarmTracker®. Within FarmTracker, a farm paddock map can be generated by digitising fencelines shown on an aerial photo. The program calculates the area of each individual paddock. Each individual mob can be set up with its own livestock parameters and targets.

The model uses animal numbers and their gender, breed and age, plus paddock size, pasture species and weather data to predict pasture growth and animal intake, using metabolic equations. Each individual paddock or each individual mob can be modelled separately, or the whole farm and all mobs can be modelled together.

The model's output shows actual animal production and target levels in both graphical and text file format, so that it can be used in spreadsheet programs, such as MS Excel. Reports include feed consumption, liveweight/ liveweight gain, milk production and predicted grass cover.

The model consists of three main parts: the pasture growth sub-model, the feed intake sub-model, and the drafting module (see Figure 59). The first two modules are similar to feed budgeting models described earlier (Brookes *et al.*, 1992).

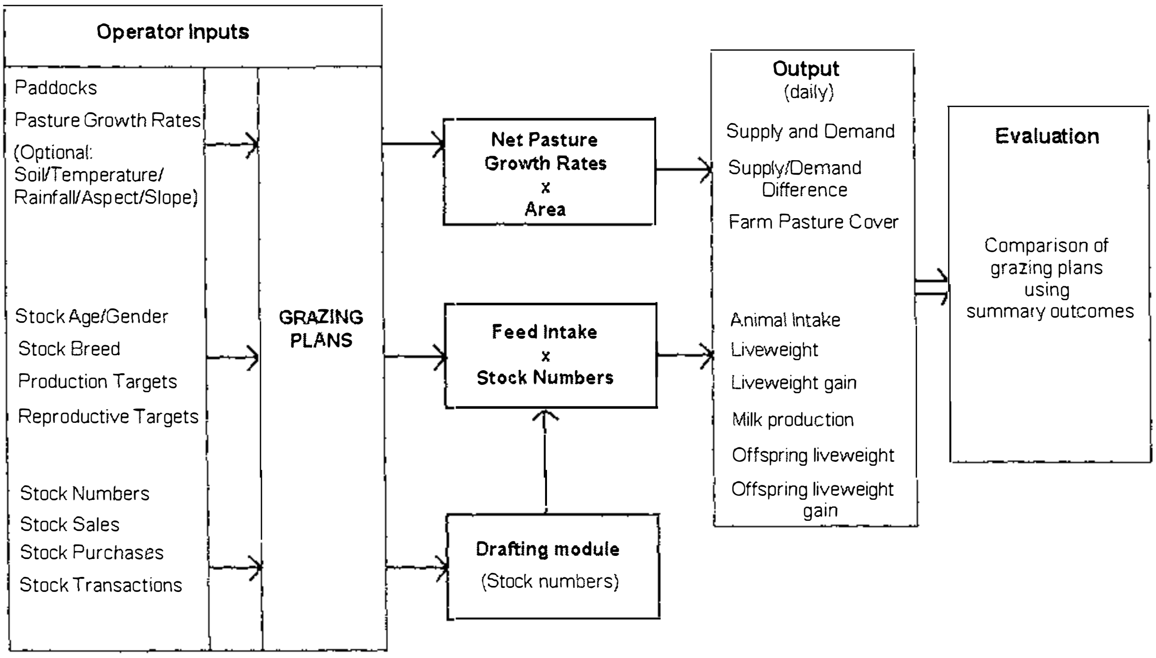


**Figure 59. Graphical display of FarmORACLE.**

The model uses deterministic equations to determine the pasture growth in each paddock, and the average potential and actual intake of animals in a mob. From these intakes it calculates the average outcomes per animal. The functions used in the model are based on unpublished and published literature, such as (Bircham and Hodgson, 1983; Thomson *et al.*, 1984; Butler, 1986; Butler *et al.*, 1987; Matthew *et al.*, 1993; Butler and Hodgson, 1993; Hodgson *et al.*, 1996; Garcia-Muniz *et al.*, 1998) The model was developed over several years, and will eventually be a commercial product. Therefore no specific equations are presented.

The purpose of the stock drafting module is to adjust stock numbers gradually according to sales over time, for example when animals get sold after they have achieved a certain target liveweight. This allows sales to be entered with a time period over which a certain number of animals is sold. The drafting model works by assigning each animal an initial live weight, carcass weight and fat depth on the basis of pre-determined normal distributions and the co-variances between these. Animals are sold when they reach a certain liveweight, carcass weight or fat depth ranges. Following the removal of animals, the average liveweight for the mob is recalculated.

## *Setting up paddocks and animal classes/mobs*

Digital paddock maps can either be imported in different software formats or created within FarmTracker by drawing over fencelines shown on a scanned aerial photograph on the computer screen (Figure 60).


**Figure 60. Creating a paddock map in FarmTracker.**

Although the main focus of the model is to compare different grazing management plans, it is necessary to enter all animal details, as each individual parameter could influence animal intake.

The data that is entered for each mob is:

Number
Breed
Age
Gender
Reproduction status
Liveweight
Stock production targets (liveweight, milk production ...)
Reproductive targets
Mating (how, when)
Drying off (dairy farms)
Calving/Lambing
Stock movements into/from mob

As more farmers use farm recording programs, the necessary information will already be available in digital format.

Table 69 presents the animal liveweight targets for dairy cows and dairy heifers. New Zealand pastoral livestock production is seasonal, i.e. calendar dependent, with most cattle and sheep being born in August each year. The annual production of a dairy cow was set to the average values achieved in the Wairarapa for the year 1998/99. These were 259 kg milksolids, which was equal to 3595 litres of milk, or 151 kg milkfat, using a percentage of 4.20% fat and 7.20% solids in milk (Livestock Improvement Corporation Limited, 1999).

**Table 69. Liveweight targets for dairy cows and heifers (in kg), used in FarmORACLE.**

| Date | Dairy cows | | Dairy heifers | |
|---|---|---|---|---|
| August | 450 | Calving | 35 | Birth |
| November | | | 70 | Weaning |
| March | | | 120 | |
| September | | | 240 | 1 yr old |
| October | 433 | Mating | 280 | Mating |
| December | | | 313 | |
| March | | | 344 | |
| July | 450 | | 444 | |
| September | | | 456 | 2 yr old, calving |

Table 70 presents the liveweight targets for beef cattle and sheep, that were used in the model.

**Table 70. Liveweight targets for beef cattle and sheep (in kg), used in FarmORACLE.**

| Date | Beef cows | Beef heifers | Beef steers | Ewes | Ewe replacements | Finishing lambs |
|---|---|---|---|---|---|---|
| August | 450 (calving) | 35 (birth) | 40 (birth) | 55 (lambing) | 4 (birth) | 4 (birth) |
| October | 455 (mating) | | | | | |
| December | | | 135 | 53 (weaning) | 25 (weaning) | 25 (weaning) |
| February | 490 | | | | | 34 |
| March | 485 (weaning) | 120 | 181 | 56 (mating) | | 39 |
| May | 480 | | 236 | | 37 | 46 |
| August | 450 (calving) | | 282 | 55 (lambing) | 38 | -- |
| October | 455 (mating) | 280 (mating) | | | 40 | -- |
| December | | 313 | 445 | 53 (weaning) | 50 | -- |
| February | 490 | | | | 53 | -- |
| March | 485 (weaning) | 344 | 491 | 56 (mating) | 55 | -- |

## *Grazing plans in FarmORACLE*

Grazing plans can be set up after paddocks and animal mobs have been entered. The main aim of this series of simulations using FarmORACLE was to compare the traditional grazing management plan on the farm with a revised plan, in which cattle and deer are excluded from grazing TB hot-spot areas during certain high-risk times of the year (July and August and November to January; see Chapter 3). The first two steps involved setting up the traditional grazing plan, and the alternative plan.

Setting up grazing plans involved allocating each mob of animals to paddocks for set time periods (Figure 61), which can be as detailed as a daily basis.

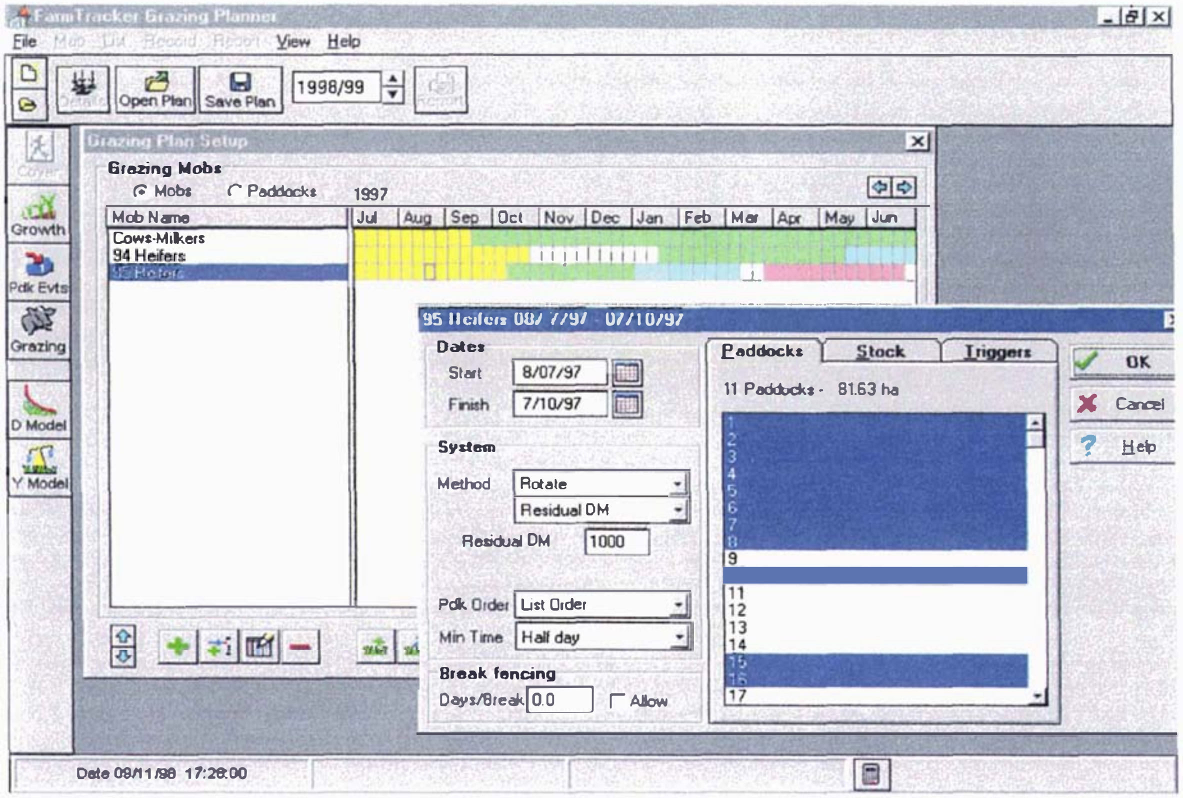


**Figure 61. Setting up grazing plans in FarmORACLE.**

Allocation of pasture to stock can be based on residual post-grazing herbage mass (kg DM/ha), on the number of days in paddocks, according to rotational systems or set-stock grazing systems. Additional parameters such as pasture type, pasture growth rates, conservation of feed, and details on supplements (form of supplements, nutritional value, time of feeding, stock class being fed to ...) can also be set. If no specific pasture growth rates are known, default growth rates for areas within the region may be used.

The program shows the location of each individual mob at any given time on the screen map, using different colours (Figure 62).

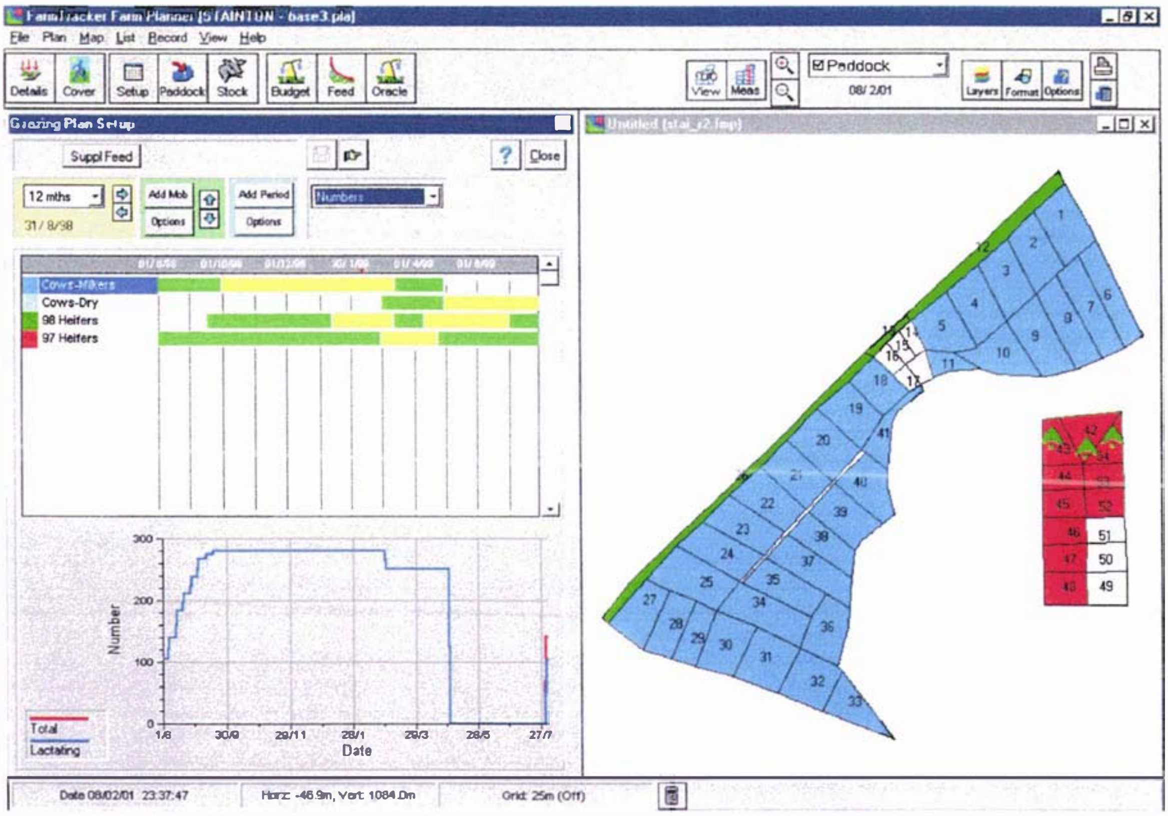


**Figure 62. Location of animal groups on the farm map in FarmORACLE.**

In the alternative grazing plans, cattle and deer are excluded from grazing hot-spot areas during November to January and July and August. On dairy farms, these paddocks were spelled, while on beef farms sheep were put into the hot-spot paddocks during these times.

## *Output of FarmORACLE*

The outputs for each individual grazing plan, shown in graphical and text file format, are:

Intake
Liveweight
Liveweight gain
Milk production
Reproductive status
Number
Supply and Demand
Supply-demand difference
Farm pasture cover
Grazed paddocks
Paddock cover

Figure 63 presents an example of the output for a dairy farm, showing animal intake (actual in green and potential in red) and farm pasture cover in kg DM/ha (pre grazing cover in red, mean cover in green, and post-grazing cover in purple).

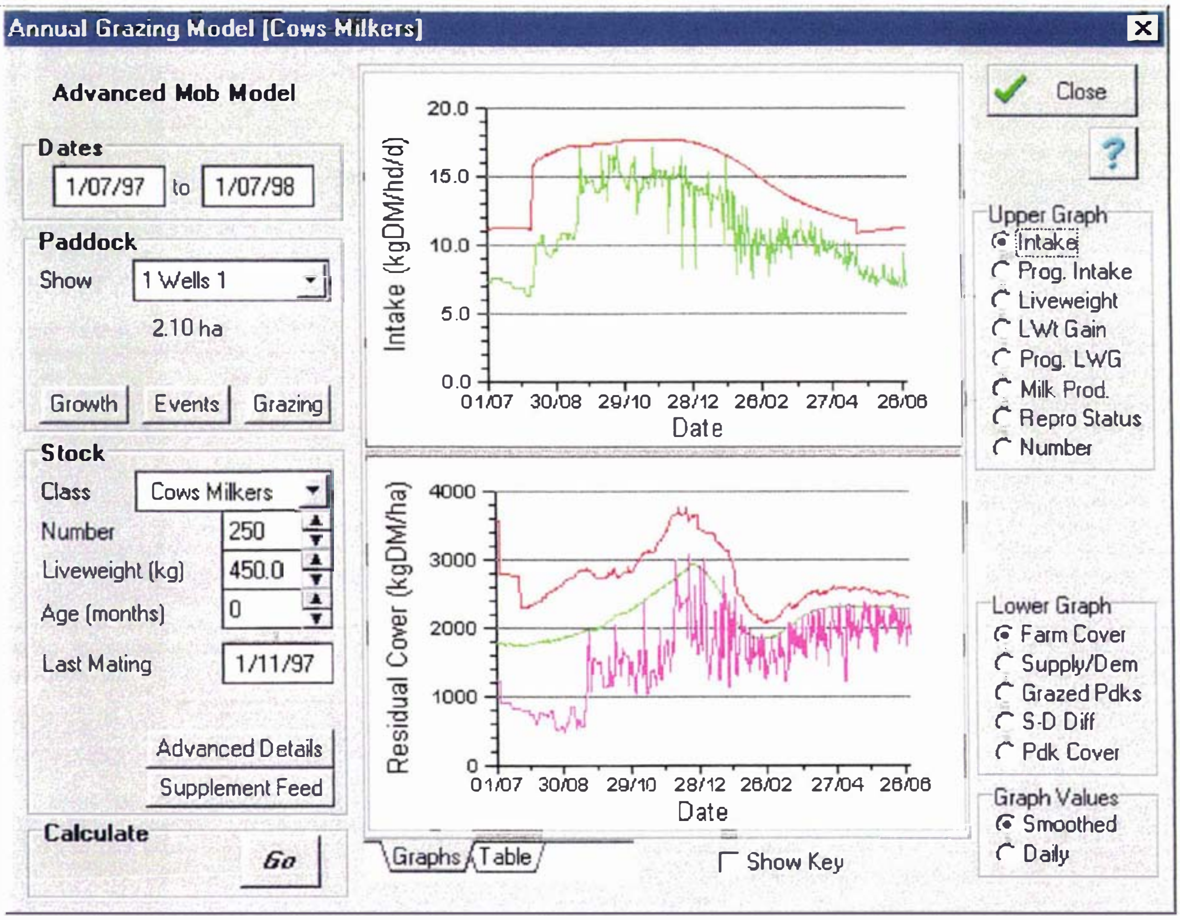


**Figure 63. FarmORACLE output of animal intake and farm cover for dairy cows.**

Figure 64 presents the milk production for dairy cows in the top part of the graph and pasture supply and demand in the bottom part of the graph. During times when demand is higher than supply cattle have to be provided with supplementary feeds.

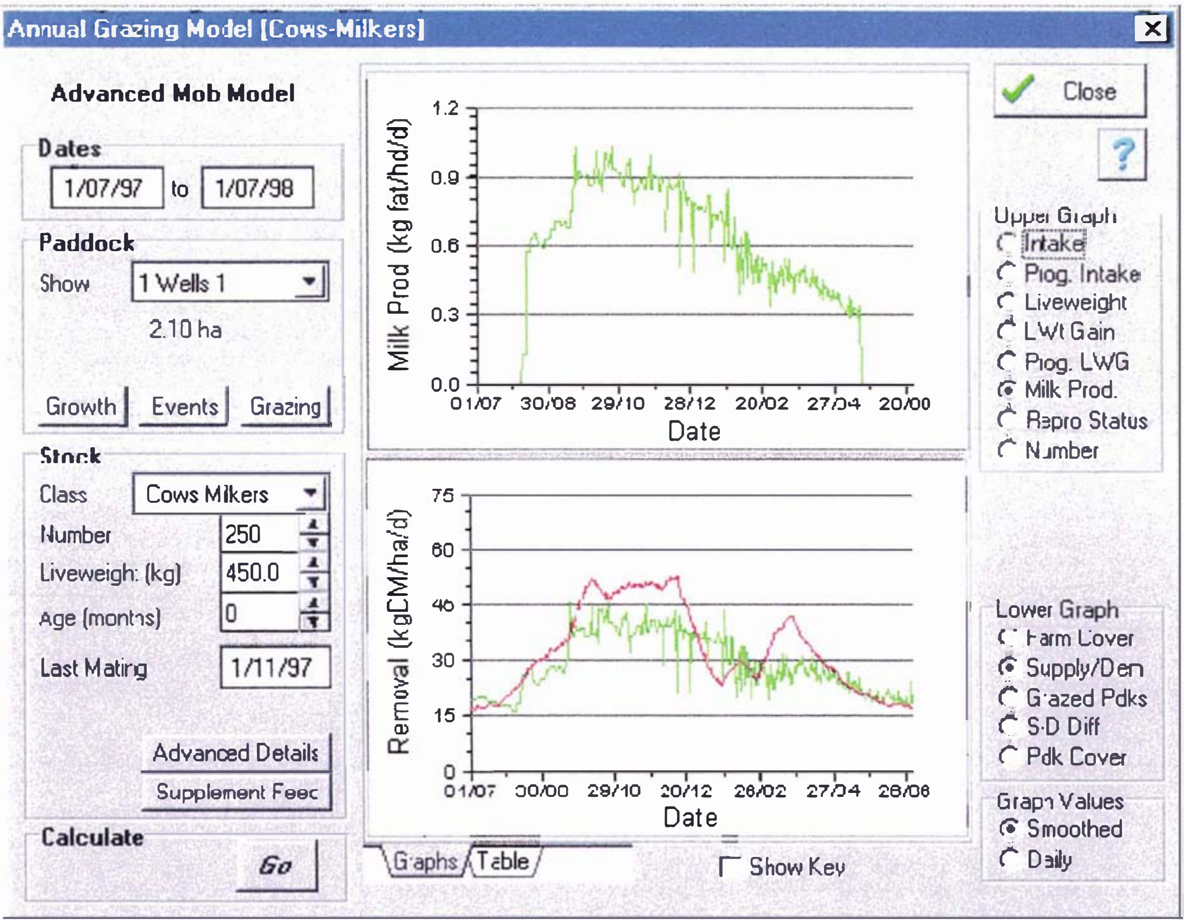


**Figure 64. FarmORACLE output of animal liveweight plus supply and demand for dairy cows.**

The model was verified by checking the biological correctness of the outcomes for each mob separately. Modifications were made to the program until the model outcomes were logical, correct and satisfactory. However, all mobs were modelled together to compare the different grazing plans. If only one mob was modelled at a time, the model assumed pre-grazing levels according to the pasture growth without removal by other mobs. When modelling all mobs together the model took into account the post-grazing levels of other stock classes that might have been grazing the same paddocks previously.

The text file outputs of the model for the traditional and the alternative grazing plans were imported into a spreadsheet for further manipulation and comparison. Economic analyses were conducted within the spreadsheet using price schedules as published by the Meat & Wool Economic Service of New Zealand (1999).

# Use of FarmORACLE on some of the Wairarapa focused control farms

Information on grazing routines and management was collected on all 34 farms where on-farm TB control interventions were conducted within the Wairarapa project (see Chapter 3 for more details). However, the detail obtained varied considerably between farms and years. The most detailed grazing information was obtained for the year July 1998 to June 1999. Thus, this farming year was used to model the farms. Only cattle farms were included in the study. The models used on two dairy farms, one beef breeding and one beef finishing farm are presented here in detail. The traditional grazing plans (base plans) were as close as possible to the grazing routines implemented by these farmers.

In setting up the grazing management plans in FarmORACLE for these project farms, no allowance was made for including additional forage crops. When taking into account the losses in production while the paddock is in forage crop and new pasture is being established, forage crops are a means of redistributing feed within the year rather than significantly increasing total herbage production on a whole farm basis (Matthews, 1994).

## *Comparing grazing plans on dairy farms*

Setting up grazing plans on dairy farms was less complex than on beef farms, as in most cases cattle were the only species grazed on the farm. In addition, the typical dairy farm only grazed dairy cows on the main farm during the lactation period, while young stock were grazed off farm, either on run-offs or on other people's land. Therefore, if the TB hot-spot was on the home farm, only dairy cows had to be modelled for the period August to May.

Normally, all paddocks were used on a rotational basis on dairy farms. In the alternative grazing plan all paddocks except the ones with a TB hot-spot were used.

### Dairy farm A

Dairy farm A was located in the south of the Wairarapa, with a total of 280 milking cows, 60 rising one-year heifers, and 60 rising two-year heifers. All male calves and surplus female calves were sold to slaughter as three-day old calves. No other stock was kept on the farm. The farm comprised a total of 124 ha, of which 93 ha were on the main farm, and 31 ha on the run-off.

Due to the high stocking rate, maize silage was usually fed to the milking cows during September to April at approximately 5kg DM/head/day. This supplementation had to be considered when modelling this farm. The time and amount of maize silage fed was used equally in all grazing plans.

modelling this farm. The time and amount of maize silage fed was used equally in all grazing plans.

The main farm was situated along a river. Cattle TB testing data indicated that this riverbed was a suspect TB hot-spot area. This area was generally used as part of the milking platform and/or for one-year heifers. Figure 65 presents the paddock map and the potential hot-spot area (in grey). Paddocks 42 to 54 are on the run-off, and are not drawn to scale. They are only shown symbolically for presentation. However, the actual paddock sizes on the un-off were entered in the model. Pasture growth was set at a lower level for the run-off paddocks than for the main farm. No irrigation was used on the farm.

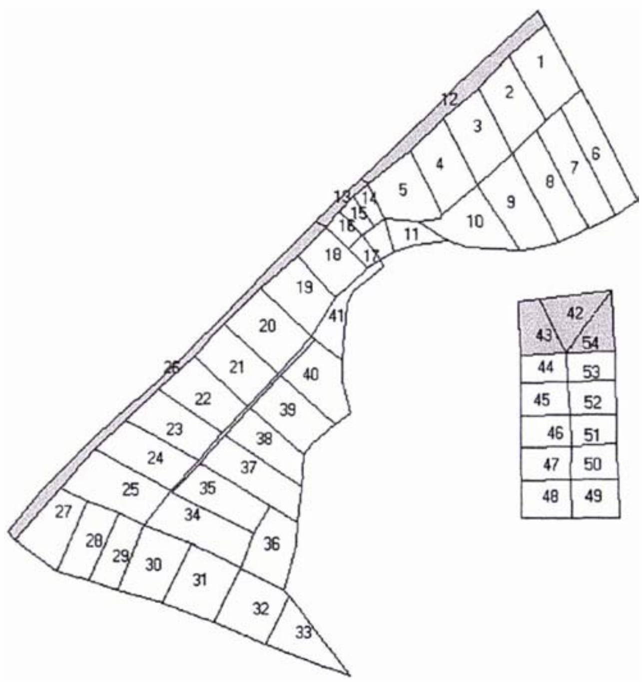


**Figure 65. Paddock map of dairy farm A, with TB hot-spot area in grey.**

### *Grazing plans used in the model for Farm A*

Figure 66 presents the traditional grazing routine during the summer of 1998/99 and the winter of 1998. Both TB hot-spot areas were included in the grazing area. During summer the four-month old calves were put into the paddocks along the riverbed on the main property, while the 16-month old heifers rotated around paddocks on the run-off, including the hot-spot paddocks. During winter no animals were grazed along the riverbed, however, the dry cows were grazed in all paddocks on the run-off.

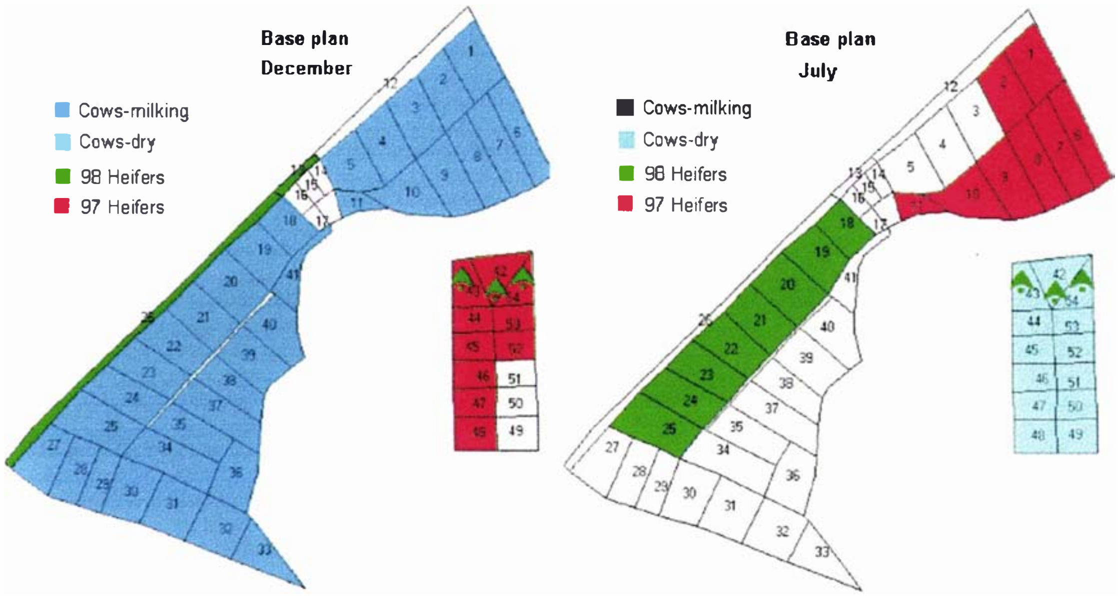


**Figure 66. Grazing routines during summer and winter on dairy farm A, using traditional grazing plans.**

These grazing plans were altered to exclude the TB hot-spot paddocks from grazing during the high risk times (November to January and July and August, see Figure 67).


**Figure 67. Alternative grazing routines during summer and winter on dairy farm A, excluding TB hot-spots from grazing at these times.**

Table 71 presents the production outcomes of the model using the base and the alternative grazing plans. Slightly less milk was produced over the whole lactation period in the alternative grazing plan, but the cull cows were heavier than in the base plan.

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

| | Date | Number of animals | Base plan | Alternative plan |
|---|---|---|---|---|
| **Total milk produced (kg milksolids/yr)** | | **280** | **62,056.4** | **61,815.1** |
| Average milk/cow (kg milksolids/cow/yr) | | 280 | 221.63 | 220.77 |
| Liveweight of milking cows (kg) | 1/5/99 | 250 | 549.7 | 547.7 |
| Liveweight of cull cows (kg) | 1/4/99 | 30 | 441.6 | 467.3 |
| | 2/5/99 | 30 | 444.0 | 467.7 |
| **Total kg cull cows sold** | | | **26,568** | **28,050** |
| Liveweight 97 Heifers (kg) | 30/6/99 | 60 | 445.9 | 454.3 |
| Liveweight 98 Heifers (kg) | 30/6/99 | 60 | 194.7 | 223.9 |

Using a milk company pay-out of $3.42 per kg milksolids (Ministry of Agriculture, 1999), the farm lost $825.25 in income from milk over the year under the alternative grazing plan. However, under this plan the total weight of the cull cows was increased by 1,482 kg, which was equal to 741 kg meat, using a dressing out percentage of 50% for the cull cows (Fleming, 1996). The average price paid to farmers in the month of sale was used for calculating the income from cull cow sales (Meat & Wool Economic Service of New Zealand, 1999). This resulted in an increased income from cull cows of $1,442.91. Thus, the implementation of the alternative grazing plan resulted in an overall net benefit of $617.66. No additional time input had to be considered on this farm when implementing the alternative grazing plan versus the traditional plan.

## Dairy farm B

Dairy farm B was situated in central Wairarapa in a typical dairy farming area. The farm milked 190 cows, and had 40 rising two-year heifers and 40 rising one-year heifers. Calving started in July and all male and surplus female calves were sold to slaughter as three-day old calves. No other stock was kept on the farm. In total the farm had 106 ha effective grazing area, of which 70.9 ha were on the main property and 35 ha on the run-off. Traditionally the new born heifers were kept on the main property until they were weaned in November/December, when they were moved to the run-off. The rising two-year heifers were grazed on the run-off during the lactation period. After the adult cows were dried off in May they were shifted to the run-off while all heifers returned to the main property.

The TB hot-spot on this farm was located on the main property. It was traditionally used all year round, for milking cows as part of the milking platform, or for young stock in winter. Figure 68 shows the paddock map and the TB hot-spot in grey. Paddocks labelled 'r1' to 'r10' comprised the run-off, which was situated about 1 km south of the main farm. These paddocks were not drawn to scale, but serve only as reference. However, the actual paddock sizes were entered for correct pasture growth. Pasture growth rates for the run-off paddocks was lower than for the main property paddocks. No irrigation was used on the farm.

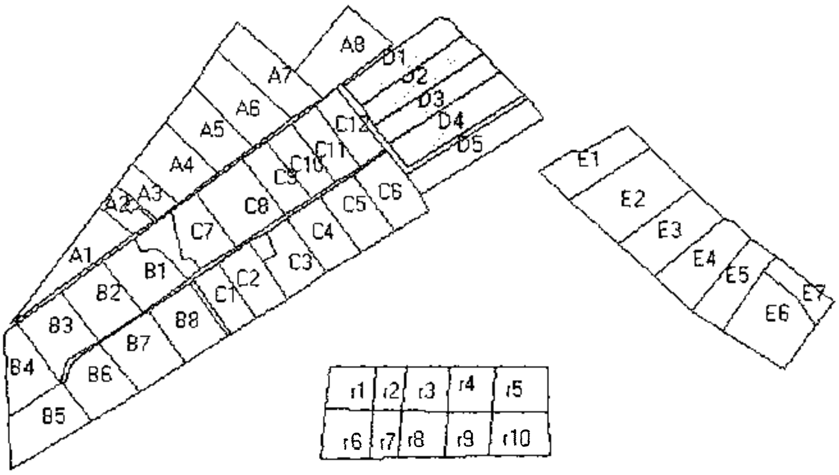


**Figure 68. Paddock map and TB hot-spot (in grey) on dairy farm B.**

The farm was modelled from July 1998 to July 1999. Under the traditional grazing routine, all paddocks on the main property, including the TB hot-spot areas, were included in the rotation of milking cows between July and April. In the alternative plans these four hot-spot paddocks were excluded from the milking platform for the months July and August and November to January. All other grazing routines were kept the same. In all grazing plans the replacement heifers were kept on the run-off during the milking season, and were shifted on to the main property during winter while the dry cows were on the run-off.

The farmer traditionally used rotational grazing, whereby the paddocks were grazed in the same order (list order) per rotation cycle. This grazing scheme was modelled in the plan 'Base List'. A second grazing plan was set up, using exactly the same criteria (rotation lengths, paddock allocations) as in the 'Base List' plan, except that paddocks were grazed from highest to lowest cover available ('Base High'). In the alternative plan ('Alter') the paddocks were grazed as in 'Base High' from highest to lowest cover, but the four hot-spot paddocks were excluded from grazing during the high risk months. Table 72 presents the production outcomes for the three different plans used on dairy farm B.

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

| | Date | Number of animals | 'Base List' Plan | 'Base High' Plan | 'Alter' Plan |
|---|---|---|---|---|---|
| **Total milk produced (kg milksolids/yr)** | | **190** | **46,592.31** | **52,938.95** | **52,181.59** |
| Average milk/cow (kg milksolids/cow/yr) | | 190 | 245.22 | 278.63 | 274.64 |
| Liveweight of milking cows (kg) | 1/5/99 | 155 | 432.3 | 457.0 | 456.1 |
| Liveweight of cull cows (kg) | 15/2/99 | 5 | 506.4 | 506.4 | 506.4 |
| | 15/4/99 | 6 | 551.4 | 551.4 | 551.4 |
| | 15/5/99 | 4 | 556.9 | 556.7 | 556.5 |
| **Total kg cull cows sold** | | | **8,068.0** | **8,067.2** | **8,066.4** |
| Liveweight 97 Heifers (kg) | 30/6/99 | 44 | 460.8 | 464.1 | 459.4 |
| Liveweight 98 Heifers (kg) | 30/6/99 | 43 | 200.4 | 221.1 | 234.2 |

The outcomes of the model indicated that the farm could increase its milk production by 12% just by changing the paddock order in which the milking cows were grazed. This would require the farmer to measure pasture height in order to identify the paddock with the highest pasture cover to be grazed next.

Milk production was slightly decreased (1.4% less than the 'Base High' plan outcome) by excluding the four TB hot-spot paddocks.

Using a dressing out percentage of 50% (Fleming, 1996) and the price schedules as paid in February, April and May 1999 (Meat & Wool Economic Service of New Zealand, 1999) resulted in the economic outcomes presented in Table 73. The alternative plan resulted in a net loss of about $2,500 in comparison with the income achieved when implementing the grazing plan 'Base High'. However, in comparison to the traditional grazing plan used on the farm ('Base List') this alternative plan still resulted in a net benefit of over $19,000. When using a grazing plan where milking cows were grazed in the paddock with the highest pasture cover, time for measuring the pasture height in each paddock had to be considered. It was assumed that it would take the farmer one hour per day to measure all paddocks. This then resulted in an overall time input of 304 hours (304 days during the lactation period July 98 to May 99). Even if farmers judged the value of their hour at $15, this would still result in a net benefit of $14,550.

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

| | | 'Base High' versus 'Base List' | | 'Alter' versus 'Base High' | |
|---|---|---|---|---|---|
| | Schedule ($) | Difference in carcass weight (kg) | Price difference ($) | Difference in carcass weight (kg) | Price difference ($) |
| Pay-out/kg milksolids | 3.42 | 6,346.63 | 21,705.48 | -757.36 | -2,590.17 |
| Price Feb99 per kg meat | 1.948 | 0 (n=5) | 0 | 0 (n=5) | 0 |
| Price April99 per kg meat | 1.965 | 0 (n=6) | 0 | 0 (n=6) | 0 |
| Price May99 per kg meat | 1.928 | -0.1 (n=4) | -0.77 | -0.1 (n=4) | -0.77 |
| **Net outcome** | | | **+ 21,704.71** | | **- 2,590.94** |

## *Comparing grazing plans on beef farms*

There are many more stock classes and groups of cattle on beef farms compared with dairy farms, resulting in more complicated grazing plans. It was found that modelling all stock classes/mobs, even if some mobs were never grazing the TB hot-spot areas, provided the most reliable model outcomes. This way liveweights, pre- and post-grazing pasture covers were calculated for all stock classes and the interactions or effects of one stock class on others were taken into account.

### Beef breeding farm

The beef breeding farm used in this example was located in the north-eastern part of the Wairarapa. Figure 70 presents the paddock map on top of an aerial photograph (Figure 69). Figure 71 presents just the paddock map and the suspected TB hot-spot in grey (paddocks 94 to 97). The dark green areas (paddocks 36 to 38) were pine plantations, where animals were rarely grazed. These three paddocks were not in pine yet when the aerial photograph was taken. All paddocks in the northern part of the farm, with numbers 65 and higher, were on steeper hill country than the paddocks in the southern part of the farm. As a result, a lower pasture growth rate was assigned to the paddocks in the northern part of the farm.

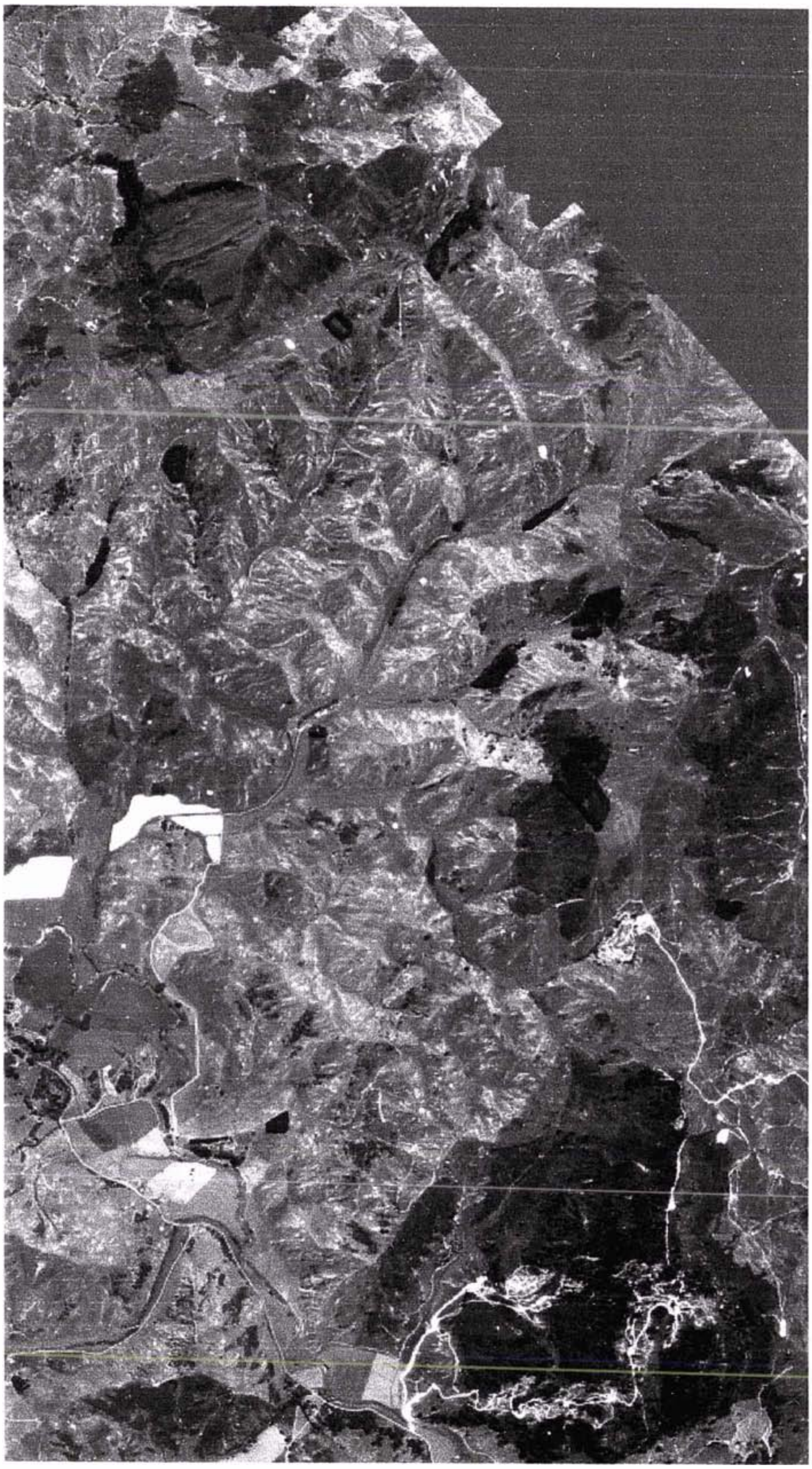

**Figure 69. Aerial photograph of beef breeding farm.**


**Figure 70. Aerial photograph of beef breeding farm with paddock layout.**

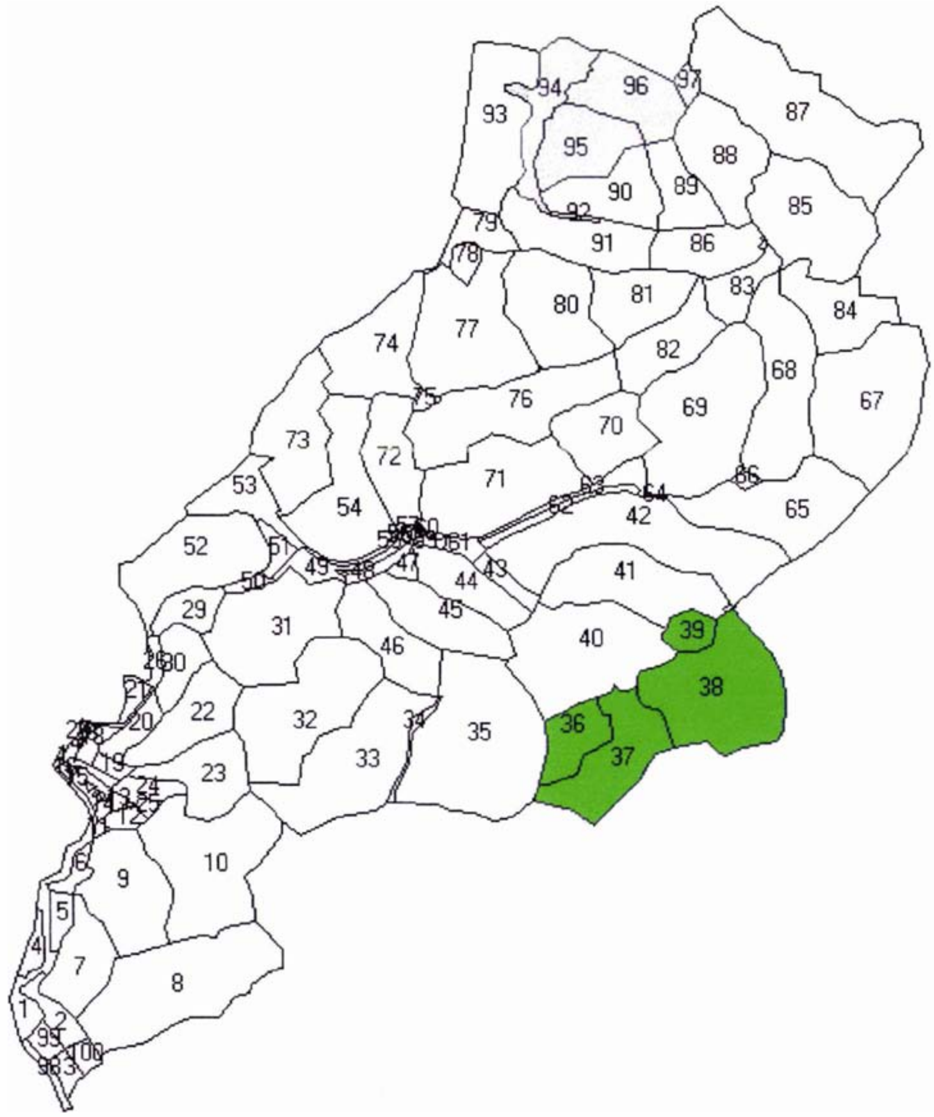


**Figure 71. Paddock map on beef breeding farm (TB hot-spot in grey, pine plantation in dark green).**

The farm was modelled for the time period 1st May 1998 to 1st May 1999. It consisted of a total of 1420 ha land of which 1145 ha was effective land. At the beginning of May 1998 stock numbers were: 200 mixed age cows, 63 rising two-year heifers, 128 rising one-year heifers, 91 rising one-year steers, 4600 mixed age ewes, 1860 rising two-year ewe replacements, 2200 rising one-year ewe replacements and 82 rams. Ewes lambed from early September onwards and weaned 130% lambs in late December. All lambs were sold at or shortly after weaning, except for the ewe replacements. The ewe replacements were mated at an approximate age of 20 months and were put into the mixed age ewe mob before lambing at an age of two years. The heifers were mated at 16 months of age and kept separate from the mixed age cows until they were three years of age.

Figure 72 presents the grazing locations of cattle and sheep during the high-risk time of August 1998. Cattle were put into blocks of paddocks and were kept there until the desired pasture residual was obtained, when they were shifted to the next block of paddocks ('set stocking'). Sheep generally rotated around their blocks of paddocks. Under the traditional grazing plan the beef cows were grazed in the hot-spot area from 1st June 1998 to 31st August 1998. During summer no cattle were kept in or around the hot-spot areas. Therefore the grazing only had to be altered to accommodate the winter high-risk period.

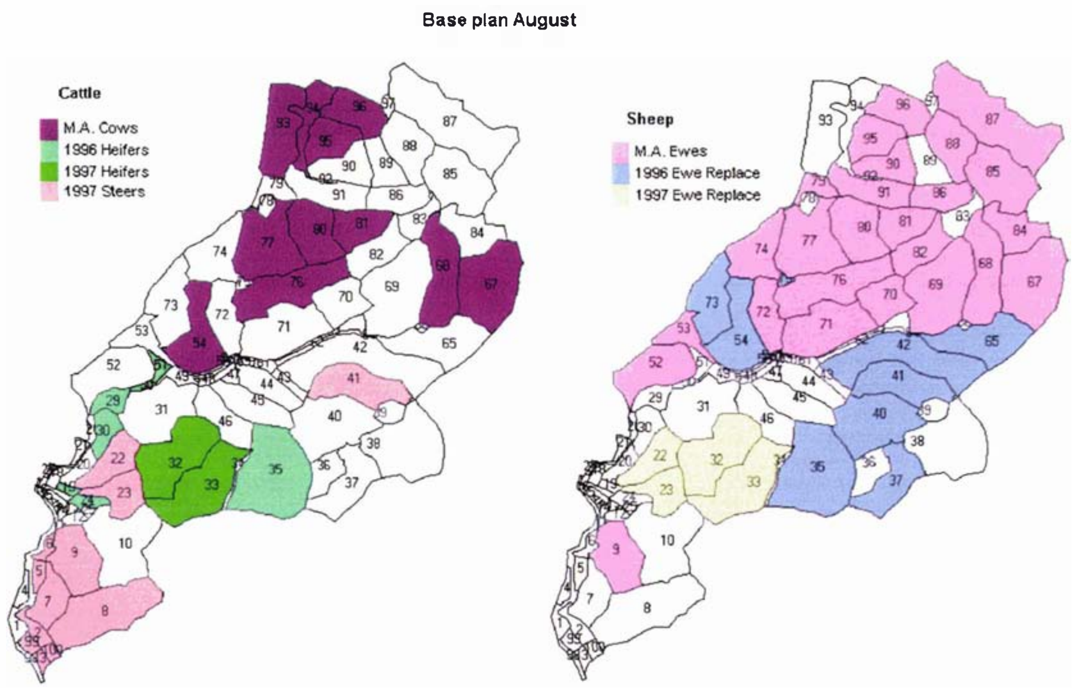


**Figure 72. Grazing locations of cattle and sheep, using traditional grazing plans, for August 1998 on the beef breeding farm.**

Under the traditional grazing regime, none of the young stock was kept on the northern part of the farm during the winter. Thus, in the alternative plan the cows were simply allocated to other paddocks in the northern part of the farm during the high risk time (for example using paddocks 85/87/88 instead of the hot-spot paddocks 94/95/96 as in alternative grazing plan 'Alter'). Exchanging these paddocks only had minimal effect on the production outcomes (Table 74). The liveweight of all animals remaining on the farm were similar in both plans.

Information was available on the dates when animals were sold. These dates were used in both the traditional and the alternative grazing plan to determine the average liveweights of animals sold at that particular time. Using the prices paid for cattle and sheep at that time, and a dressing out percentage of 53% for cattle and 45% for sheep, the adoption of the alternative grazing plan resulted in a net benefit of $2,054 (Table 74). Although the cull cattle were slightly lighter than in the traditional grazing plan, the sheep, mainly the male lambs (wethers), had heavier weights.

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

| | Base grazing plan | Alternative grazing plan | Difference | Economic value of difference ($) |
|---|---|---|---|---|
| Cattle | 76,019.7 kg | 75,894.1 kg | -125.6 kg | - 130.70 |
| Sheep | 230,705.4 kg | 232,649.0 kg | +1,943.6 kg | + 2,185.07 |
| **Net outcome** | | | | **+ 2,054.37** |

The only change made in the alternative plans was to exchange three hot-spot paddocks for three adjacent paddocks during July and August for the mixed age cows. Thus, no additional management was required to implement this change.

## Beef finishing farm

The beef finishing farm was situated in the south of the Wairarapa and bordering on its east side to Lake Wairarapa. The farm comprised 330 ha on the main property, of which 274 ha were effective. Additionally the farm had a lease block of 35 ha, which was not modelled in the current study, as animals usually were shifted there and from there were sold directly to slaughter, without returning to the home property. The farm had no beef breeding cows; all cattle were bought in with the sole purpose of finishing them to slaughter.

Figure 73 shows the paddock map of this farm. The area north of the hot-spot paddocks (grey shaded in the figure) was bush and not used for grazing. In the traditional grazing scheme cattle were spread over the whole farm, except the three hot-spot paddocks. In the alternative grazing plan the cattle were excluded not only from these paddocks, but also from hot-spot neighbouring paddocks (numbers 14 to 18).

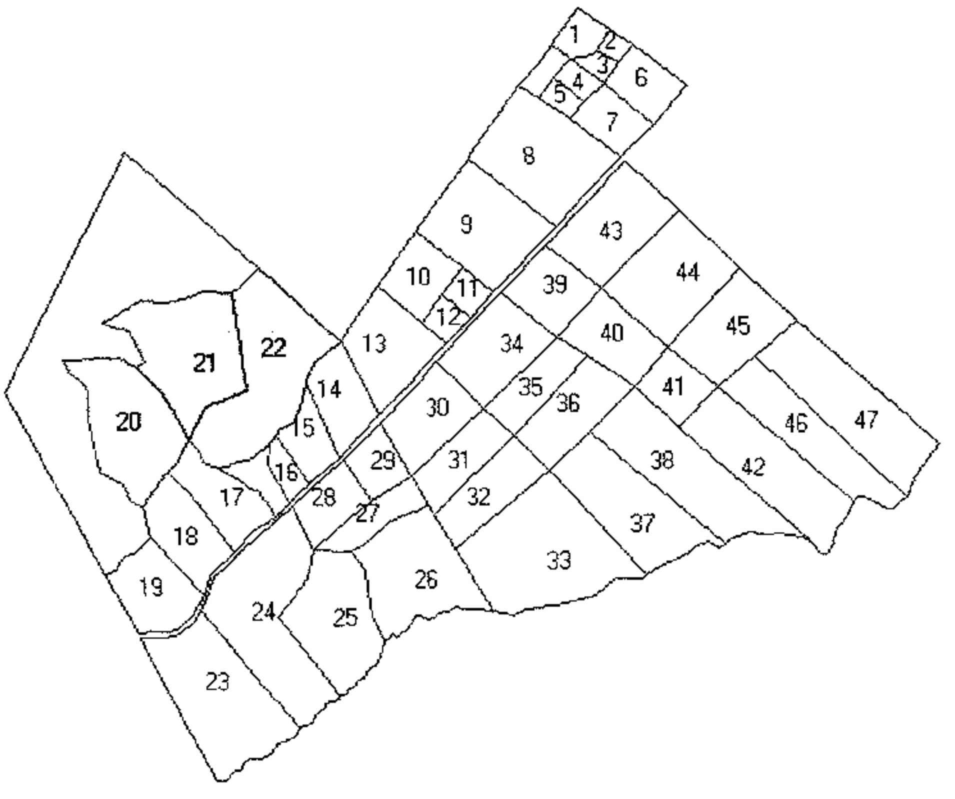


**Figure 73. Paddock map and TB hot-spot (in grey) of the beef finishing farm.**

The farm was modelled for the period July 1998 to June 1999. The stock numbers on the home property at the beginning of July 1998 were: 24 rising one-year old heifers (1997 heifers), 51 rising one-year steers (1997 steers), 750 mixed age ewes, 600 rising three-year ewes, 720 rising two-year ewe replacements, and 230 rising one-year ewe replacements. In October 1998 another 43 rising two-year heifers (1997 heifers) were bought, in March 1999 23 rising one-year heifers (1998 heifers) and 22 rising one-year steers (1998 steers).

From March to August 1999 the 1997 steers and between March and December 1999 the 1997 heifers were gradually sold according to their weight (all heifers with a weight greater than 520 kg and all steers with a weight of greater than 570 kg, drafted every 30 days). All young sheep for sale were taken to the run-off property first and sold from there. The only sheep sold from the main property were 230 old ewes (termed 'gummies'), that were drafted and sold if their liveweight was over 52kg.

Figure 74 and Figure 75 present the grazing locations of sheep and cattle groups during the high risk times of August and December 1998. Cattle and sheep were presented separately, as some cattle and sheep mobs were grazing paddocks simultaneously. During the high risk time in August only the 97 steers were in paddocks adjacent to hot-spot paddocks, while during the December high risk period the 97 steers and the 97 heifers were in these paddocks.

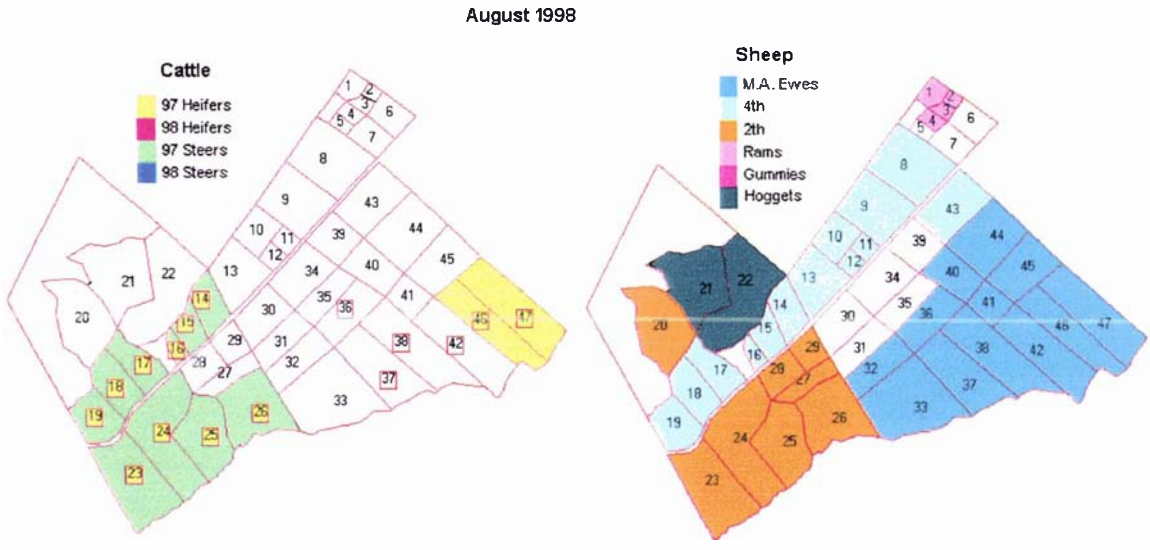


**Figure 74. August grazing plans under the traditional grazing scheme for cattle and sheep on the beef finishing farm.**

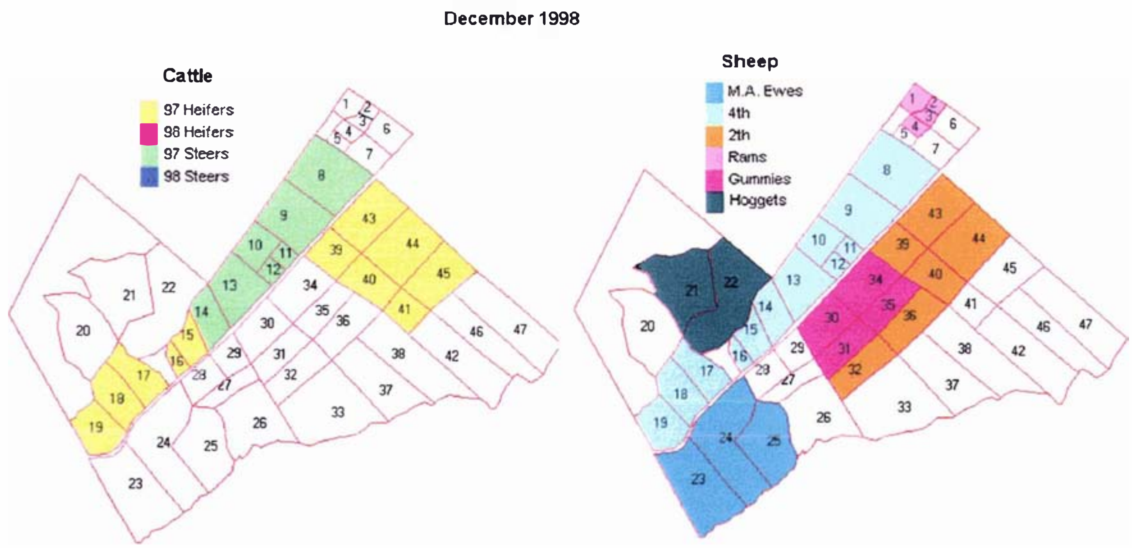


**Figure 75. December grazing plans under the traditional grazing scheme for cattle and sheep on the beef finishing farm.**

In the alternative plans the sheep grazing pattern was kept as in the traditional plans, but the grazing for the 97 heifers and the 97 steers was changed to exclude paddocks 14 to 19 during high risk times (Figure 76).

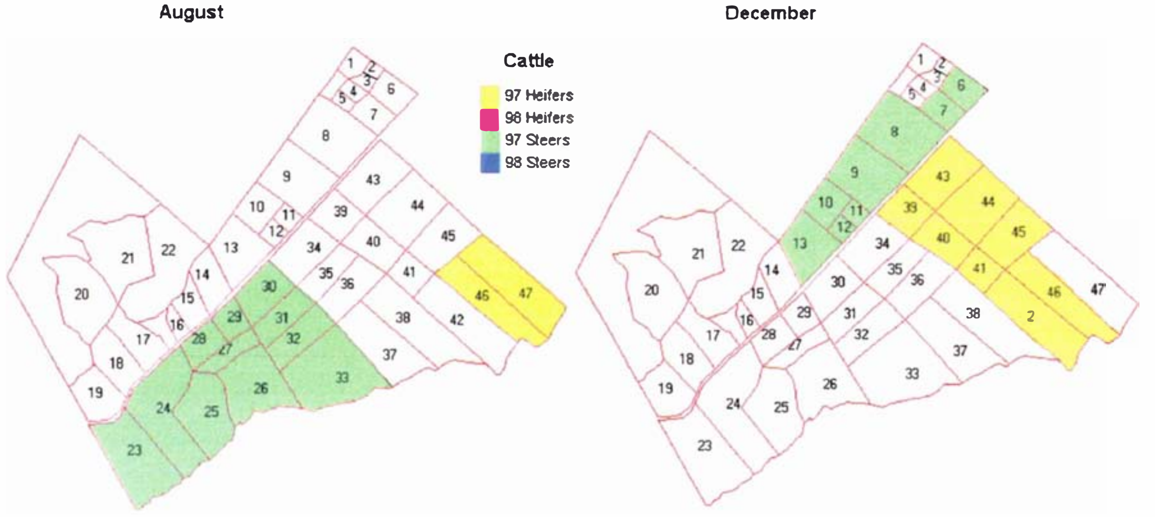


**Figure 76. Alternative grazing plans for cattle during high risk times (winter and summer).**

An alternative plan was set up (Alter), whereby the cattle were allocated to other paddocks not next to the TB hot-spot areas. The only criteria set for the sheep mobs was that they stayed above their target liveweights. Table 75 presents the liveweights of cattle and sheep and thc dates these were drafted for sale, for the base plan and the alternative plan.

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

| | | Base plan | | Alternative plan | |
|---|---|---|---|---|---|
| | Date drafted | Number of animals drafted | Total liveweight (kg) | Number of animals drafted | Total liveweight (kg) |
| 97 Heifers | 31/3/99 | 7 | 3,676.2 | 43 | 22,774.4 |
| | 30/4/99 | 42 | 22,840.0 | 24 | 12,920.1 |
| | 30/5/99 | 18 | 9,780.1 | | |
| 97 Steers | 31/3/99 | 24 | 13,870.2 | 51 | 30,531.0 |
| | 30/4/99 | 18 | 10,377.3 | | |
| | 30/5/99 | 7 | 4,062.2 | | |
| | 28/6/99 | 2 | 1.154.0 | | |
| **Total kg for sale from cattle** | | | **65,204.0** | | **66,225.5** |
| Cull ewes | 31/1/99 | 198 | 11,310.4 | 221 | 13,312.2 |
| | 2/3/99 | 8 | 418.6 | 0 | 0 |
| | 1/4/99 | 17 | 908.2 | 3 | 156.7 |
| | 1/5/99 | 7 | 387.9 | 6 | 331.2 |
| **Total kg for sale from cull ewes** | | | **13,025.1** | | **13,800.1** |

The outcomes of the model indicate that the alternative plan achieved greater production as the traditional grazing plan 'Base', without putting cattle at risk of getting infected by tuberculous possums in high risk areas. Both cattle groups, 97 Heifers and 97 Steers were sold quicker when using the alternative grazing plan than when using the base plan. Both plans used the smae drafting criteria.

Using the dressing out percentages of 53% for cattle and 45% for sheep (Fleming, 1996) and the price schedule for the months the animals were drafted and sold (Meat & Wool Economic Service of New Zealand, 1999), the adoption of the alternative plan resulted in a net loss of -$140.42, despite the fact that the alternative plan produced a higher liveweight of cull animals (Table 76). The net loss resulted as a consequence of the price schedule for beef, which increased in April, when most of the animals in the alternative plan were already drafted and sold. However, in deciding which grazing plan to adopt, one also has to consider the pasture being available for other stock classes once the cull animals have been removed. In the alternative plan, all paddocks used by the 97 steers would be freed up by the end of March, while in the base plan the paddocks were used until the end of June.

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

| | Base plan | | Alternative plan | |
|---|---|---|---|---|
| | **Total carcass weight** | **Economic value** | **Total carcass weight** | **Economic value** |
| Heifers | 18,942.4 | 36,856.54 | 18,918.1 | 36,099.77 |
| Steers | 15,615.8 | 35,937.66 | 16,181.4 | 36,181.68 |
| Cull ewes | 5,861.3 | 5,872.89 | 6,210.1 | 6,245.22 |
| **Total** | | **78,667.09** | | **78,526.67** |

In beef farms the program might also be used to compare an ad hoc grazing management, with a detailed grazing strategy. Some farmers move their cattle only, when they see, that the pasture is grazed down, often resulting in a residual pasture cover of less than 1,000 kg DM/ha. For this purpose, a grazing plan with a residual pasture cover of 800 kg DM was compared with one using 1,600 kg DM/ha, all other parameters were held constant. As Table 77 shows, the low residual grazing regime resulted in all liveweights being lower than if using the residual pasture cover of 1,600 kg DM/ha.

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

| | Livestock weights at 30/6/99 | |
|---|---|---|
| | Residual 800 kg DM/ha | Residual 1600 kg DM/ha |
| 97 Heifers | 486.4 | 570.8 |
| 98 Heifers | 227.2 | 253.6 |
| 97 Steers | 527.6 | 600.1 |
| 98 Steers | 282.8 | 326.5 |
| MA Ewes | 54.7 | 55.6 |
| 4th replacement ewes | 56.7 | 58.6 |
| 2th replacement ewes | 49.9 | 53.6 |
| Cull ewes | 63.9 | 64.7 |

## Discussion

The FarmORACLE software model can be thought of as a decision support system, as it attempts to support decision-making using many variables, and allowing users to combine their epidemiological knowledge about tuberculosis in possums and livestock with biological, physical and economic factors. Using the model to evaluate the production and economic outcomes of different grazing strategies showed that it is not impossible to find a grazing regime that excludes TB hot-spot areas at equal or better production/financial outcomes. FarmORACLE models different grazing strategies in order to prevent possible direct contact with terminally ill tuberculous possums, a method which was suggested as main transmission pathway between possums and livestock (Sauter and Morris, 1995).

In all four farms a grazing regime was found that excluded TB hot-spot areas from grazing by cattle during high risk times, with increased profitability. The alternative grazing strategies presented for each farm are only one of a multiple range of potential combinations of paddocks, animals and time periods. In the grazing plan on the beef breeding farm it was found that the sheep were gaining more weight in the alternative grazing plan. This was due to the fact that the sheep were grazing exclusively the hot-spot paddocks instead of sharing them with the beef cows. The increased sheep liveweight resulted in increased carcass weights of lambs, which more than compensated for the slightly lower liveweights of cull cattle. The results on the beef finishing farm indicated that the alternative plan led to a shorter fattening period for heifers and steers, however, the financial outcome was slightly reduced by $140 due to the lower price schedule for cattle at the earlier sale date. The knowledge of the price schedule could also be in important additional point when choosing grazing strategies.

However, the model not only showed that grazing plans which exclude cattle from TB hot-spots at certain high risk times, can result in an equal or improved economic outcome, but it also indicated other areas of improvement. The results on dairy farm A, using the alternative grazing plan resulted in a higher dry-cow liveweight. Although feeding dairy cows better in winter results in an increase in total feed demand per cow over the winter, this was offset by the reduction in stock numbers and the shorter wintering period resulting in an overall reduction in supplement requirements over winter (Ma hews, 1997). The results on dairy farm B showed that using pasture height, rather han the paddock order, to determine the grazing rotation on a dairy farm can result in a high increase in milk production, without any other changes. Using the height of the pasture uses the fact that high pre-grazing pasture covers will result in an increased decay and decreased nutritive values (Matthews, 1995).

The model can also be used as a farm management tool for economic evaluation of 'what if' decisions. For example the model could be used to evaluate the effect of reducing cattle numbers and increasing sheep numbers on beef farms, or comparing the performance of steers versus bull fattening or comparing grazing strategies with low versus high post-grazing levels. Results on the beef finishing farm, comparing grazing regimes with 800 versus 1600 kg DM/ha post-grazing residual, showed that the high residual resulted in all animal groups having higher end liveweights. This would be in accordance with the quality of pasture declining if pasture covers gets too high (Matthews, 1995). Often farmers use an ad-hoc grazing regime, shifting cattle only once the pasture is completely grazed. The results of the model indicate that this management decision is not optimal.

The use of a computer model such as the one presented, allows the farmers and other decision makers to evaluate different grazing strategies in terms of their production and economic outcomes. In agriculture more and more computer models are developed, however, they mostly focus on one specific part of the enterprise to try to maximise its profit. Several computer programs are available for dairy farms (Larcombe, 1990; Uribe *et al.*, 1996; Lockhart *et al.*, 1997) and for pig farms (Vaillancourt *et al.*, 1992; FarmPro Systems Limited, 2000). Less programs are available for sheep enterprises (Gray *et al.*, 1992; Parker *et al.*, 1992; Parker *et al.*, 1998) or beef enterprises (Bircham and Sheath, 1986). The present model not just accommodates one particular livestock species, but incorporates all the different livestock enterprises present on farm. Additionally, the model can take epidemiological knowledge relating to tuberculosis into account. A similar combination of epidemiological knowledge and pastoral systems was also used in a model of ovine fascioliasis in sheep in Australia (Meek and Morris, 1981).

Any software developed for agricultural enterprises is intended to assist farm management in allocating limited physical, financial and human resources in order to achieve certain objectives (Parker *et al.*, 1994). The increasing complexity of farm management and decreasing profit margins require more information to enhance decision-making. Therefore, more and more farmers will use farm recording programs, and information on existing grazing management will be readily available.

Apart from being able to model all animals present on farm, another main advantage of the program is the representation of individual farms, rather than an 'average' farm. Especially in the sheep/beef farms it was found that the 'average' farm may not be relevant to the particular case (Morris *et al.*, 1995). With FarmORACLE each individual farm can be modelled, by entering farm specific parameters, such as livestock details and targets, pasture growth rates and paddock information.

There are varying degrees of uptake of simulation or mathematical models. Some models contribute to research and understanding, but not to management decisions. For a model to be used in practice requires that it addresses a definite management question, and that it is actively 'sold', which in turn necessitates an easy to understand graphical display and proactive demonstrations of the use to potential users (Barlow, 2000). In order to be used the model should be easy to use, flexible and capable of being linked with other programs (Brookes *et al.*, 1992). One of the advantages of the present model is the use of many graphical features, facilitating use. For example, by using the paddock map and different colours for the individual stock classes, it is easy to describe stock movements on the farm. Rather than having to enter the paddocks on a purely tabular basis, such as in PRO Plus (McPhee *et al.*, 2000), the end user can see the map of the individual farm and enter data through this interface.

Studies in Australia on the uptake of innovations in general found that the unpredictability of income discouraged the adoption of new techniques (Anderson, 1982). With a program such as FarmORACLE it is possible to reduce the uncertainty of the outcome. Thus the uptake of control programmes like adopting grazing regimes that exclude cattle and deer from grazing TB hot-spot areas, should be increased.

Regarding the adoption of decision support systems Lynch *et al.* (2000) suggested, on the basis of a British study in 1996 (OASIG, cited in Lynch *et al.*, 2000) that the success of a product depends on the interrelationships between software developers, potential adopters of the product and the contexts in which the software is developed. In the present study, traditional grazing plans were set up with the particular farmers on ten farms, at the computer, using the actual model. These first applications of the software resulted in many suggestions by farmers to improve the ease and usefulness of the model and thereafter alterations of the software.

In using the model, the only knowledge required is about the grazing routines for the different stock classes on farm, information that is known by farmers. No additional information is required, but can be entered optionally if available. In an Australian study it was found that the low adoption rate of computer software within the agricultural system is also due to the fact that farmers have to provide data that they do not normally collect (Glyde and Vanclay cited in Lynch *et al.*, 2000). Within the current program the information required is a minimum and is readily available to farmers. Furthermore when modelling the traditional grazing strategies on farms, the farmers can compare the model outcome with the outcome they perceive their strategy achieves. If this comparison results in outcomes close to field reality, then the trust in the output of the model using alternative grazing strategies might be increased. This trust was found to be necessary for successful adoption of innovations, as the farmers have to make a choice between their years of experience and outcomes of a computer model (Lynch *et al.*, 2000).

In order to keep the model in the present study as simple and generalisable as possible, only minimal field-gathered information was used. However, the program has many features already included that were not used in the present study, such as entering slope and aspect of each individual paddock, specific temperatures and rain fall data in order to calculate the pasture growth more exactly, conserving pasture or cropping on farm.

In the beef farms no supplement feeding was used in the present model. Beef farms are less likely to buy in supplements, but use their own hay and silage. Sheep were less likely to interact with simulated tuberculous possums (Sauter and Morris, 1995), therefore in the model sheep were used in hot-spot areas during the summer and winter months of highest risk.

Another factor which was not included in the present study, but could be included in further studies, was pasture damage by cattle. Often farmers put their cattle during the winter months into rough areas with less productive pasture, and often incidentally plenty of potential possum habitat, in order to save the pasture quality of better paddocks. The present study did not take any potential damage to pasture into account.

Although the model devised on each of the participating farms may not have simulated the real situation perfectly, in comparing a standard grazing plan with an alternative plan, the assumptions were equal for both plans. By changing any of the underlying principles, such as pasture growth rates or potential animal intake, it is likely that the comparison between the two grazing plans still holds. Although the final economic output has only a guidance function, the comparison between the plans stills shows, which plan is better, and whether excluding hot-spots from grazing can compete from an economic point of view. By using slope and aspect of each individual paddock pasture growth can be predicted more accurately. Vegetation maps can be overlaid on the paddock maps, giving a true percentage of effective land in each paddock. Using vegetation hot-spot maps can also help in identifying likely hot-spot areas (McKenzie, 1999).

### *Potential further development of FarmORACLE*

In order to validate FarmORACLE it would be necessary to observe the grazing regimes, actual pasture growth, animal production and economic outcomes in more detail on dairy and beef farms. Then the outcome of the model could be compared with the actual situation on farm, and necessary changes made to the program. However, the data required for validation has to be detailed and exact and it will be difficult to get precise data in pasture based enterprises, as sward conditions and characteristics vary considerably between paddocks and over short periods of time.

Further development of FarmORACLE could include adding parameters that would allow to model the variations in pasture digestibility, between seasons as well as between paddocks (Wilson *et al.*, 1995). Additionally, FarmORACLE could be linked to EpiMAN(TB) (McKenzie, 1999), to automatically transfer to FarmORACLE information about TB hot-spots, using vegetation and slope data obtained from satellite images. EpiMAN(TB) uses these two measurements to classify the risk of TB hot-spots into low, medium, and high risk. FarmORACLE could also be further developed to use satellite images to calculate the true effective size of each individual paddock. Control programmes for other diseases in grazing animals could also be modelled in FarmORACLE. By creating 'base' scenarios with standard prices etc., but without consideration of disease control issues, the model could then be used to assess different disease control programmes on equal terms.

### *Conclusions*

FarmORACLE has five main benefits:

- It can be farm specific, with specific livestock and paddock details, rather than simulating an 'average' farm.
- It models all livestock enterprises present on farm, and with it the interactions between different stock groups and pasture availability.
- It can be used to evaluate different grazing regimes to accommodate disease prevention measures or to evaluate different basic grazing principles used on the farm, such as

rotational grazing of paddocks in list order versus rotational grazing on the basis of pasture cover.

- It can reduce the unpredictability of management decisions relating to grazing strategies.
- It uses farm maps and graphical display of paddock and animal allocations, as well as text files for model outputs.

FarmORACLE has shown that grazing regimes can be found for dairy and beef farms, that exclude cattle from grazing TB hot-spot areas during high risk times, and still result in an equal or even better economic outcome than the traditional grazing regime used.

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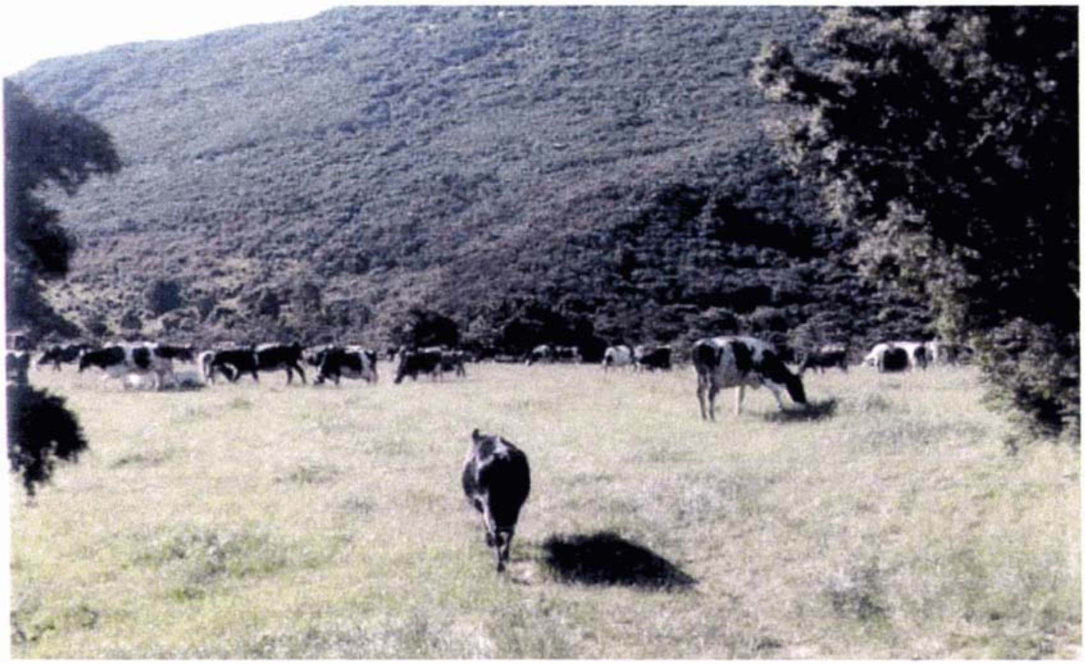

**Dairy farm in the Wairarapa**

**Beef farm in the Wairarapa**

# Chapter 8

# General Discussion

## Introduction

This large and complex study has yielded some simple, and readily applicable concepts for adoption by the farming industry, which will assist the reduction of TB prevalence.

Bovine tuberculosis is a global disease. However, the eradication of tuberculosis is complicated in some countries by the existence of wildlife species which act as reservoirs of infection and vectors which transmit TB to domestic stock. A notable example is the brushtail possum in New Zealand (Morris *et al.*, 1994) (see Introduction to this thesis for more examples). In 1998 about 23% of New Zealand's land area was classified as Vector Risk Areas, where wildlife infection is the primary source of livestock infection (Animal Health Board, 1998). The disease is a major threat to New Zealand's agricultural economy (Oliver *et al.*, 2000). Currently 2% of New Zealand's cattle and deer herds are infected. This level has to be reduced to 0.2% in order to achieve internationally recognised TB-freedom.

Control of TB in New Zealand consists of three major components: stock movement control; stock testing and slaughter; and vector control. Most possum control is done by poison-baiting, using aerial and ground application of poison baits (Morgan and Hickling, 2000). Expenditure on vector control was $28.4 million in 1998/99 (Coleman and Livingstone, 2000). However, despite possum control operations reducing TB in livestock (Pannett, 1995; Livingstone, 1997; Animal Health Board, 2000), a number of Vector Risk Areas have expanded (Oliver *et al.*, 2000).

While nationally and regionally operated control programmes have achieved significant reduction in herd incidence, there is an opportunity to complement these official control efforts with complementary individual farmer efforts (Oliver *et al.*, 2000). This study evaluated the potential of farmers helping the eradication of TB from their own, and consequently from New Zealand's cattle and deer herds. In order to advance such efforts, several questions have to be answered: Are there any control methods available to farmers? If so, are they practical and easily implemented on farms? Are such methods effective? Are they financially worthwhile? What are the attitudes of farmers towards control and towards individually contributing to TB control? What understanding of behaviour is important to achieve change?

It can be proposed from the present study that the first three questions can be answered with 'yes'; while the fourth question is dependent on herd type, number of TB animals on farms and legislation regarding TB. In answer to the fifth question there is an overall positive attitude amongst farmers towards TB control, but individual responsibility is still low; and in answer to the sixth question a literature review showed that a change in attitude, thinking, knowledge and motivation is required to achieve change.

## Are there any control measures available for farmers?

It was found that farmers generally had good knowledge about potential TB hot-spot areas on their farm, that farms which grazed cattle in hot-spot paddocks had higher TB incidence in cattle, and that grazing management was flexible to a greater degree on beef farms than on dairy farms (see Chapter 2). The findings of this part of the study together with epidemiological knowledge on TB and its transmission between vector species and livestock emanating from other research was used to develop potential on-farm control measures to reduce or prevent the direct contact between infectious vectors and livestock. This contact was the most likely transmission pathway for tuberculosis between the two species (Sauter and Morris, 1995; Paterson and Morris, 1995). These control measures consisted of targeted possum control in spring and autumn; and grazing management to avoid close vector-livestock contact during the high risk times of November to January and July and August.

Thus there are appropriate measures that farmers can implement to assist TB control on their own farms.

## Are these on-farm methods practical and easily implemented?

The analysis of the open interviews conducted with farmers in the Wairarapa who were managing TB infected herds (Chapter 2) showed that grazing management was flexible, especially on beef farms where it often was adapted to short-term changes.

The suggested control measures mainly involve time in servicing bait stations and conducting possum control, as well as planning appropriate grazing placement of animals on the farm. However, these measures are easy to implement and of relatively low cost, in comparison to the official Regional Council control programmes.

In order to facilitate the adoption of grazing management that excludes cattle and deer from grazing TB hot-spot paddocks in summer and winter, the farm can be modelled using FarmORACLE. The programme can be tailored to each specific farm. It models all stock classes present on the specific farm, which is an advantage over using 'average' farms (Morris *et al.*, 1995). Thus, it can reduce the unpredictability of management decisions relating to grazing strategies, a major hindering factor in the adoption of innovations (Morris *et al.*, 1995). The graphical display of grazing routines and production outcomes facilitates the use of the programme.

Thus the methods evaluated are practical and easily implemented.

## Are these on-farm control measures effective?

Evaluation of these on-farm control measures provided evidence that they are effective in reducing TB in livestock (see Chapters 3 and 4). Both intervention studies achieved a higher reduction in cumulative TB incidence in focused control farms than in standard control farms. The Wairarapa project interventions achieved a higher proportion of focused control farms coming off Movement Control than standard control farms.

The evaluation of the national project suggested that providing farmers with only advice on control methods and strategies, rather than actual control work as well, had some effect (see Chapter 4). The Wairarapa interventions achieved higher reductions in TB incidence than observed in the national intervention study. Thus it was concluded that the approach using a small team with hands-on practice, as applied in the interventions in the Wairarapa project, was more successful than using a larger team with an advisory role only.

It is therefore proposed that the control measures evaluated are effective if adopted intensively, and do assist the control and eradication of TB at the farm level.

## Are these on-farm control measures financially worthwhile?

Economic issues were found to be a major factor in deciding whether to conduct any on-farm TB control (Chapter 2). However, the answer to the question whether the on-farm control measures are financially beneficial, is dependent on herd type, the number of TB animals on farm, and legislation regarding TB. The economic analysis (Chapter 6) used both deterministic and stochastic modelling, plus decision analysis. The results showed that under the current compensation level for cattle of 65% the adoption of on-farm control measures generally resulted in a net gain for dairy farms. The control measures were economical for beef farms only if they reduced their TB animal numbers to zero and the herd came off MC. If the compensation level was reduced to zero, the situation was not altered significantly. In this case, the net gain for dairy farms increased, the situation in the beef breeding farms remained similar, and for beef finishing farms the adoption of control programmes became economically beneficial only if it resulted in a reduction of two or more TB animals annually.

Therefore, in contrast to dairy farms, a reduction of compensation level does not create a significant incentive for beef farmers to adopt on-farm control measures for TB. In addition, farmers believed that the removal of compensation could result in less co-operation by farmers, and therefore lead to results contrary to the intended ones. Thus other incentives or stringent rules and regulations may have to be put in place to encourage or force farmers to conduct their own control programmes. It is suggested that a phased scheme is introduced that provides financial incentives for farmers to adopt on-farm control measures. Financial incentives were found to be major factors in determining the adoption of innovations (Walker and Bell, 1994; Morris *et al.*, 1995). In a second phase, compensation for TB reactor cattle can be reduced in order to create more financial incentive to adopt on-farm control measures.

Thus, the current TB legislation for cattle farms does not create enough financial incentive for beef farms to adopt on-farm control methods, even if compensation for cattle reactors is reduced.

## Attitudes of farmers towards TB control

Overall a positive attitude existed among farmers about the importance of TB eradication. However, the majority of farmers interviewed in this study were not in favour of stricter Movement Control regulations, removal of compensation or having to pay TB testing costs directly. Their main reason was the potential loss of co-operation by farmers. In a contemporary study by Corner *et al.* (2000) it was found that deer farmers were generally more in favour of reducing compensation and having to pay costs directly. It is noteworthy that both groups strongly favour the system currently in place for their industry, and oppose the system being used in the other industry.

Although many farmers saw 'farmers in general' as being responsible for TB control, many farmers saw the responsibility of TB control and eradication belonged to official organisations, such as Regional Council, Government, and Animal Health Board. Reasons for this were manifold and not always based on fact. Farmers argued that TB is a national problem, not the individual farmer's; that farmers pay rates to the Regional Council and therefore already pay for the control; some farmers believed that control had to be over whole districts/regions to be effective, and that any control farmers themselves would do would be ineffective, sporadic and not cost-effective (see Chapters 2 and 5).

Therefore, farmers do not see the need yet for themselves to be involved in a major way in the control of TB. Thus, any future eradication strategy should include methods for improving farmer motivation in addition to an extension programme that addresses technical issues such as control strategies and financial implications of TB.

## What understanding of behaviour is important for achieving change?

However, before on-farm control measures have reasonable prospect of being adopted, one has to answer other questions, such as: What change is necessary for farmers to adopt such on-farm control measures? What incentives have to be created for farmers to employ on-farm control measures? Which are the best ways to convey the information to farmers?

Review of the literature about human behaviour indicates that the process of behaviour change consists of three stages: acceptance of need to change, awareness of options for change, and acquisition of the skills required for the implementation of the change (Greer and Greer, 1996) (Chapter 1). From the results of the questionnaires used in the present study (Chapter 5) it was indicated that many farmers did not see themselves as being responsible for TB eradication. They believed organisations such as Government, Regional Council, AgriQuality, AHB and others were. This observation indicates that many farmers have not accepted the need for change. Therefore more emphasis and extension work has to be put on explaining to farmers the whole TB situation, so that they have all the information on costs and benefits on their own farm, but also on the national scale. Alternatively the structure of the programme could be changed to encourage more individual farmer consequences.

Another field of investigation should focus on how farmers can best be motivated and encouraged to apply these control measures, involving different extension forms and incentives/penalties, possibly dependent on herd enterprise type. From the economic analysis of the TB situation and the control measures (Chapter 6) it was found that the application of additional targeted control in beef breeding farms was less economical than in dairy herds. Therefore beef farmers need more financial incentives, such as rewards if they achieve Clear TB status, or free poison/equipment. Methods like this could be evaluated using intervention studies or even surveys, asking farmers if they were prepared to do the control if they receive certain incentives. In order to evaluate how many of the farmers then actually would implement the control, one could set up a study using randomly selected farmers from only that group that responded positive to the question. This would give an estimate of the proportion that could be expected to use these methods. The results of this study would then give indications if penalties would have to be applied. One of the problems with promoting such schemes is to capture a commercial return on technology transfer, as it is easier to sell an individual product or a special service than a management concept (Journeaux *et al.*, 1997).

## Opportunities for enhancement of on-farm programmes

Any further study of the nature of the present one could potentially be improved by using regular farmer meetings/discussion groups, to obtain group adhesion and achieve active discussions amongst farmers (Wegener *et al.*, 2000). However, discussion groups may not appeal to all farmers (Morris *et al.*, 1995). In the present Wairarapa project (Chapter 3) one meeting of all farmers was held. Although there was a good relationship between the research team and the farmers, the farmers did not have much contact amongst themselves in this project.

Additional focus could be put on the financial impact of TB on the farms by including an advisory person trained specifically in farm economics. In the present study it was noticeable that a lower proportion of national focused control farmers in the one-on-one programme (Chapter 4) than the Wairarapa focused control farmers (Chapter 3) or the standard control farmers in both studies, considered the cost of TB to be zero or unknown. These farmers had interactions within their team meetings with a financial person, most likely resulting in a more detailed and maybe more correct analysis of the financial impact of TB.

## Future research proposals emanating from this study

### *Adoption of control methods studied*

In order to further support the findings in this study, it is recommended that similar studies are conducted in VRAs, focusing on beef breeding farms and/or non-Regional Council controlled areas. From the Wairarapa project (Chapter 3) it was suggested that especially the beef breeding farms could gain from additional targeted control above the control received of the Regional Council control. Therefore a study could be conducted that only involved beef breeding farms. As the farms in non-Regional Council controlled areas achieved a higher reduction in cumulative incidence in the Wairarapa project, it would be worthwhile to conduct a study like the one presented using only farms in non-RC areas. This could investigate if on-farm control measures like the ones applied in this study could achieve effectiveness similar to blanket control delivered by RC. However, a study like this would be very difficult, as more and more area within the VRAs are under control. For example in the Wairarapa 67% of farmed area was under control in 1999 (Animal Health Board, 1999). Furthermore, targeted control might become more and more important even within the Regional Council delivered control. As an example of adoption of result of the present study, a modelling study was conducted by a research colleague looking at the potential of applying targeted control rather than blanket control on a regional level, which indicated that a mix between different intensities of targeted control might be most cost-effective (McKenzie, 2000).

### *FarmORACLE*

In order to facilitate the implementation of grazing strategies that exclude cattle and deer from certain areas during winter and summer time, computer programs such as FarmORACLE (Chapter 7) have great potential. If farmers can be convinced that a changed grazing regime can result in equal or better economic outcomes, they will be more likely to adopt these changes. Therefore it is recommended that programs such as FarmORACLE are tested and evaluated on a range of farms with different locations and enterprise types. The use of programs like this is aided by the current trend that more and more farmers are using farm recording programs. Thus information on grazing routines is readily available. The ease and use of the program can be enhanced by linking the program to EpiMAN(TB) (McKenzie, 1999), a program using satellite images to obtain data on vegetation and slope, in order to classify the risk of TB hot-spots. Using satellite images within FarmORACLE could also result in easier and more accurate calculation of the effective hectare size of each individual paddock. By linking FarmORACLE to other software, such as the economic models used in Chapter 6, would provide a basis for calculating costs and benefits of employing the control measures on each individual farm.

Further, the use of FarmORACLE is not limited only to grazing regimes with respect to TB, but it could have wide-ranging applications in the control of other diseases that occur in patches, such as infection with fasciola hepatica (Radostits *et al.*, 1994), or ryegrass staggers and diarrhoea due to endophyte-infected grass (Pownall *et al.*, 1993).

## Implications of the methods studied for TB control

Findings from this study suggests that it is possible that farmers can and will participate in the control and eradication of TB. It is proposed that the best approach to achieve this, is using a phased scheme, including incentives and penalties. Farmers in New Zealand readily change in response to financial signals (Walker and Bell, 1994). Therefore, financial incentives should be offered first, with a phased reduction of compensation for reactor animals and introduction of penalties for having TB animals or not applying control methods.

In the future, in addition to targeted possum control and grazing management, vaccination of possums could also be part of on-farm control measures (Aldwell *et al.*, 1995; Corner *et al.*, in press). This and other newly researched practices will enhance the acceptability of farmer-operated vector control.

## Conclusion

Overall the results in the present study provide evidence that TB control can be assisted by farmers themselves by adopting appropriate vector control and farm management practices. However, the results also indicated areas where more research and emphasis is needed in relation to farmer adoption of these changes. Financial incentives are likely to be the principal drivers of change. These findings give direction to decision makers within the National TB control and eradication programme for cattle and deer in New Zealand.

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# Appendix

# Appendix I: Questionnaire used for the interviews (Chapter 2)

The questions were used as guidelines and key words only.

MASSEY UNIVERSITY

**FARM MANAGEMENT QUESTIONNAIRE**

## *1. Farm Details:*

**a) Name of owner:**
**b) Address:**

**c) Interview date:**

**d) Property details**

Farm ID:
Herd No:
Type of operation:
Labour units:
Years farm owned:
Farm structure:

1. *Home farm*
   location:
   Size (effective/total)
   Ownership:

2. *Run-off 1*
   Location:
   Own/lease?
   Used Since?

3. *Run-off 2*
   Location:
   Own/lease?
   Used Since?

## *2. Stock numbers (30 June 1995)*

<u>Cattle:</u>
Milking cows:
Breeding cows:
R 2yo heifers:
R 2yo steers:
R 2yo bulls:
R 1yo heifers:
R 1yo steers:
R 1yo bulls:

Breeding bulls:

Sheep:
Ewes:
Ewe hoggets:
Wether hoggets:
Rams:

Deer:
Hinds:
Weaners:
Stags:

Other animals:

### 3. TB history

Test how often?
TB history the way farmer told it:
TB in one particular stock group?
TB infected on homefarm/run-off?

### 4. Grazing management

Start AI:
Start Mating:
Start calving:
Wean calves: (how heavy are calves in kg / or how old are calves in months)
Dry cows off:

Grazing management for Calves

Grazing management for Yearlings

Grazing management for Cows

Grazing management for Heifers

Grazing management for Steers/bulls

### 5. Major changes to grazing management?

Yes/no, what changes?

### 6. Influence of change on TB.

Yes/no, what way?

### 7. High risk areas?

Are there any high risk areas?
What animals are grazed there?/when?

### 8. High risk areas and grazing management

does farmer take the high risk into account?

### 9. Grazing bush

Yes/no, what sort? When grazed? What animals graze it?

### 10. Pasture shortage

When are times of pasture shortage?

### 11. Farmer possum control

any possum control done by farmer or farmer employed people?

### 12. Herd replacement/purchasing

### 13. TB and purchasing

anything bought that had TB/white tags?

### 14. Off-farm grazing

yes/no, when and what animal groups?

### 15. Grazing other owner's cattle

Yes/no, when, what sort of animals, from where?

### 16. Stock selling policies

### 17. Classes of stock

were there any changes in the classes of stock over the years? Due to TB?

### 18. Feral animals

any feral animals on farm? Any found with TB?

### 19. Views on TB

### 20. Cost of TB

### 21. Methods of possum control

### 22. Sources of information on TB

### 23. Other comments on TB

## Appendix II: List of categories and codes used in WinMAX98

List of categories and codes used in the interview analysis of TB history and grazing management. The list of codes was taken out of WinMAX98, which stores the codes in alphabetical order.

- Farm Management
  - Changes
    - Reasons
      - Economic
  - General Comments
  - General Management
    - Mating/Calving
  - Herd Replacement
  - Off-farm Grazing
    - Reasons
    - Times
  - Other land
  - Other owner's cattle
  - Purchasing
    - TB bought
    - View on affecting TB
  - Selling
    - By TB affected
  - TB consequences
    - Loss of flexibility
    - Reasons for accepting TB
- Grazing
  - Changes
    - Effect on TB
  - Flexibility
  - General
    - General motives
  - Grazing Bush
    - Reasons
  - Grazing hot-spots
  - Mobs

    - Bulls
    - Cows
    - TB reactors
    - Younger cattle
  - Pasture shortage
    - Management
  - Supplements
- TB
  - Control
    - Grazing
    - Motivation
    - Possum Control
      - Effect
        - On TB
        - On wildlife
    - Farmer Control
      - Convenience
      - Awareness
    - RC Control
    - Views on methods for possum control
  - Cost
    - Control
    - Non-control related
  - Farmer's perception
    - Regarding farm management
    - Regarding MAF/RC control
  - Farmer's theories
  - TB history
    - Reactors
      - Circumstances
      - Grazing/management (reactors)
      - Subgroups
      - Time
    - Hot-spots
      - Areas
      - Grazing
      - TB cattle

Vegetation

Wildlife

Interesting quotes

Sources of information

Suggestions

TB testing

Farmer's view

Wildlife

General wildlife

TB infected wildlife

# Appendix III: Regulations regarding TB control and testing

The following definitions and rules are taken from the 'Five year national bovine tuberculosis pest management strategy' 1998 (Animal Health Board, 1998).

### *TB classification*

Classification of Areas: For TB control reasons New Zealand is classified into 'TB Vector Risk Areas' and 'TB Vector Free Areas'. Vector Risk areas (VRAs) are where *M. bovis* infection is present in wild animals, and where there is epidemiological evidence of clustering of infected herds and/or the persistence of TB in herds despite an intensive test and slaughter program.

Herds are classified into 'Clear', 'Suspended' and 'Infected' as a measure of the risk of TB infection: A herd changes from Clear to Suspended if a TB test positive animal or lesions in slaughter animals are found. All test positive animals have to be slaughtered unless an ancillary test is conducted. This herd changes back to Clear if the slaughter or ancillary test provide no indication of tuberculosis. The status changes to Infected (I) if TB has been confirmed by testing, post-mortem or other approved diagnosis. A newly infected herd will be classified as I1, with the number incremented for every year it remains infected. Herds with no evidence of TB are classified as Clear (C). Again, the number will be incremented for each year the herd has been confirmed by testing to be remaining clear of infection. For a herd to shift from Infected to Clear 1 (C1) all test positive animals have to be slaughtered and the herd must have two consecutive clear whole herd tests with a minimum of six months between tests, with no further evidence of disease. Under normal circumstances it will take at least one year for a herd to change from Infected to Clear status.

Beef dry stock herds have the option of obtaining the status 'Works Monitored', depending on the area they are in and the percentage of cattle going to slaughter within 12 months. These herds require no on-farm testing.

### *TB testing*

The standard test for TB in cattle is the Caudal Fold Skin Test, whereby 0.1 ml of bovine tuberculin is injected intradermally and the test is read 72 (±6) hours after the injection. A positive test under standard interpretation is any palpable/visible reaction at the site of the injection. Any animal reacting positive to this test is termed 'reactor'. Similar testing procedure and interpretation applies to deer, but at the mid-cervical site.

As an ancillary test in cattle the Comparative Cervical Test (CCT) may be used, injecting bovine and avian tuberculin intradermally. The test is read 72 (±6) hours after the injection and under standard interpretation a positive test is present if any reaction at the site of the bovine injection is greater than any reaction at the site of the avian tuberculin.

Another ancillary test in cattle is the Gamma Interferon Test (marketed as BOVIGAM), which is approved as an ancillary serial test in cattle, to be used only on Caudal Fold test positive cattle. The test has to be performed 13-30 days after the injection of tuberculin into the caudal fold. A positive test is obtained if the bovine antigen minus the nil antigen is $\geq 100$, AND the bovine antigen minus avian antigen is $\geq 100$. Ancillary tests in deer include BTB and post-skin test ELISA (for more details on these tests see (Griffin *et al.*, 1993).

In cattle herds with Clear or Works Monitored TB status ancillary serial testing is used on skin test positive cattle using BOVIGAM only (if less than four skin test positive animals to be re-tested) or using a combination of BOVIGAM and CCT or CCT alone (if four or more skin test positive animals are to be re-tested). In this case, the CCT is read under the modified interpretation, where a difference in skin thickness of at least 4 mm exists between the two sites of injection (bovine and avian).

The application of ancillary serial testing in cattle herds with an Infected or Suspended TB status depends on the TB area classification and the control/eradication objectives in this area. In Vector Free Areas and VRAs where the objective is eradication of TB, ancillary tests are normally not applied on herds with Infected/Suspended status. Exemptions are made when specific epidemiological information are evident, such as evidence of skin TB, or Johnes vaccinated cattle, unexpected large number of test positive animals considering the TB history, or test positive animals in a management or age group, that is normally not associated with infection.

In VRAs where the objective is control only or where there is no vector control program, ancillary tests can be used in areas where the skin test positive rate is very low or within herd exemptions apply. The standard interpretation of the CCT is used under these conditions.

The TB status of a herd is monitored through on-farm TB testing and/or post-mortem inspection of all cattle processed in a slaughterhouse. TB testing in cattle herds is paid through the Animal Health Board (through levy funded by farmers per head of cattle slaughtered) and time frames are set for regular testing, depending on herd status and area classification. Deer farmers pay directly for TB testing costs.

In cattle herds with a Clear2 status or better in VFAs, all animals over 24 months of age have to be tested at least every 3 years. In herds with a status of Clear1 all animals over three months of age have to be tested at least every 12 months. Beef dry stock herds have the possibility to obtain 'Works Monitored' status, whereby no on-farm testing is required. This is provided if 45% of animals in a triennial testing area, or 60% of animals in a biennial testing area go to slaughter over a 12 months period.

In VRAs all animals over the age of 3 months have to be tested at least once every 6, 12 or 24 months, which is defined in regional TB plans. All herds with a status of C1 have to be tested annually. For Beef dry stock herds works surveillance can be applied when over 90% of the animals go to slaughter within 12 months. Test eligibility in deer herds varies slightly from that of cattle.

### Compensation

All test positive cattle have to be slaughtered as soon as possible, within 30 days after diagnosis. For all reactor cattle slaughtered, the owner gets paid 65% of 'Fair Market Value' of the animal. This value is assessed at the time of testing and considers the value the animal had at that time, assuming it was TB free. The maximum value payable is determined by the New Zealand Dairy Board (for dairy cattle) and Meat New Zealand (for beef cattle). The money for compensation and TB testing is partly obtained through a levy per head of cattle being slaughtered, paid by all farmers.

Deer farmers do not pay a levy per slaughtered animal, and no compensation is paid for deer reactors.

### TB Movement Control Restrictions

Cattle and deer movements from herds with an 'Infected' status are restricted in order to prevent the spread of disease. Movement restrictions are lifted once the herd achieves a 'Clear' status again.

In infected deer herds all animals are only allowed to move to slaughter directly. Owners of infected cattle herds have to obtain a Permit-to-Move, for all cattle leaving their farm except for cattle that go directly to slaughter. This permit is issued if all cattle six weeks or older are tested negative within 60 days of the movement date and all are identified with an official (AHB) white Movement Control ear tag ('white-tagged' cattle). The purpose of the white ear tags is to indicate a potential risk. Often this 'white-tagged' animals can only be sold at a discount, as the market for these animals is limited, since farmers in TB non-endemic areas are reluctant to buy these animals.

If a TB reactor is diagnosed at a pre-movement test a permit is only issued if the lesion reactor rate at the pre-movement test is less than 0.1% or if the animals go to an Infected herd within a VRA. In both cases all the animals have to be white-tagged. All reactors have to be identified with official orange TB Reactor ear tags and can only be moved to slaughter directly.

An Infected herd is classified as 'Infected (High Risk)' if the TB lesion incidence in any test is 5% or greater if the herd size is at least 50 cattle, or if five or more lesioned animals are found in a single test where the herd is less than 50 animals. For Infected (High Risk) herds the same rules apply, except that all animals to be moved and all animals in contact with them within the previous 60 days have to be tested negative. Additionally if TB reactors are identified in a pre-movement test, the remainder of the tested animals has to stay on the property or move only to slaughter.

Suspended herds have to fulfil the same requirements as Infected herds if the cattle are to be moved before the final result on the TB reactor is obtained and if there is a 'reasonable probability ($\geq$30%)' that the suspected animal is tuberculous. Otherwise suspended herds obtain a movement permit without the requirement of a pre-test. Movements directly to slaughter never require a permit.

For all white-tagged cattle the movement has to be traced and they have to be tested again within 60 to 120 days after leaving their herd of origin, but with at least 90 days between the pre- and post-movement test.

As from January 1st 2000 a new policy is in place, whereby cattle can only move to other herds, if the herd already had one clear test and the group to be moved passed a clear test within 60 days of movement. Animals from infected herds without a clear test will have to pass a skin test and a parallel blood test. If these conditions are met, then the animals can move subject to a permit, with white ear tags, and they must be tested a minimum of 90 days after pre-movement test. In addition the purchaser's herd status will be suspended and only restored to C1 after a clear whole herd test a minimum of six months after the post-movement test (Animal Health Board, 1999).

### Bibliography

Animal Health Board (1998). Five Year National Bovine Tuberculosis Pest Management Strategy to 30 June 2001. Animal Health Board, Wellington, New Zealand.

Animal Health Board (1999). Movement from infected cattle herds. Documentation provided by the Animal Health Board, Wellington, New Zealand

Griffin, J.F.T., Chinn, D.N., Mackintosh, C.G., Rodgers, C.R. and Buchan, G.S. (1993). Serial ELISA and Skin Testing in Deer for Diagnosis of Mycobacterium bovis Infection. Proceedings of a Deer Course for Veterinarians. Deer Branch, New Zealand Veterinary Association, 10: 288-296.

# Appendix IV: Questionnaire used on Wairarapa and national project farms

## *TB Control Programme Questionnaire*

Please fill in the blank spaces and tick or circle the appropriate box

Example: when meaning YES

Yes ☐ No ☐ or Yes ☑ No ☐

Massey University

Name:

Date: ____/____/____

## 1) Introduction and General Information

1. What is the size of your farm? Please fill in the size of your farm (both total size and effective size) and other land used by your farm. (where stock is shifted by truck, land is classified as 'Other', please indicate the distance in km from your home property for these areas)

| | | *Total size (in ha)* | *Effective Size (in ha)* | *Distance from home property (in km)* |
|---|---|---|---|---|
| Owned Land | Main property | | | -------- |
| | Other owned land | | | |
| Leased Land | Locally leased | | | -------- |
| | Other leased land | | | |

2. How many labour units are working on the farm? Full-time workers __________

   Part-time workers __________

3. Which of the following categories describe your enterprise type (multiple answers are possible, please give approximate percentage of total farm income)

| *Enterprise type* | | *% of gross farm income* |
|---|---|---|
| Cattle breeding | ☐ | |
| Cattle finishing operation | ☐ | |
| Dairy herd<br>Town supply ☐<br>Seasonal supply ☐ | ☐ | |
| Sheep flock | ☐ | |
| Deer breeding | ■ | |
| Deer finishing operation | ☐ | |
| Velvetting deer operation | ☐ | |
| Others (e.g. goats, pigs, plantations)<br>Please specify: ________________ | ☐ | |

4. How many animals do you run on your farm? (Please give the numbers as at 30th June **1998** for each of the groups – If numbers have changed over the last 3 years, what were they at 30th June 1995?)

| | *Sex* | *Main Breed* | *Age 0-1 year* 06/95 | 06/98 | *Age 1-2 years* 06/95 | 06/98 | *Age > 2 years* 06/95 | 06/98 |
|---|---|---|---|---|---|---|---|---|
| **Cattle** | Female | | | | | | | |
| | Male | | | | | | | |
| **Deer** | female | | | | | | | |
| | male | | | | | | | |
| **Sheep** | Ewes | | | | | | | |
| | Hoggets | | | | | | | |
| | Rams | | | | | | | |
| **others** | | | | | | | | |

5. Current TB status of your herd:

| | *Cattle* | *Deer* |
|---|---|---|
| Infected | Yes ☐ No ☐ | Yes ☐ No ☐ |

6. How important is off-farm grazing to your farm?

Crucial ☐ Important ☐ Moderately ☐ Minor ☐ Unimportant ☐

7. How important is trading of cattle and deer (e.g. through private sales, sale yards, but **not to slaughter**) to your farm?

Crucial ☐ Important ☐ Moderately ☐ Minor ☐ Unimportant ☐

8. Numbers of stock (only cattle/deer) leaving the farm in the last 12 months. If you are currently on MC, please fill in also the last column, indicating the number of animals you would sell if your herd were not infected.

| *Number of animals leaving for* | *current situation* *Deer* | *Cattle* | *if your herd was not infected* *Deer* | *Catte* |
|---|---|---|---|---|
| slaughter | | | | |
| private sale / sale yards | | | | |

9. How do you replace your herd? Please tick the appropriate box and indicate the percentage each type contributes to the total replacement of your herd.

| | *Cattle* | *Deer* |
|---|---|---|
| Own breeding | % | % |
| Buying in | % | % |
| Other (please specify) ________ | % | % |

10. How often do you purchase cattle/deer?

Every year ☐ every now and again ☐ never ☐ Other (please specify) ☐ ______

11. From how many different herds do you buy cattle/deer in a normal year?

1-3 herds ☐ more than 3 herds ☐ from sale yards or similar source ☐

12. Number of animals (cattle/deer), which entered the farm in a normal year. Please indicate the time of the year when the animals were brought on to the farm, the class of stock and the number of animals:

| | *Time of year* | *class of stock brought in* | *number of animals* |
|---|---|---|---|
| **Bought animals** | | | |
| | | | |
| | | | |
| | | | |
| **Grazers** | | | |
| | | | |
| | | | |

13. Did you buy any white-tagged cattle? Yes ☐ No ☐

If yes, what were your main reasons to buy white-tagged animals? ________________

________________________________________

14. Which of the following factors do you consider as having contributed to your current or past TB infection? (Please tick the box, if you think it contributed to your TB problem)

| | *Contributed?* |
|---|---|
| Bought-in cattle/deer | ☐ |
| Cattle/deer grazed on-farm | ☐ |
| Cattle/deer grazed off-farm | ☐ |
| Problems with the TB-skin test | ☐ |
| Neighbours (incl. DOC and RC land) | ☐ |
| TB infected feral animals<br>Possums ☐ Ferrets ☐ | ☐ |
| Others (specify please)<br>____________________ | ■ |

15. Do you have any crops on your farm Yes ☐ No ☐

If 'Yes': what sort of crop ________________________________

________________________________________

## 2) Individual Areas of TB Risk

### I. On-farm Stock Grazing Management

16. Are there areas of your farm, which you know or believe, pose a high TB risk?

Yes ☐ No ☐ Unknown ☐

If 'Yes' do you graze your cattle/deer in these areas? Yes ☐ No ☐

If 'Yes', what time of the year do you graze your cattle/deer there? ____________

____________

What factors do you take into account when you graze these areas (open question)?

____________

____________

17. Do you graze any cattle/deer in a bush area? Yes ☐ No ☐

What sort of bush? Heavy dense bush ☐ Open bush ☐

Other (please specify) ☐

____________

18. Do you graze any cattle/deer near a bush area? Yes ☐ No ☐

19. What is your average stock density per ha?

| | *Over all* | *Cattle* | *Deer* | *Sheep* |
|---|---|---|---|---|
| *Stock density/ha* | | | | |

20. As a management system, do you

☐ move animals regularly between groups to meet grazing needs

☐ keep animals together in the same groups as far as possible

21. Do you identify your cattle/deer mobs permanently? (ear tags, by breed) Yes ☐ No ☐

22. Does each mob graze a specific part of the farm? Yes ☐ No ☐

23. During which months of the year do you normally experience your most severe shortage of pasture? (Please circle appropriate months)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |

24. How often does it happen that your cattle/deer get mixed up with those of your neighbours?

Never ☐ 1-5 times a year ☐ more than 5 times a year ☐

25. Within the last five years, have you had any neighbours that were infected with TB?

Yes ☐ No ☐ Unknown ☐ If yes: what year(s)? ____________

### II. Grazed in Stock and Stock sent off farm grazing:

26. Are cattle/deer belonging to another owner grazed on your farm? Yes ☐ No ☐

27. From how many farms do you graze stock? ____________

28. Within the last 3 years, did you send any stock for off-farm grazing? Yes ☐ No ☐

29. What stock classes were sent for off-farm grazing? ______________________________

________________________________________________________________

**III. Weather influence**

30. What changes would/did occur due to drought (with regards to grazing/stock/general farm management)? ______________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

## 3) TB and Vector Control

**I. TB in your herd**

31. How often do your animals get tested for TB? If you are currently off MC please indicate in the last column how often your animals were tested while the herd was infected.

| | *Cattle* | | *Deer* | |
|---|---|---|---|---|
| | *Currently* | *While herd was infected* | *Currently* | *While herd was infected* |
| Twice a year | ☐ | ☐ | ☐ | ☐ |
| Once a year | ☐ | ☐ | ☐ | ☐ |
| Once every two years | ☐ | ☐ | ☐ | ☐ |
| Other (please specify): | ■ | ☐ | ☐ | ☐ |

32. How would you classify your TB problem?

Continuous ☐ on and off ☐ seldom ☐ no problem any more ☐ never ☐

How likely do you think it is that you get TB back on your farm?

Less than 25% chance ☐ Between 25% and 50% ☐

Between 50% and 75% ☐ Over 75% ☐ 100% ☐

33. Where did your TB-reactors get infected? Homefarm ☐ current Run-off ☐ other ☐

________________________________________________________________

34. Has one class of stock been more affected than others with regards to TB reactors?

Yes ☐ No ☐ Unknown ☐

If 'Yes': which class/classes? ______________________________________

35. Has one breed of cattle/deer been more affected than others with regards to TB reactors?

Yes ☐ No ☐ Unknown ☐

If yes? What breed? ______________________________

36. Have you changed your cattle/deer selling policies as a result of having TB on your farm?

Yes ☐ No ☐

37. Have you changed the mix of classes of cattle/deer on your farm as a result of having TB?

Yes ☐ No ☐

38. Over the last five years, did the number of TB reactors on your farm

Increase ☐ Decrease ☐ Stayed about the same ☐

If there was a change, to which factors do you contribute this change?__________

______________________________________________________________

______________________________________________________________

**II. Cost of TB**

39. How much do you spend annually on TB control (e.g. possum control)?

On poison: $ ______________

On labour: $ ______________

40. What do you expect to be the annual cost of TB to your farm, if you have TB on your farm or if you had TB back on your farm? (e.g. lost income) $ __________

Due to what reasons? ______________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

**III. On-farm Feral Animal Control**

41. Are the following wildlife species present on your farm (please tick the appropriate boxes) and how likely do you think is contact between your stock and the wildlife species?

| | *species present on farm* | *Contact unlikely* | *Contact possible* | *Contact very likely* | *unknown* |
|---|---|---|---|---|---|
| possums | ☐ | ☐ | ☐ | ☐ | ☐ |
| ferrets | ☐ | ☐ | ☐ | ☐ | ☐ |
| wild cats | ☐ | ☐ | ☐ | ☐ | ☐ |
| wild pigs | ☐ | ☐ | ☐ | ☐ | ☐ |
| wild deer | ☐ | ☐ | ☐ | ☐ | ☐ |
| wild cattle | ☐ | ☐ | ☐ | ☐ | ☐ |
| hedgehogs | ☐ | ☐ | ☐ | ☐ | ☐ |
| rabbits | ☐ | ☐ | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ | ☐ | ☐ |

42. Has feral animal control been undertaken on your farm at any time within the last 5 years

Yes ☐ No ☐ Unknown ☐

43. If 'Yes', when? Please tick all years when possum control was conducted.

1993 ☐ 1994 ☐ 1995 ☐ 1996 ☐ 1997 ☐ 1998 ☐ 1999 ☐

44. If 'Yes' who performed this work (may nominate more than one)

| | |
|---|---|
| Unknown | ☐ |
| Regional Council / MAF | ☐ |
| Farmer group (please specify who did the work) | ☐ |
| ______________________________ | |
| You, your family, farm worker | ☐ |
| Person from outside, employed for the work | ☐ |
| Others (please specify) | ☐ |
| ______________________________ | |

45. What type of control was performed over this period. Please distinguish between work done by the Regional Council (first column) and work done by yourself or persons you employed (second column).

| | | *Control done by RC* | *Control done by farm* |
|---|---|---|---|
| Shooting | | ☐ | ☐ |
| Trapping | | ☐ | ☐ |
| Poison | | ☐ | ☐ |
| *If you know which* | Phosphorus | ☐ | ☐ |
| *Poison, please tick* | 1080 | ☐ | ☐ |
| *appropriate box* | Talon | ☐ | ☐ |
| | Cyanide | ☐ | ☐ |
| Other (please specify) | | ☐ | ☐ |

46. Extent of the TB control work conducted over the last 12 months. How many days per year would you (first column) or the Regional Council (second column) have done each form of control (trapping, poisoning, shooting ...) (please specify in days per year) Please tick if the work is being done on a regular basis, meaning at least once a months)

| | *Work done by farm* | | *Work done by RC* | |
|---|---|---|---|---|
| | *days/year* | *regularly* | *days/year* | *Regularly* |
| Trapping | | ☐ | | ☐ |
| Poisoning | | ☐ | | ☐ |
| Shooting | | ☐ | | ☐ |
| Others (specify) | | ☐ | | ☐ |

How many days would you have worked on possum control three years ago? ________

______________________________________________

47. What feral species was the control aimed at?

| | | | | |
|---|---|---|---|---|
| Possums | ☐ | Cats | ☐ | Others (please specify) ☐ |
| Ferrets | ☐ | Rabbits | ☐ | ______________ |

48. What proportion of the farm is subject to wildlife control (%)?

Percentage of your total area controlled by Regional Council ____________%

Percentage of your total area controlled by yourself ____________%

49. Intensity of wildlife control over the last 5 years, distinguished between what the Regional Council did and what was done by the farm itself. Has the intensity of wildlife control on your farm

| | | | |
|---|---|---|---|
| RC initiated: | increased ☐ | decreased ☐ | stayed stable ☐ |
| Farm initiated: | increased ☐ | decreased ☐ | stayed stable ☐ |

50. Which forms of possum control do you consider best in reducing TB in your cattle?

Poison ☐ Trapping ☐ Shooting ☐

51. Which of the two types of programmes do you consider better in reducing TB in your cattle?

Regional programmes ☐ Individual Farm Efforts ☐

52. Where do you think individual farm efforts could play an important role? (open question)

________________________________________

________________________________________

________________________________________

## 4) Attitudes

53. How important is it to you to eradicate TB from your herd

| crucial | important | moderately | minor | not important at all |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

54. Do you believe TB can be eradicated on your farm? Yes ☐ No ☐ Unknown ☐

55. If 'no' what are the factors hindering the progress? (open question) ____________________

________________________________________

________________________________________

56. Who do you see as having responsibility for eradicating TB from infected farms? (tick them please and rank them in terms of your priority, with '1' being the highest priority.)

| | *Responsible?* | *Priority* |
|---|---|---|
| All farmers | ☐ | ☐ |
| Only farmers with the problem | ☐ | ☐ |
| All landowners | ☐ | ☐ |
| Government | ☐ | ☐ |
| MAF/AHB | ☐ | ☐ |
| Regional Council | ☐ | ☐ |
| RAHC | ☐ | ☐ |
| Local farming action group | ☐ | ☐ |
| Local veterinarian | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ |
| ____________________ | | |

57. Who do you see as having responsibility for **doing the work** required for eradicating TB from infected farms?

| | *Responsible?* | *Priority* |
|---|---|---|
| all farmers | ☐ | ☐ |
| Only farmers with the problem | ☐ | ☐ |
| all landowners | ☐ | ☐ |
| Government | ☐ | ☐ |
| MAF/AHB | ☐ | ☐ |
| Regional Council | ☐ | ☐ |
| RAHC | ☐ | ☐ |
| Local farming action group | ☐ | ☐ |
| Local veterinarian | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ |
| ______________________ | | |

58. If you were asked to do your own TB control on your farm where would you expect to get help from, and what would be your expectations about the nature of this help?

| | | What would you expect? |
|---|---|---|
| MAF/AHB | ☐ | ______________________ |
| Regional Council | ☐ | ______________________ |
| Government | ☐ | ______________________ |
| RAHC | ☐ | ______________________ |
| Neighbours (incl. forestry…) | ☐ | ______________________ |
| Veterinarian | ☐ | ______________________ |
| Other (specify) | ☐ | ______________________ |
| None | | ☐ |
| None of these, I would get out of farming cattle | | ☐ |

59. Do you think movements of **cattle** from MC farms should be more strictly controlled? (e.g., only animals to slaughter) Yes ☐ No ☐ Less ☐ Not known ☐

Why?______________________________________________________________

______________________________________________________________

______________________________________________________________

60. If compensation for reactors was removed altogether, what do you believe the effect on TB control would be? TB eradication achieved quicker ☐ slower ☐ no change ☐

Why? ______________________________________________________________

______________________________________________________________

______________________________________________________________

61. Do you believe that control of TB in **cattle** would be achieved quicker if cattle farmers, like deer farmers, had to pay testing costs directly? Yes ☐ No ☐ Not known ☐

Why?______________________________________________________________

______________________________________________________________

______________________________________________________________

62. Do you think the current control scheme is satisfactory for controlling TB in New Zealand?

Yes ☐ No ☐ Not known ☐

What improvements could be made to the current control policy/ what incentives could be put in place? ______________________________

______________________________

______________________________

## 5) Changes

63. Over the last three years were there any management changes in relation to livestock policies, grazing management and pest control for your farm? (open question)

______________________________

______________________________

______________________________

64. What factors influence you most in deciding whether to conduct any TB control on your farm?

| Control effort would | increase | Decrease |
|---|---|---|
| Increased farm profitability | ☐ | ☐ |
| Decreased farm profitability | ☐ | ☐ |
| Adverse climatic events | ☐ | ☐ |
| Time (conflicts with other farm priorities) | ☐ | ☐ |
| Reduction of the externally funded programmes (AHB/RC/Farmer group) | ☐ | ☐ |
| Pressure from other farmers | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ |

## 6) Information on the herd manager

65. Gender male ☐ female ☐

66. What age group are you in? <20 years ☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐ >60 ☐

67. Do you live on the farm Yes ☐ No ☐

68. Do you have any other employment commitments? Yes ☐ No ☐

69. Can you cover your living expenses from your farm income? Yes ☐ No ☐

70. What is your relation to the property?

Owner ☐
Share milker ☐ (50% ☐, 39% ☐, 29% ☐, others ☐)
manager ☐
lessee ☐
other (specify) ☐

71. Who makes decisions concerning grazing management/buying in animals?

- you solely ☐
- you in partnership with someone else ☐
- others (please specify their function) ☐

72. How frequent is contact between the decision-maker and you?

Daily ☐, at least once a week ☐, at least once a month ☐, less than once a month ☐

73. How long have you been working on **this** farm? ______________________________

74. How many years have you worked in farming? ______________________________

75. How many years have you worked in non-farm jobs? ______________________________

76. What is your farming background

- started farm job without having any farming background ☐
- brought up on farm ☐
- other (please specify) ☐

77. What kind of farm-specific formal qualifications do you have

- none ☐
- technical agricultural institute ☐
- diploma/degree ☐
- other (please specify) ☐

## 7) Comments:

We would like to hear any comments you have on the current TB control policy, what could be improved, what could be changed, or any comments to the questionnaire.

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

## 8) Farmer's self concept

This is the final question and here we would like you to give us an assessment of your personal characteristics. These questions were created for a dairy farmer in England who has got six dairy farms. Despite the similarity of the farms (sheds, number of animals, location, breeding material) he got different milk yields for each of the farms and he attributed this to the managers. Therefore he asked a psychology professor to set up a questionnaire, looking at personal characteristics of his managers and farm management. After conducting this questionnaire with many farmers and managers in England, they found that there is a certain zigzag pattern which makes a good animal person, others which make a good communicator and so on. With this question we would like to study if the same principles also hold for New Zealand farmers.

For this purpose, please try to describe yourself on the scale in relation to the following characteristics. (For example, if you think you are very easy going please tick the box to the right, if you think you are in between 'easy going' and 'not easy going' please tick the box in the middle.)
You do have the option not to fill in these questions, if you feel uneasy about it, but I assure you that all information is treated anonymously.

| | | |
|---|---|---|
| Not easy going | ☐☐☐☐☐ | Easy going |
| Meek | ☐☐☐☐☐ | Not meek |
| Patient | ☐☐☐☐☐ | Impatient |
| Unsociable | ☐☐☐☐☐ | Sociable |
| Not modest | ☐☐☐☐☐ | Modest |
| Persevering | ☐☐☐☐☐ | Giving up Easily |
| A worrier | ☐☐☐☐☐ | Not a worrier |
| Cheerful | ☐☐☐☐☐ | Grumpy |
| Talkative | ☐☐☐☐☐ | Not talkative |
| One who speaks one's mind | ☐☐☐☐☐ | One who keeps quiet |
| Difficult to get on with | ☐☐☐☐☐ | Easy to get on with |
| Lacking confidence | ☐☐☐☐☐ | Confident |
| Liking change | ☐☐☐☐☐ | Suspicious of change |
| Forceful | ☐☐☐☐☐ | Giving in easily |
| One who prefers machinery | ☐☐☐☐☐ | One who prefers animals |
| One who prefers buying a new machine | ☐☐☐☐☐ | One who prefers choosing a new animal |
| Dislike to learn | ☐☐☐☐☐ | Very keen to learn |
| Still learning | ☐☐☐☐☐ | Very knowledgeable |
| One who likes to avoid hard work | ☐☐☐☐☐ | One who values hard work |
| One who dislikes using records | ☐☐☐☐☐ | One who likes using records |
| One who values traditional ways | ☐☐☐☐☐ | One who likes adopting new ideas |
| One who does not like to set targets | ☐☐☐☐☐ | One who likes setting targets for him/herself |
| One who likes to look after his/her favourite animals a bit better than the rest | ☐☐☐☐☐ | One who likes to strictly monitor performance of the herd |

If you have any questions, please feel free to contact me any time.

**Thank you very much for your co-operation, which is very much appreciated.**

## Deterministic model for dairy farms

| | A | D | E | F | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Dairy farm:** ***Partial budgeting on-farm control programmes*** | | | | | | | | | | |
| 2 | | compensation: | 65% | | | reactor scenario | | | | | |
| 3 | **Returns** | | | | | 5 -> 2 | 5 -> 0.5 | 5 -> 0 | 2 -> 0.5 | 2 -> 0 | 1 -> 0 |
| 4 | | | | | *Number saved* | 3 | 4.5 | 5 | 1.5 | 2 | 1 |
| 5 | *Increased prices reactors:* | | *%* | *$/hd* | | | | | | | |
| 6 | Dairy cattle > 2 yrs | | 35% | $ 850 | *returns ($)* | 893 | 1339 | 1488 | 446 | 595 | 298 |
| 7 | | | | | | | | | | | |
| 8 | | | | | *OFF MC* | 0 | 0 | 1 | 0 | 1 | 1 |
| 9 | %discount | | 10% | | | | | | | | |
| 10 | *Increased prices "white tagged"* | *Number* | | *$/hd* | | | | | | | |
| 11 | Dairy cattle > 2 yrs | 50 | | $ 850 | *returns* | $ - | $ - | $ 4,250 | $ - | $ 4,250 | $ 4,250 |
| 12 | Dairy cattle 1-2 yrs | 6 | | $ 750 | | $ - | $ - | $ 450 | $ - | $ 450 | $ 450 |
| 13 | Dairy Cattle 6wks - 1 yr | 10 | | $ 375 | | $ - | $ - | $ 375 | $ - | $ 375 | $ 375 |
| 14 | | | | | | | | | | | |
| 15 | | | | | | | | | | | |
| 16 | | | | | *% change* | 0.006 | 0.009 | 0.01 | 0.003 | 0.004 | 0.002 |
| 17 | | *Kg Ms* | | *$/kgMs* | *in milk production* | | | | | | |
| 18 | Increased milk production | 71407 | | $ 3.63 | *return ($)* | 1,555 | 2,333 | 2,592 | 778 | 1,037 | 518 |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | ***Total additional returns*** | ***2,447.74*** | ***3,671.62*** | ***9,154.57*** | ***1,223.87*** | ***6,706.83*** | ***5,890.91*** |
| 22 | | | | | | | | | | | |
| 23 | **Costs** | | | | | | | | | | |
| 24 | | | *hrs* | *$/hr* | *costs* | | | | | | |
| 25 | Management (extra labor) | | 100 | $ 12 | | $ 1,200 | $ 1,200 | $ 1,200 | $ 1,200 | $ 1,200 | $ 1,200 |
| 26 | | | *est cost* | | | | | | | | |
| 27 | Poison/traps for possum control | | 180.00 | | | $ 180.00 | $ 180.00 | $ 180.00 | $ 180.00 | $ 180.00 | $ 180.00 |
| 28 | | | | | | | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | ***Total additional costs*** | ***$ 1,380*** | ***$ 1,380*** | ***$ 1,380*** | ***$ 1,380*** | ***$ 1,380*** | ***$ 1,380*** |
| 31 | | | | | | | | | | | |
| 32 | | | | | | | | | | | |
| 33 | | | | | **Returns - Cost** | ***1,067.74*** | ***2,291.62*** | ***7,774.57*** | ***-156.13*** | ***5,326.83*** | ***4,510.91*** |

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Beef breeding farm:** ***Partial budgeting on-farm control programmes*** | | | | | | | | | | | | | | |
| 2 | | | | compensation: | 65% | | | | reactor scenario | | | | | | |
| 3 | **Returns** | | | | | | | | 5 -> 2 | 5 -> 0.5 | 5 -> 0 | 2 -> 0.5 | 2 -> 0 | 1 -> 0 | 16 -> 2 |
| 4 | | | | | | | | *Number saved* | 3 | 4.5 | 5 | 1.5 | 2 | 1 | 14 |
| 5 | *Increased prices reactors:* | | | | *%* | *$/hd* | | | | | | | | | |
| 6 | Beef breeding cattle > 1 yr | | | | 35% | $ 695 | | *returns* | ***$ 730*** | ***$ 1,095*** | ***$ 1,216*** | ***$ 365*** | ***$ 487*** | ***$ 243*** | ***$ 3,406*** |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | *OFF MC* | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| 9 | %discount | | | | 15% | | | | | | | | | | |
| 10 | *Increased prices "white tagged":* | | | *Number* | | *$/hd* | | | | | | | | | |
| 11 | Beef breeding cattle > 1 yr | | | 16 | | $ 695 | | *returns* | $ - | $ - | $ 1,668 | $ - | $ 1,668 | $ 1,668 | $ - |
| 12 | Beef breeding 6 wks - 1 yr | | | 21 | | $ 315 | | | $ - | $ - | $ 992 | $ - | $ 992 | $ 992 | $ - |
| 13 | Steers&bulls 6 wks-18mnths | | | 42 | | $ 495 | | | $ - | $ - | $ 3,119 | $ - | $ 3,119 | $ 3,119 | $ - |
| 14 | Breeding bulls | | | | | $ 2,798 | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | |
| 16 | | | | | | | | ***Total additional returns*** | ***$ 730*** | ***$ 1,095*** | ***$ 6,995*** | ***$ 365*** | ***$ 6,265*** | ***$ 6,022*** | ***$ 3,406*** |
| 17 | | | | | | | | | | | | | | | |
| 18 | **Costs** | | | | | | | | | | | | | | |
| 19 | | | | | *no of hrs* | *$/hr* | | *costs* | | | | | | | |
| 20 | Management (extra labor) | | | | 110 | $ 12 | | | $ 1,320 | $ 1,320 | $ 1,320 | $ 1,320 | $ 1,320 | $ 1,320 | $ 1,320 |
| 21 | | | | | *est cost* | | | | | | | | | | |
| 22 | Additional fencing | | | $ | $ 1,000 | | | | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 |
| 23 | | | | | | | | | | | | | | | |
| 24 | Poison/traps for possum control | | | $ | $ 950 | | | | $ 950 | $ 950 | $ 950 | $ 950 | $ 950 | $ 950 | $ 950 |
| 25 | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | |
| 27 | | | | | | | | ***Total additional costs*** | ***$ 3,270*** | ***$ 3,270*** | ***$ 3,270*** | ***$ 3,270*** | ***$ 3,270*** | ***$ 3,270*** | ***$ 3,270*** |
| 28 | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | |
| 30 | | | | | | | | **Returns - Cost** | ***-2,540.25*** | ***-2,175.38*** | ***3,725.00*** | ***-2,905.13*** | ***2,995.25*** | ***2,752.00*** | ***135.50*** |

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Beef finishing farm:** ***Partial budgeting on-farm control programme*** | | | | | | | | | | | | |
| 2 | | | compensation: | 65% | | | | reactor scenario | | | | | |
| 3 | **Returns** | | | | | | | 5 -> 2 | 5 -> 0.5 | 5 -> 0 | 2 -> 0.5 | 2 -> 0 | 1 -> 0 |
| 4 | | | | | | | *Number saved* | 3 | 4.5 | 5 | 1.5 | 2 | 1 |
| 5 | *Increased prices reactors:* | | | *%* | *$/hd* | | | | | | | | |
| 6 | Steers&non-breeding bulls>18mnths | | | 35% | $ 970 | | *returns* | $ 1,019 | $ 1,528 | $ 1,698 | $ 509 | $ 679 | $ 340 |
| 7 | Steers&bulls<18 mnths | | | 35% | $ 695 | | | | | | | | |
| 8 | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | |
| 10 | | | | | | | ***Total additional returns*** | ***$ 1,019*** | ***$ 1,528*** | ***$ 1,698*** | ***$ 509*** | ***$ 679*** | ***$ 340*** |
| 11 | | | | | | | | | | | | | |
| 12 | **Costs** | | | | | | | | | | | | |
| 13 | | | | *hrs.* | *$/hr* | | *costs* | | | | | | |
| 14 | Management (extra labor) | | | 55 | $ 12 | | | $ 660 | $ 660 | $ 660 | $ 660 | $ 660 | $ 660 |
| 15 | | | | *est cost* | | | | | | | | | |
| 16 | Additional fencing | | | $ 500 | | | | $ 500 | $ 500 | $ 500 | $ 500 | $ 500 | $ 500 |
| 17 | | | | | | | | | | | | | |
| 18 | Poison/traps for possum control | | | $ 450 | | | | $ 450 | $ 450 | $ 450 | $ 450 | $ 450 | $ 450 |
| 19 | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | |
| 21 | | | | | | | ***Total additional costs*** | ***$ 1,610*** | ***$ 1,610*** | ***$ 1,610*** | ***$ 1,610*** | ***$ 1,610*** | ***$ 1,610*** |
| 22 | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | |
| 24 | | | | | | | **Returns - Cost** | ***-591.50*** | ***-82.25*** | ***87.50*** | ***-1,100.75*** | ***-931.00*** | ***-1,270.50*** |

# AND LAST, BUT NOT LEAST

Thanks is also due to all chocolate manufacturers – their products kept me going for all these years.

I would not dare to count up the kilograms of chocolate I have eaten during the years of my PhD, but it is certainly more than ten times that of the average New Zealander, who eats 2.2 kg chocolate per year[a].


[a]Gray, A. (2000) The World Cocoa Market Outlook, http://www.acri-cocoa.org/acri/LMCrep1.pdf.