Review of the science undertaken for the purpose of managing Bovine Tuberculosis in New Zealand

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Review team:

Dr Ian Ferguson, Departmental Science Advisor, Ministry for Primary Industries
Dr John Hellström, Chair, National Animal Welfare Advisory Committee

Summary:

New Zealand's TB research programme should be seen as a remarkable success story, with TB incidence in cattle broadly under control in 2015. This success, however, comes with a warning: no matter whether the future policy is eradication, containment or a locality-based combination, relaxation of operational or research intensity is likely to reverse this progress and result in substantial disease outbreaks in the future. That experiment was carried out very effectively in the 1980s, when TB prevalence climbed rapidly after the TB programme was eased back. While cost efficiency is critical, it shouldn't be at the expense of risking the current status of disease control or its future improvement.

TBfree has spent approximately $9 Million on the TB research programme since the last review. Overall it has delivered value for money and has been sufficiently nimble to respond to any emerging issues. It has been important to explore a range of options, such as alternative toxins, vaccines and bio-control measures. However, in planning the research programme ahead, these areas should be relegated to a lower level of activity: maintenance, a watching brief, or ceasing to fund. There should also be greater leverage off the work of other research providers, with the development of a wider TB research plan across agencies.

The progress to date has been grounded in science: a comprehensive programme of funded research and a pool of world-rated expertise has been critical to achieve this. As future plans are formulated, there should be a continuing insistence on science providing evidence for decision-making, and no relaxation of the science principles of robustness, independence, review and excellence. In particular, thinking about risk assessment and appetite for risk is important. Science informs decision-making around risk.

Because of the levels of control achieved, the landscape of the programme has changed: the dynamics of possum behaviour in low density populations has become more important; inherent disease levels in herds and wildlife have become more exposed; a wider range of technologies and approaches may become more important, and perhaps more economic, at late stages of eradication or containment; some parameters around risk assessment and management have changed; and social license becomes more important. Whether eradication or containment options are pursued, a future science programme needs to look at these and other issues relating to diminishing/shrinking Vector Risk Areas.

Many of the specific science options will depend on the new policy regarding containment or eradication, or localised combinations. In each case, it is clear that a number of technologies and

treatments will be needed to either achieve the last stages of eradication, or to adjust operations for long-term containment. This has implications for decisions on funding, back up options, and more expensive technologies, which might be needed on smaller scales for specific purposes.

The available science supports eradication. There is less available science supporting a containment option (such as what are the sustainable levels of cost-effective vector control), and particularly a lack of social science investigating the long-term use of 1080, or alternatives, and public perceptions of the continuing use of toxins.

Operationally, there is a clear continuing emphasis into the future on regional or locality-specific approaches and solutions. This needs to be matched to science directions, policy on containment/eradication, and an understanding of issues such as how much disease can be acceptable in contained areas. In this regard, an option for eradication versus containment is unnuanced and some precise definition of what containment might actually mean is required.

Cost effectiveness has been a major driver in much of the research development. It is important however, to be continually reassessing this as circumstances and policy decisions change; changes in the science, social or political landscapes may make some technologies and approaches more cost-effective in future times. The cost benefit of a technology or treatment will be different at clean up stages of an eradication programme or for long-term containment and control, than under current implementation.

Overall, this review has not identified any substantial gaps in research approaches or activity. Given the history and amount of research that has been done, this should not be a surprise. However, as technologies change (e.g. genome sequencing, other aspects of biotechnology) there is an on-going need to be alert to international developments that might be beneficial in the New Zealand programme, and where cost-benefits might become more favourable as the programme develops.

We have identified that it is time for more focus, less projects, and a more strategic approach to the science required. We believe that the research to date has delivered on broad objectives, but the time has come to take a more targeted approach.

Recommendations:

For overall context, we consider that an active research programme must be retained, but one which is more focussed, integrated and strategic, and comprises fewer individual projects. This more focussed approach should not, however, preclude the ability to respond quickly to new technologies or approaches. We emphasise the danger of reducing research effort at a time when there is a perception that control is well in hand. The consequent dangers of reversing this positive trend are proven by past experience.

In particular we consider that:

- Greater publication of research, with wider accessibility of results, should be encouraged and built into programme funding;
- The TBfree Technical Advisory Group (TAG)[1] should have more independent, external science expertise; and
- Greater leverage of research with New Zealand science funders and providers should be pursued to develop a more comprehensive, less vulnerable, partnership-based research

[1] Membership details: http://www.tbfree.org.nz/technical-advisory-group.aspx

portfolio, including consideration of maintaining critical expertise and capability into the future.

We recommend the following priorities for a future TB research programme, in order of importance:

1. An integrated programme should be refocused on achieving locality eradication faster and more cheaply. This should be achieved with the continued development and refinement of control tools, application and monitoring technology, epidemiology, ecology and modelling. In particular:

    - Enhancing models for operational forecasting should continue with new inputs on possum dynamics and behaviours, decision theory, improved information on TB incidence, TB transmission rates, etc. This would allow more realistic prediction of freedom to be made and greater flexibility in their use as management tools.
    - Testing models at lower estimates of probability of success.
    - Developing tools that utilise NAIT-derived data on individual animals for tracing and risk-based testing policies.
    - Continuing investment in research that will increase the efficiency and effectiveness of 1080 to control possums.

2. Social science research should be undertaken on the risk communication issues that need to be addressed to ensure on-going use of 1080 with a 10-year horizon.

3. Whole genome sequencing, genomic-based isolate identification and tracking, should become a routine part of operations, with new research on adapting new technologies and bioinformatics analysis. It is critical to retain activity and research capability in this area to support understanding of how Tb spreads.

4. Diagnostic tests in animals can be improved, particularly with regard to specificity, with combinations of tests, and there is a need to follow international developments on new technologies. More accurate rapid tests to detect *M. bovis* would benefit abattoir surveillance.

5. Further work on the evaluation of BCG vaccines in possums and cattle should be predicated on a clear strategic intent of how and where they would be utilised for containment or eradication and how their shortcomings could be managed. Use of vaccines as other than a niche control mechanism is currently not an option nor cost-effective. The possible emergence of higher efficacy vaccines could change this but is likely to be some years away and TBfree should not be funding their development.

6. Further research on alternative toxins should not be considered a high priority other than refining how some of the existing alternatives, such as sodium nitrite, could support existing control such as in specific localities where 1080 or cyanide cannot be used. Further work on developing an alternative to 1080 for aerial use should be predicated on social science to identify the relative acceptability of an alternative, including consideration of multi-target and biodiversity benefits.

7. There should be a continuing watch on international research for new advances in biocontrol of vector species, but no specific investment.

Background:

Control of TB in New Zealand is carried out under a National Pest Management Plan (Plan) under the Biosecurity Act 1993 (the Act) managed by TBfree New Zealand Ltd (formerly the Animal Health Board).

The Minister for Primary Industries is required to start a statutory review of the Plan by 1 July 2016, pursuant to s100D of the Act. The review must be on the basis of a proposal, which can be prepared by the Minister or any other party. The Plan was last reviewed following notification of an amendment proposal by the Minister of Agriculture in September 2009 (at that time pursuant to s88 (6) of the Act). An Order in Council amending the Plan came into effect on 1 July 2011.
A Plan Governance Group (PGG) has been established, representing the TB Plan funding parties, with membership including the Chief Executives of Beef+Lamb, DairyNZ, DeerNZ, OSPRI and an MPI representative, the Chair of the OSPRI Stakeholders Council, with an independent member and an independent Chair. It will prepare the proposal, which will bring together an overall review of the TB Plan and describe how it will be funded. As part of this work, the requirement for an independent review of the science research for TB management has been identified. This particularly relates to the quantum and efficacy of research investment to date.

Scope and Objectives of the review:

The expert reviewers will write a report on the scientific research programme carried out since 2009, taking a future-focus based on past performance, and considering the quantum and efficacy of research investment. In examining the scientific basis for the formulation of new objectives for the TB plan for the coming decade, the review will report on:

- the effectiveness of the TB science research, adequacy of uptake of research findings, and whether there were any constraints to the implementation of research findings;
- future TB research opportunities, including research into any alternatives to 1080;
- whether levels of investment into TB science have been appropriate to date, and what level of investment is appropriate in the future. This includes consideration of wider related research investment across agencies;

and will:

- provide recommendations for the direction of research needed to support the implementation of the Plan over the next 10 years and on the implementation of this research, informing the choice of TB management options for the next term of the TB Plan

Areas outside of the scope of the review include:

- Looking at research into the control of TB vectors for biodiversity purposes (a need has been identified for separate scientific research into the impacts of TB plan vector control on biodiversity values, and on the interplay between possum control for TB disease management purposes and NZ biodiversity conservation objectives. The PGG is considering this issue); and
- Commenting on the operational management of the TB Plan, i.e. how scientific research is incorporated into TBFree NZ's operational policies and reflected in key performance measures against which achievement of the Plan's objectives are met.

Review of the research portfolio:

This review is in the format of observations, comments and recommendations based on a number of questions.

Immunology, vaccines and diagnostic tests

Has the research to date delivered on expectations?

Vaccines
BCG vaccine has been shown to work in both possums and cattle at a 70-80% efficacy. However, any current value is likely to be only in localised application where possum control is prohibitive. Field trials are still underway testing efficacy. New bead technology under commercial development is providing the possibility of diagnostic testing that will discriminate between vaccinated and infected animals. Published work has shown a degree of efficacy with possum vaccination and current work is around delivery mechanisms. Projects include:

Studies to evaluate the use of BCG as a future control tool

- Efficacy of BCG vaccination in protecting cattle against possum TB
- Efficacy field trial of the commercial SSI Danish BCG vaccine for protection of cattle against bovine tuberculosis

Genomic analysis of isolates
Next generation DNA sequencing has dramatically reduced the cost of sequencing whole bacterial genomes. Typing schemes based on whole genome sequences of *M. bovis* now provide improved information for tracing the origin and spread of infections. This has the potential to have a significant effect on the final stages of eradication. Projects include:

Studies to identify isolates as a tool for determining sources of infection

- VNTR typing for New Zealand isolates of *Mycobacterium bovis*
- Pilot study of VNTR typing for New Zealand isolates of *Mycobacterium bovis*
- Genomic characterization of NZ isolates of *Mycobacterium bovis*

Diagnostics
Improved diagnosis of bovine TB is now possible using specific mycobacterial proteins in the intradermal test, to reduce non-specific reactivity in cattle infected with MAP (Johne's disease), that are naturally sensitised to environmental mycobacteria, or are vaccinated with BCG. Projects include:

Studies to improve precision of diagnostic tests

- Increasing the pool of *Mycobacterium bovis* antigens in the Special Antigen BOVIGAM blood test for cattle to improve sensitivity and specificity
- Evaluation of the sensitivity of the Modified ETB test relative to the ETB test
- Improvements to the Gamma Interferon Test
- Development of a hand-held diagnostic test for bovine TB
- Develop a new bovine tuberculin for use in tuberculosis testing in herds that give false negative results
- Review of the SA Gamma Interferon (Bovigam)
- Comparative study of Polybatics test reagent (Assign-bTB™) with AsureQuality's Observe 3,000 PPD tuberculin for use in TBfree New Zealand's National TB control programme

Development of support tools
Two small but important studies to successfully validate key diagnostic tools:

- Validation of a Liquid Culture System
- Comparative Study of an imported Tuberculin formulation for use in the National TB Control Programme

What has been implemented

Studies to evaluate the use of BCG vaccination as a future control tool
Over $1.2m has been spent on cattle vaccination studies, to little benefit for the current control scheme. The results of the studies are unremarkable apart from demonstrating that oral BCG vaccine is about as effective as injected vaccine. The use of vaccine does not appear to be currently cost-effective, it increases the complexity of herd TB eradication, and the long-term implications of its use do not appear to have been adequately considered. While the vaccinated animals are only directed at the NZ market, there is a risk of consumer rejection (the "why should we eat it if no one else does?" risk). The future role of vaccination of cattle in the TBFree scheme is at best unclear.

Studies to identify isolates as a tool for determining sources of infection
The two VNTR studies have delivered a valuable tool for identifying sources of infection and thus focusing eradication efforts. Whole genome sequencing (WGS) work is producing valuable information and looks like the future tool of choice.

Studies to improve precision of diagnostic tests
The ETB enhancement has provided some small gains for deer testing and the use of the Bovigam test has been enhanced. Although the project to evaluate the precision of the Polybatics test reagent is still underway, it is showing real promise to improve the sensitivity of Tb testing cattle. The other studies have not so far delivered any useful enhancements

There has been a move to use of pooled samples for wildlife diagnostics with a reduction in costs.

Development of support tools
The development of an alternative culture system for *M. bovis* and validation of a new tuberculin were both successful.

What is needed in the future?

Vaccines
Given the published work on efficacy, more work on vaccine delivery options in possums could provide a niche tool for specific localities where toxins may be difficult to use. However, current costs for widespread vaccination of possums are too high and this is probably not worth pursuing at this stage.

An effective TB vaccine could be used to protect cattle and deer herds without on-going possum control, relying on vaccination to keep TB rates low in herds. Discriminating tests have been developed but there remains potential risk for masking residual active infection. Consumer reaction to significant numbers of vaccinated animals is a potential risk and could lead to market access issues. Cattle vaccination would only likely be used within a containment policy. It is possible that new generation vaccines being developed to combat tuberculosis in humans may have a role for the control of TB in livestock. However, this is not something that TBfree logically should be involved in other than keeping a watching brief. Such options would be 10 to 20 years away.

Diagnostic tests
Diagnostic tests continue to be improved overseas and we should be alert to international developments. Reducing false positives with more specific diagnostics would provide considerable benefit. There should be a priority on improving the speed, cost-effectiveness and accuracy of tests (currently culture and PCR) with regard to abattoir surveillance.

Greater specificity of tests may be more important than sensitivity, to reduce the number of reactors and unnecessary culling. Use of combinations of cellular immune tests, including the tuberculin intradermal and IFN-γ tests, with new commercial serological tests for the diagnosis of bovine TB, may reduce the problem of non-reaction in some cattle. However, future work on sensitivity and specificity will be predicated on policy decisions around containment, longevity of control programmes, regional approaches and testing costs.

Genome sequencing to improve precision of *M. bovis* subtype identification is the way of the future and should be an operational function, with continuing research on adapting new and faster technologies and ensuring there is adequate capability in bioinformatics analysis. Given the technology now available and associated reduction in costs, sequence information should be assembled for all new outbreaks, adding to the library of isolate sequences. The benefits from this are improvement in identification of source and traceability of infection, including a better understanding of mutation rates, and the consequences for control and management of TB. This could be seen as an operational cost, but there is still research to be done in adapting new sequencing technologies and bioinformatics. Maintenance of research capability in this area is critical.

Recommendations

Further work on the evaluation of BCG vaccines in possums and cattle should be predicated on a clear strategic intent of how and where they would be utilised for containment or eradication and how their shortcomings could be managed. Use of vaccines as other than a niche control mechanism is currently not an option nor cost-effective. The possible emergence of higher efficacy vaccines could change this but is likely to be many years away.

Whole genome sequencing, genomic-based isolate identification and tracking, should become a routine part of operations, with new research on adapting new technologies and bioinformatics analysis. It is critical to retain research capability in this area.

Diagnostic tests in animals can be improved, particularly with regard to specificity, with combinations of tests, and there is a need to follow international developments on new technologies. More accurate rapid tests to detect *M. bovis* would benefit abattoir surveillance.

Toxins

Has the research to date delivered on expectations?

The research has apparently had 3 broad goals: developing alternatives to 1080, minimising its poor image and improving the effectiveness and efficiency of its use.

Development of alternatives to 1080
Much of the work in this area has been to develop “anything but 1080” toxins and so far has only provided limited benefits. Some may be useful for ground control using Spitfire type bait applicators. It is uncertain that alternatives to the aerial use of 1080 are likely to be any more acceptable to the public. On the basis of research evidence none of the toxins currently under investigation are as effective as 1080:

- C+C (Cholecalciferol and Coumatetralyl) bait has significant formulation problems
- D+C (Cholecalciferol and diphacinone) bait may overcome formulation problems of C+C but is less humane than 1080
- KOLEE - Aerially applied KOLEE cholecalciferol cereal bait is substantially less effective than 1080 and much less humane, with question around eco-toxicity.

- Microencapsulated sodium nitirite (MSN) bait is more humane and safer but has failed in field trails
- Microencapsulated Zinc phosphide (MZP) bait been moderately successful in field trials
- Microencapsulated Zinc phosphide (MZP) paste has been registered

Improvement in the public "acceptability" of 1080

A number of projects have been undertaken to address aspects of concern about 1080. Some of these were carried out under the New Tools or Epidemiology research categories. They include:

- Bird repellents for 1080 baits
- Can 'thermogenic' compounds mitigate welfare costs in possums poisoned with 1080 by decreasing time to death?
- Fluoroacetate in tea - A source of human exposure?
- Aerial application of alternatives to 1080 for possum control in dense habitats
- Long Term Benefits of 1080 Operations on Tomtits
- Estimating the maximum probable concentration of Sodium monofluoroacetate (1080) in streams following aerial applications
- Natural plant toxin (NPT) for pest control
- Comparative bait preferences in captive Kea (*Nestor notabilis*)
- Ecological outcomes for plants from aerial 1080 operations
- Maori interest in natural occurrence of 1080 in NZ Plants
- Aerobic transformation of sodium fluoroacetate (1080) in soil
- Green Epro Deer Repellent (EDR) use on RS5 cereal pellets
- Movement behaviour of 1080 poisoned possums
- Effect of a thermogenic compound on bait acceptance and progression of 1080 poisoning in possums
- Welfare of wild deer - Where does 1080 poisoning sit on a relative scale of welfare impact?
- Improvements to modelling 1080 concentrations in surface waters - Adding in spatial sensitivity and soil-water transport mechanisms
- Effects of aerial 1080 operations on kea populations
- Effectiveness of deer repellent in preventing livestock from eating carrot and cereal possum baits
- Comparative bait preferences in captive Kea (*Nestor notabilis*)
- Attractiveness of RS5 & No.7 cereal baits, with and without deer repellent, to honey bees

Improved use and effectiveness of 1080

Projects to improve the effectiveness of 1080 that have been undertaken include:

- Eliminating TB from Molesworth Station
- No Possums, No TB
- Improving the effectiveness of ground-based control of difficult-to-access areas
- Better aerial baiting systems and strategies
- Effect of rat interference on possum kill during aerial 1080 poisoning

What has been implemented

Alternatives to 1080

MZP gel and C+C in bait stations have been implemented but both are of limited use. Over $1milion of research has provided little more than some marginal gains and there appears nothing of

significant value in the pipeline as an aerial alternative. Existing alternatives are only likely to have value as ground baits if a policy of containment were to be adopted. It is also worth pointing out that a ramped up policy of eradication raises the possibility of a reduction or elimination of 1080 use in 10-15 years time.

Improve the public "acceptability" of 1080
Nearly $2million has been spent on research to provide data on the environmental and public health effects of 1080, especially in aerial application. It seems strange that efforts have been made to reduce the animal welfare impacts of 1080 while implementing an extensive research programme into the use of Cholecalciferol and/or anti-coagulants that cause significantly greater harm to animal welfare.

Most of the data generated in these studies supports the previous information that 1080 is broken down relatively rapidly in the environment and does not accumulate in waterways, but this information is of little worth in changing public concern because many of those concerns are not evidence-related.

Some of this research has been effective in reducing by-catch from aerial 1080 but again most opponents of 1080 are unlikely to be swayed by this information.

Improved use and effectiveness of 1080
This area of research, building on the previous work to improve the efficiency and effectiveness of 1080 aerial control has continued to be one of the most successful areas of research undertaken. That it has become possible to greatly reduce the amount of toxin applied, whilst substantially increasing the number of possums killed is a major success for the TBFree programme. In spite of this success there appear to be still further opportunities to enhance this work. Just over $0.9million has been spent on this work

What is needed in the future?

There is a significant risk that much of the research, which relates to the on-going use of 1080 and the development of alternatives as a response to continuing public concern, is missing the point. As was clearly demonstrated by Green & Rohan (2012), the current approach to risk communication about the use of 1080 is well short of best practice. Generating yet more evidence to support the use of 1080 is neither unlikely to deliver any significant change in public attitudes, nor is it clear, given the outrage factors that drive opposition to 1080, that the aerial use of alternative toxins will be significantly more acceptable. Social science research to determine what would constitute a more publically acceptable approach to possum control, including the on-going use of 1080, should be a priority along with implementing risk communication best practice for the current control programmes. As Green and Rohan (2012) observe "Science is an important voice to be at the table, but is only one among several."

TBfree correctly identifies the possible loss of access to 1080 as one of the greatest threats to its goals, yet the approach to the threat is unnuanced. The problem is not a handful of extreme opponents but rather the large number of New Zealanders who do not support the current use of 1080 (Green & Rohan, 2012). That is where the threat to the programme lies. TBfree does not currently have sufficient social licence to be confident that the positive conclusions of the Parliamentary Commissioner for the Environment and leading scientists will continue to sway politicians in the long term. A policy of containment, under current knowledge, will be predicated on long-term 1080 use, and there is insufficient security around this at the moment.

Bait improvement may become more crucial as the programme proceeds, particularly if there is any threat to use of 1080. Bait fragmentation during operations can be a problem because it may result in sub-lethally poisoned possums likely to avoid bait in the future. While using appropriate bait densities largely overcomes this problem, control efficacy could be increased through development of bait types less prone to fragmentation, but still palatable to possums. Research and development work is in progress towards such bait improvements.

Recommendations

Research on alternative toxins can't be considered a high priority other than refining how some of the existing alternatives, such as sodium nitrite, could support existing treatments such as in specific localities were 1080 or cyanide cannot be used. Further work on developing alternatives to 1080 for aerial use should be predicated by social science to identify their relative acceptability

Undertake critical social science research on the risk communication issues that need to be addressed to ensure on-going use of 1080 with a 10-year horizon.

Continue to invest in research that will increase the efficiency and effectiveness of 1080 to control possums, including consideration of multi-target and biodiversity benefits.

New control tools, application, monitoring

Has the research to date delivered on expectations?

The set of projects in this category include:

- Replication of Project R-80660 "Best practice for monitoring low density possum populations"
- A field evaluation of a new ferret bait
- Updating the 2004 Ferret Control Manual
- Preventing weka exposure to Feratox® during possum control (Stage 2)
- Preventing weka exposure to Feratox during possum control (Stage 3).
- Feratox for ferrets
- Development of a cyanide bait for pigs
- Pen trial to compare the performance of the Excluder and modified Sentry bait stations when using Feratox for possum control
- Calibrating indices of possum abundance against absolute numbers
- Optimising trapping effort: how many traps and trap-nights to catch enough possums for control or surveillance?
- Use of an automated lure dispensing system to improve effectiveness of control tools
- Aerial infrared video detection of possums on farmland
- Extending existing DNA recovery protocols for WaxTags to Chew Cards and evaluating the potential of both devices as a monitoring tool for possums
- Studies into effectiveness of chemical lures

What has been implemented?

Approximately $0.8million has been spent on these studies. Not all have produced useful results, but amongst them a new C+C meat bait for controlling ferrets shows promise. The infrared detection of possums also has promise but the technology is not yet sufficiently miniaturised for practical use, though it can be used from a helicopter.

An effective bait station has been developed for the use of Feratox for possums, which substantially reduces collateral poisoning of weka.

Cost-effective trapping methodology for surveillance has been developed.

The population density monitoring studies confirmed that accurate assessment of low-density populations is poor, with none of the current tools, Residual Trap Catch Index, Chew Cards or Wax Tags providing a reliable predictive relationship. There was a high degree of variability in the relationships between indices and estimated density, and between the indices themselves.

What is needed in the future?

The value of more accurate tools for population density estimates for modelling and decision-making tools needs to be critically evaluated to inform further studies of density monitoring, an area which is of some importance.

While chemical lures have given disappointing results, the proposed studies into the effectiveness of acoustic lures (and repellents?) for possums appears to be worth conducting.

There are also some ecological questions that may require study to better refine the predictive models such as the effectiveness of pigs as a monitor of ferret TB.

Epidemiology, ecology and modelling

Has the research to date delivered on expectations?

The set of projects in this category include:

- Local elimination: Co-funded development of a new strategic approach to large-scale control of small mammal pests
- Determining the most likely cause of TB persistence in livestock in the Blythe Valley, North Canterbury
- Juvenile possum dispersal and implications for TB control
- Bovine TB in New Zealand
- Developing NDCM-usable software for estimating TB freedom
- Improving predictions and decisions with the Proof of Freedom utility.
- TB Eradication, Proof of Concept
- Extending and validating the Landcare Research TB possum model by considering possum aggregation.
- Eliminating TB from Molesworth Station
- Improved protection of Tb-containment areas: West Coast of the South Island as a case study
- Identification of risk factors in cattle herds at Karamea and their particular relationship to the outcomes of the possum control programme
- Fast tracking proof of TB freedom for North Canterbury
- Post-control possum aggregation in forest and near forest farmland.
- Publication of the conservation benefits of AHB vector control
- Identification of dairy herds at risk of TB recrudescence using social network analyses

What has been implemented?

This has been the most effective area of research over the period. Approximately $2million has been spent on these studies that have identified a number of key factors in the interactions between the different species infected with TB. This knowledge has led to effective spatial possum modelling and the development of the Proof of Freedom software tool, which is a key part of the operational decision-making process to withdraw from vector control and possum surveillance.

Probability of TB freedom is based on data modelling around wildlife surveillance. This has led to the 95% level for freedom and is likely a conservative level given some deficiencies in the inputs into the modelling. For example, inclusion of herd testing and slaughterhouse data would provide a better evidence framework. Theoretical work has been done on the cost and consequences of reducing the level to 80%.

What is needed in the future?

Modelling

There should be continuing development and refinement of the models to improve the employment of current diagnostic tests, particularly addressing the relative importance of bovine and wildlife sources of TB. This will help focus effort on locating and eliminating residual infection and characterising new outbreaks of TB.

Current work on the spatial model is mainly on inputs rather than on internal function. Low-density populations are not necessarily covered and the model is used mainly in the pre-eradication phase to predict likelihood of eradication and level of control necessary. A major assumption of the model is that carrying capacity and transmission rate are inversely related. Possum parameters are largely adequate, but TB parameters are more elusive. In this regard, we currently have a good understanding of TB dynamics in contiguous landscapes, but poor on discontinuous landscapes and low-density populations and this should be a focus over the next 5 years. It is critical that the current spatial model be sustained with the inclusion of demographic and behavioural aspects of possums in relation to low population densities. This would lead to better prediction.

There are other deficiencies such as decision theory, which would allow models to be better used as management rather than just scientific tools, and inclusion of very basic, but still lacking information, such as the frequency of possum/cattle TB transmission. Adding more data and information would provide a more robust basis for decisions on freedom and the establishment of the target probability for declaring success, which remains relatively arbitrary. Current practice does not objectively balance the costs of making an incorrect decision. For example, lowering levels to 80% in specific localities of low risk and low consequence should be investigated as an option within a framework of potential political and economic acceptability, building on theoretical work to date. A result that has different optimal thresholds for each location and situation could be a major improvement.

Testing, surveillance and herd management

There appears to be some inherent residual infection pools in herds not derived from recent possum transmission. This suggests that there should be more attention to individual animal movements, particularly with regard to intensifying dairying practises with larger numbers of movements. Current 3 year testing may be sufficient to detect and eliminate residual levels, but may be confounded by modern herd dynamics. The knowledge gained from social network analysis suggests a shift from blanket herd testing to targeted risk-based testing utilising the NAIT database and a tracing tool; the science component of this is in providing the framework for risk management.

In areas free of wildlife TB, current tools are likely to be effective, however, stricter policies to intensively manage infected herds will be necessary as the programmes moves into a next stage of management. As mentioned above, this would lead to a much greater focus on individual animals rather than herds. Electronic ID plus suitable tests should be able to clear the last few herds of residual infection. Improved TB risk profiling of individual herds, through the improved livestock movement data provided through NAIT, combined with the assessment of the land-based risks associated with TB from wildlife, and slaughterhouse surveillance data, should also allow the majority of low-risk closed herds to be managed under more simple quality assurance programmes. While most of the issues here are more of management than those requiring new science, there is a need for better surveillance technologies to generate faster and more comprehensive data on livestock TB risk.

In summary, there may still be the need to develop tools that will combine analysis of land-based risks associated with wildlife infection, movements of livestock, previous infection history, abattoir surveillance and previous TB testing to provide cost-effective individual herd level test policies that should improve farmer awareness of risky management behaviours within their herds.

With regard to residual infection in possums or other wildlife, there seems to be a need for more clarity around the relationship of detected infection in other wildlife such as ferrets, deer, and pigs, and the classification of infection in possums. A consideration of functional extinction might suggest that some areas are being controlled longer than necessary, and more data on this should provide cost savings.

Population data and surveillance

There is a deficiency in understanding of the relationship of population densities and kill data. This is likely a product of management practise, but has resulted in little empirical data on populations that can give an accurate estimate of control outcomes. Detection technologies are available and should be investigated. This is an issue that has become of increasing importance with the current stage of the programme and the upcoming decisions on containment/eradication.

Requirements for large-scale eradication will require more cost-effective possum control and surveillance of TB in wildlife, more cost effective diagnostics, and a better understanding of the duration of spillback risk, particularly from ferrets, the frequency and distance over which infected possums spread TB, and further refinement and empirical validation of possum-TB models.

Sensitivity analysis has identified ferret and pig transmission rates as having the most influence on persistence of TB. Ferrets are valuable and cost-effective sentinels for assessing freedom in possums. However, more research is needed to ascertain the number of years of active surveillance of ferrets without any detection of TB. Future work should focus on determining transmission rates to determine if multi-host dynamics could be jeopardising TB eradication programmes.

Management of aerial 1080 operations

Research on strip and cluster sowing methodology suggests that relative to broadcasting, bait sowing rates can be significantly reduced without loss of effectiveness, especially where possum density is relatively low. Use of these new sowing options could significantly reduce the amount of 1080 being applied to the environment. However, further work is still required to improve consistency of possum kill while reducing bait application rates and costs. This could be a priority for future research, particularly as low-density possum populations become the norm.

In summary, we largely agree with a summary from Anderson et al (2013) where reducing the time to eradication could be assisted by better assessment of TB incidence in possum populations using;

- new technologies to identify possum locations for specific targeted control e.g. aerial infrared technology;
- using new and future research findings on possum feeding behaviour in the design of lower cost aerial baiting operations;
- using sampling theory to determine the probability that TB has been eradicated from possums over large areas of extensive forest, where there are few sentinel species and where the cost of sampling possums themselves would other-wise be prohibitive.

For containment, we need science on determining levels, boundaries, surveillance outside containment areas and surveillance intensity. For eradication, we need the science to provide the means to ramp up cost-effectiveness of eradication, looking at areas where efficiencies can be made, such as focusing on risk-based testing

Recommendations

Models for operational forecasting should be improved with new inputs on possum dynamics and behaviours, decision theory, improved information on TB incidence, TB transmission rates, etc, to allow more realistic prediction of freedom to be made and to allow greater flexibility in use as management tools.

Tools should be developed utilising NAIT-derived data on individual animals for tracing and risk-based testing policies.

There should be continued investment in research that will increase the efficiency and effectiveness of 1080 to control possums

Biological control

Biological control was a national strategy in 1989-92. It was seen as a viable long-term option and was largely funded by the Foundation for Research, Science and Technology or equivalent government funding. TBfree (then the Animal Health Board) concentrated on more short and medium term research such as toxins, poisons, epidemiology, etc. Biocontrol funding stopped in 2009 and has not been renewed. General results showed that while an 80% reduction in reproductive viability was achievable, the genetic modification technology needed for this was not acceptable or sustainable. In this regard, the research was really more a proof-of-concept project. A conclusion is that biocontrol in terms of fertility control currently is not really an option for TB management, but potentially could be a longer term option for biodiversity imperatives.

Recommendations

There should be a continuing watch on international research for new advances in biocontrol of vector species but no current investment.
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General comments on the research portfolio

Management

In general, the operations comprising priority setting, requests for proposals, evaluation, funding and monitoring and review are robust. TBfree's Technical Advisory Group (TAG) plays a critical role in this area, so would benefit from a slightly different membership balance. The TAG needs more independent members with scientific expertise, to avoid conflicts and capture by the relatively small community of interested parties. The TAG operates within its own cycle of priority setting, proposal evaluation and review, and would benefit from more external science input into these processes. This would ensure more independence in advice, and possibly greater opportunity for new ideas and approaches to be considered. The TAG currently has no particular mechanism for capturing broader new ideas.

Leverage

There is greater opportunity to leverage research through negotiation with research providers, such as Crown Research Institutes. This is increasingly important with regard to maintaining capability and expertise in genomics, vaccine development and modelling. There is vulnerability with the existing MBIE programme being mapped into the Biological Heritage National Science Challenge, where decisions on redirecting the funding may occur, and with existing support from AgResearch core funding. This highlights the need for leveraged partnerships with research providers and funders in critical areas, spreading risk and allowing more focussed prioritisation of TBFree spend.

Capability and expertise

There is considerable risk of the loss of expert capability in some areas. CRIs and Universities have their own imperatives in regard to capability development and maintenance, heavily driven by financial issues. There is no guarantee that in the absence of strong TBfree support, they will maintain specific staff, capability or facilities. TBfree therefore needs to have some stance or plan on identifying critical capability and on the potential for loss. There is an associated need to nurture science and technical staff who may be critical for continuing expert input and future proofing.

Publication

There is a slight tension between scientists and TBfree regarding publication. Publication of research as papers in peer reviewed journals is not just a matter of ensuring that this can contribute to personnel career development, although TBfree should be aware of the dangers of loss of critical expertise (see above). Publication also provides a measure of independent quality control, which should be of interest to TBfree in ensuring that the contracted science is robust and of appropriate quality. Publication also provides an international profile, stimulating associated science interactions and dialogue, which can only be of advantage to the NZ programme. Publication of research should be an integral part of the contracting of research, and there should not be the need for separate funding. There should be an expectation that scientists will write up research, with the usual provisos of confidentiality and commercial sensitivity where appropriate.

Recommendations

An agile, more-focussed research programme must be retained, with a more integrated programme developed comprising fewer individual projects. In particular:

- Greater publication of research, with wider accessibility of results, should be encouraged and built into programme funding;
- The TAG should have a greater emphasis on more independent external science expertise; and
- Greater leverage of research with NZ science funders and providers should be pursued to develop a more comprehensive, less vulnerable, partnership-based research portfolio.

Personnel and organisations consulted for the review:

Lindsay Burton, Fonterra
Nita Harding, Dairy NZ
Chris Houston, Beef & Lamb
Terry Ryan, Consultant
Dan Coup, Deer NZ
Lesley Collins, UCOL, Palmerston North
Landcare Research: Bruce Warburton, Mandy Barron, Dean Anderson, Penny Fisher, Dave Morgan, Janine Duckworth, Phil Cowan, Graham Nugent
Massey University: Tim Carpenter, Arata
AgResearch: Marion Price-Carter, Bryce Buddle
Polybatics: Tracy Thompson

Literature and written material:

AHB research reports 2008-09; 2009-10; 2010-11; 2011-12; 2012-13
NZVJ Papers 1-9
Spreadsheets and summaries provided by Dr Paul Livingstone
Additional unpublished and published material provided by Dr Graham Nugent, Dr Marion Price-Carter

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