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White Paper

A framework for the future: Investing in animal biosecurity research

Axel Heiser and John Kean
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Contents

Executive Summary

This paper is designed to address a particular need identified in the AgResearch Science Plan for "developing strategies and tools to prevent incursions and manage pests and diseases" (under Impact Measure B).

In the context of livestock, animal biosecurity refers to the measures taken to keep pathogens that are new to Aotearoa New Zealand from infecting animals. Animal biosecurity also needs to address the risks from zoonotic diseases, i.e., diseases that can spread to humans, and from infectious diseases that might endanger Aotearoa New Zealand's wildlife.

This paper articulates a vision for "a world-class animal biosecurity system for Aotearoa New Zealand, in which all stakeholders are aware of the high value of biosecurity to the health of the national herd/flock and our wildlife, to our ability to access international markets, and to the economy as a whole". It summarises activities and lessons learned from the Better Border Biosecurity (B3) initiative and the Mycoplasma bovis incursion. Stakeholder workshops were held to review and prioritise animal biosecurity research, focusing on four areas: risk analysis, surveillance and data management, diagnostics, and social science and economics (Figure 1).

It recommends four "Theme Champions" be nominated and funded for three years to work with stakeholders to further develop and execute AgResearch's animal biosecurity strategy, including identifying at least one case study (e.g., zoonotic tick-borne diseases) with which to develop an end-to-end collaborative research agenda and seek external funding for it. The aim is for a gradual, voluntary evolution towards a more co-ordinated and strategic approach to animal biosecurity research, resulting in enough critical mass and momentum to ensure that critical animal biosecurity research capability is supported into the future.

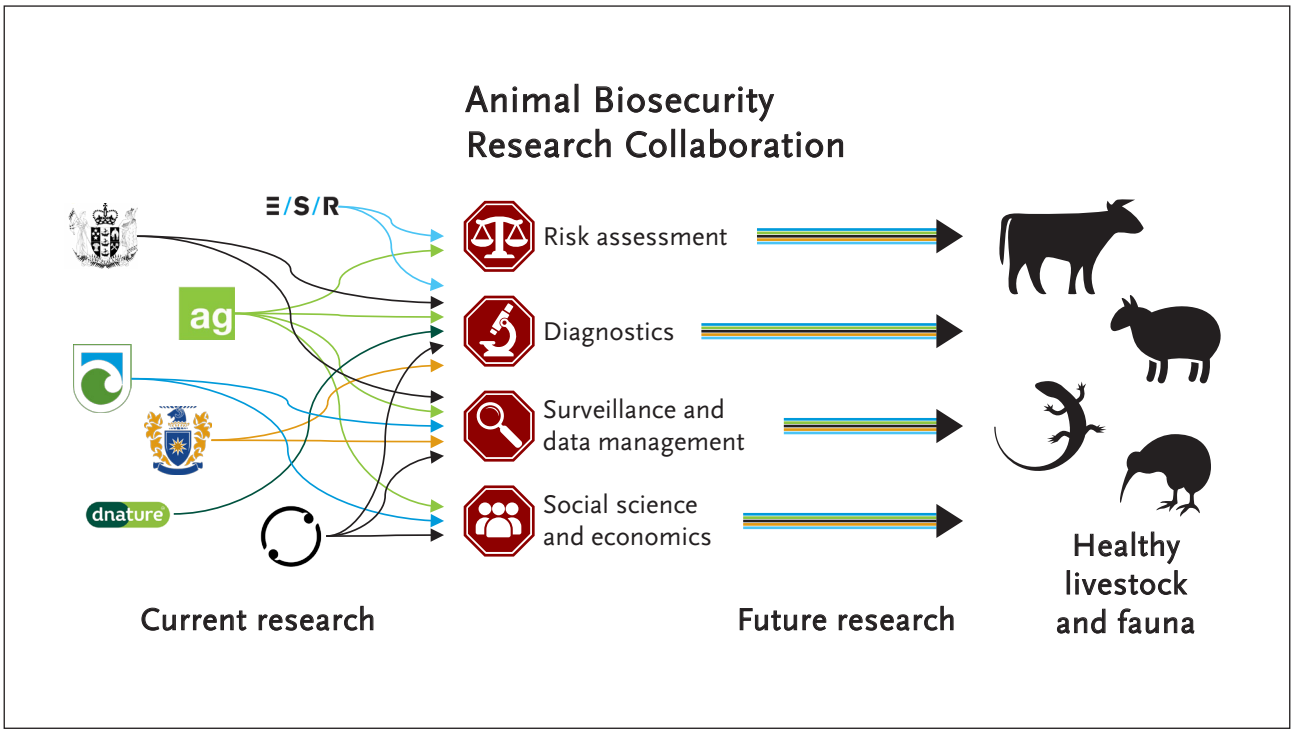

Figure 1: Current animal biosecurity research is fragmented and reactive. Future research could be more collaborative and structured around four strategic themes.

Introduction and background

Why a foresight paper

This paper is designed to address a particular need identified in the AgResearch Science Plan1 for "developing strategies and tools to prevent incursions and manage pests and diseases" (under Impact Measure B). Every year since the surveys began 12 years ago KPMG surveys have identified the need for Aotearoa New Zealand to have a "world-class biosecurity system" as the top priority for agri-businesses[2]. Te Ara Paerangi Future Pathways Green Paper[3] refers to biosecurity as one example for a priority research area the government might proactively invest in.

In the context of livestock, animal biosecurity refers to the measures taken to keep pathogens from infecting populations, herds or groups of animals where they do not yet exist. Animal biosecurity also needs to address the risks from zoonotic diseases, diseases that can spread to humans such as via direct contact or tick bites, and from emerging diseases that might endanger Aotearoa New Zealand's wildlife. Unlike the rest of New Zealand's primary production systems (for example horticulture and forestry), pastoral systems consist of several trophic levels (soil + pasture + livestock). This makes pastoral systems uniquely vulnerable to a wider range of invasive pests, weeds and pathogens of both animals and plants. Animal biosecurity takes into account the epidemiological triad for disease occurrence: the individual host, the disease and the environment in contributing to disease susceptibility.

Biosecurity research strategies have been developed, or are under development, for: pasture plants (Better Border Biosecurity, B3), weeds (within AgResearch led by Graeme Bourdôt), and biocontrol (within AgResearch led by Sofia Orre-Gordon). However, no such strategy currently exists for animal biosecurity. AgResearch currently engages in animal biosecurity research, but most is in response to immediate operational needs (e.g. Mycobacterium bovis eradication, Mycoplasma bovis eradication, COVID-19 response) rather than as a co-ordinated, forward-thinking strategy. In addition, to successfully meet the challenge we need to integrate a wider range of skills across AgResearch and beyond including diagnostics, epidemiology, risk analysis, pathology, automation technologies, social science, farm systems and rangahau Māori.

Animal biosecurity efforts in Aotearoa New Zealand are led by Ministry for Primary Industries (MPI) but we believe a broader research strategy is needed. Development of such a strategy is the first necessary step towards implementing and resourcing a comprehensive approach to protecting Aotearoa New Zealand's valued animals from unwanted pests and pathogens. This initial step has been largely within AgResearch, but we have consulted with key external stakeholders in MPI, Department of Conservation (DOC), regional councils and the livestock industries, as well as other research providers.

Objective

This paper reviews the current animal biosecurity research landscape (including border protection, surveillance, incursion response, containment and eradication, and pest management) to identify knowledge and technology gaps, and prioritise research needs to protect and preserve valued animals in Aotearoa New Zealand from exotic pests and pathogens.

The intent is that this paper will supplement AgResearch's Science Plan as a guide to prioritising future research on animal biosecurity, specifically "developing strategies and tools to prevent incursions and manage pests and diseases".

Impact

This paper will bring together regulators, industry and researchers into a conversation about research needs for animal biosecurity. It will guide future investment (and funding applications) in animal biosecurity.

Better Border Biosecurity (B3)

The evolution of a co-ordinated approach to plant biosecurity research in New Zealand provides a potential model for animal biosecurity research. In the late 1990s and early 2000s a series of highly visible and costly plant pest incursions raised the profile of plant biosecurity. These included large-scale eradications of Mediterranean fruit fly, painted apple moth, fall webworm, Hokkaido gypsy moth and red imported fire ant, mostly in urban areas. The co-operative, cross-disciplinary, technical research required to support these responses led to the recognition of plant biosecurity science as a distinct discipline and, in 2003, the funding of a multi-agency research programme called Improved Biosecurity. Two years later, this grew to become Better Border Biosecurity (nicknamed "B3", https://b3nz.org.nz) which is now one of Aotearoa New Zealand's largest and longest-running research programmes.

A new co-ordinated approach to animal biosecurity might benefit from some of the lessons learned by B3 over its evolution. These include

- A well-defined scope to ensure clarity of purpose.
- Co-ordination across diverse research providers to give a single point of contact for all plant biosecurity research (within the well-defined scope).
- A collaboration council including an independent chair, an independent Māori representative, and high-level representatives from each of the research providers (Plant and Food Research, AgResearch, Scion, Manaaki Whenua Landcare Research and

Lincoln University) and industry stakeholders (MPI, DOC, EPA, Te Ara Pūtaiao, Forest Owners Association, Horticulture New Zealand, Federated Farmers).

- Co-ordination with international biosecurity research groups, including CEBRA, PBRI, USDA and Euphresco.
- An independent science advisory group.
- Multiple lower-level stakeholder representatives to promote inclusion and avoid bottlenecks.
- Research organised into themes that map to stakeholders' organisational structures: risk analysis for intentional introductions (EPA focus); risk analysis for unintentional introductions (MPI focus); pathway risk management; diagnostics; surveillance; eradication and response. This helps to access stakeholder expertise, data and to ensure uptake of research-based solutions.
- Ability to quickly pivot research to address new incursions.
- Stated priorities of leadership, performance, uptake, capability development and co-investment in research.
- A recent shift to adopt a more Treaty-informed bicultural approach.

Mycoplasma bovis response

In July 2017, Mycoplasma bovis (M. bovis) was discovered in cattle on a South Island dairy farm. On 28 May 2018, the New Zealand government, along with the dairy and beef industries, made the decision to eradicate M. bovis through a national response led by MPI. Urgent, early science needs were addressed by the operations response team, mainly delivered by Animal Health Laboratories (AHL; Wallaceville, Wellington), Aotearoa New Zealand's national veterinary laboratory. The government announced a $30 million investment over two years for science to support the eradication efforts. The M. bovis Strategic Science Advisory Group (SSAG) was established in July 2018 to support prioritisation of science and provide high-level recommendations to the M. bovis Governance Board.

In October 2018, the M. bovis science plan was released, identifying the highest-priority science needed to eradicate the disease from Aotearoa New Zealand. It was developed with input from local and international experts from science, veterinary and educational organisations, industry and government agencies.

Research is being carried out across seven specific areas, five of which focus on gaining information and learning to support M. bovis eradication efforts. They are:

1. Epidemiology
2. Diagnostics
3. Direct impacts of the disease
4. Entry pathways
5. Behaviour drivers and incentives.

The programme has also commissioned research on the social and economic impacts associated with the eradication to understand these impacts at farm, community and national level.

In July 2021, the Report of the Independent Review into the Mycoplasma bovis Programme4 made recommendations aimed at embedding changes that will result in a stronger biosecurity system capable of dealing with animal disease incursions. They include developing independent science capability to identify priorities aimed at accelerating the eradication of the animal disease and to develop a science plan to guide research and funding decisions.

One Biosecurity

The One Biosecurity concept5 has developed recently from a recognition that animal, human, plant and environmental biosecurity tend to be researched and managed separately despite considerable overlaps and interconnectedness. It builds on the One Health movement that brings together human and animal health research to capitalise on their strengths and address complex problems like zoonoses. In a similar way, the One Biosecurity concept aims to break down the barriers between different sectors researching and managing invasions across international borders so they can more effectively address major sociological and environmental challenges to biosecurity, including climate change, urbanisation, agricultural intensification, human global mobility, loss of technical capability, and public resistance to pesticides and vaccines.

One Biosecurity aims to address and bolster the limited science connections between human, animal, plant and environmental health, at global, national and local scales (Figure 2). Though new the concept is building some momentum with sessions at conferences and the establishment of the Centre for One Biosecurity, Research, Analysis and Synthesis (COBRAS) at Lincoln University.

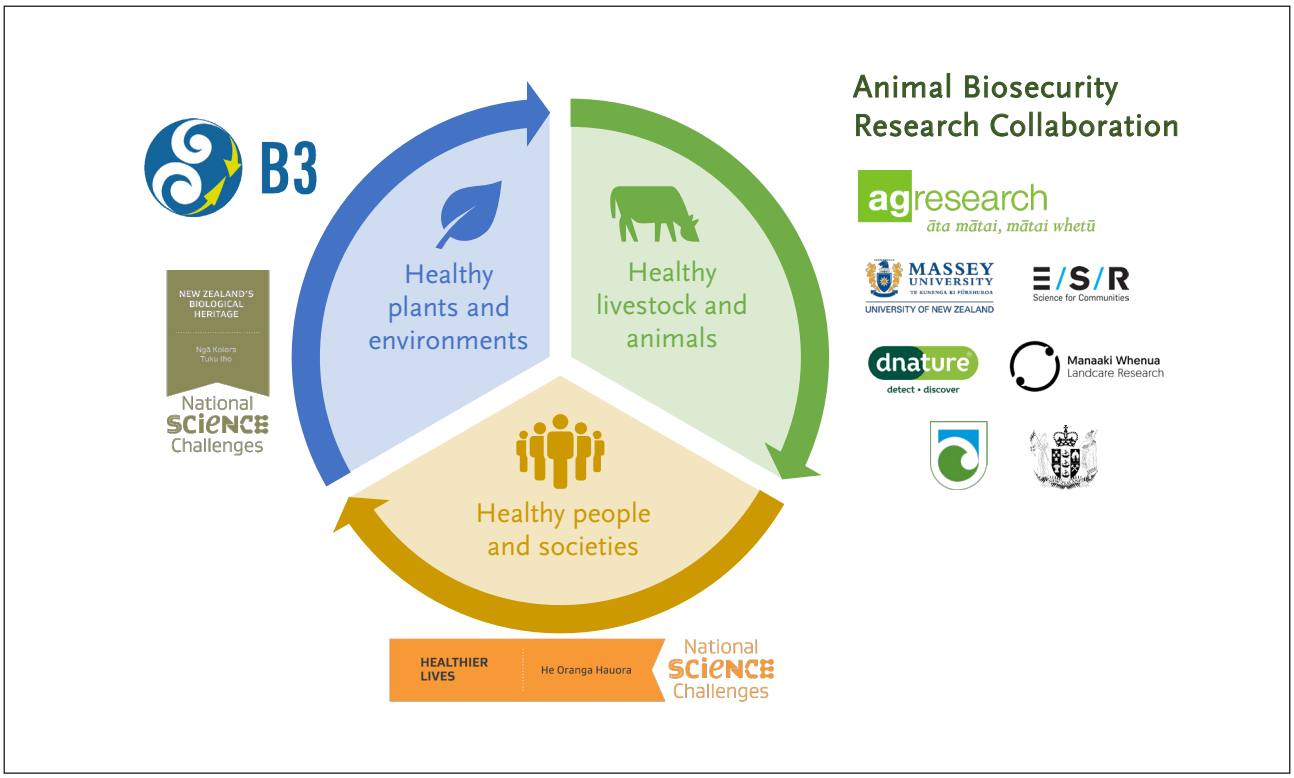

Figure 2: The One Biosecurity concept, analogous to One Health.

Problem statement

While research towards plant border biosecurity is well coordinated through B3, animal biosecurity research remains fragmented, with limited interactions across research providers, no consistent stakeholder connections and little strategic vision. A more co-ordinated approach is needed to enable research to address multiple global changes threatening animal biosecurity, including climate change, pandemic zoonoses, agricultural intensification, drug resistance and an increasing public voice in policy.

This paper aims to identify key issues in animal biosecurity and suggest a way to transform animal biosecurity research co-ordination and investment to address current and future challenges.

Strategy foundations

Vision

A world-class animal biosecurity system for Aotearoa New Zealand so all stakeholders are aware of the high value of biosecurity to the health of the national herd/flock, to our wildlife, our ability to access international markets and to the economy.

Goals

- Minimise the entry and establishment of unwanted organisms impacting the health of Aotearoa New Zealand's valued livestock and fauna.
- Reduce the prevalence of endemic disease, and improve the health and welfare of the national herd and flock.
- Protect biodiversity and the welfare of our environment.
- Improve collection, use, dissemination and communication of information on biosecurity.
- Reduce the use of antimicrobials and antiparasitic medicines.
- Improve food safety.
- Improve farm productivity, efficiency, and sustainability.
- Underpin investor confidence for sector growth and innovation.
- Support New Zealand's efforts to expand access to international markets for animal-based exports.

To achieve these goals:

- Engage in and maintain partnership with stakeholders, including mana whenua.
- Co-ordinate research to identify needs.

- Identify and advance promising research discoveries and technologies relevant to animal biosecurity.
- Promote the maintenance and development of relevant capability.
- Seek sustainable R&D investment.
- Educate undergraduate and graduate students, fellows and residents about the fundamental issues in animal biosecurity, spanning medicine, biology, public health, public policy, bioengineering, computer science, business, law and other fields of study.

Scope

In scope: research on high impact, harmful organisms impacting animal health in productive and natural terrestrial systems that delivers improvements to pre-border, at-border, immediate post-border and on farm biosecurity.

Out of scope: research and development of diagnosis, prevention or treatment of endemic infectious animal diseases.

Animal biosecurity challenges

Biosecurity systems are complex, reflecting the diversity of potentially damaging and damaged organisms (Figure 3). However, at a high level, border biosecurity systems simply aim to identify and exclude unwanted exotic organisms by disrupting their pathways of entry, establishment, spread and impact. To do so, biosecurity agencies may implement a range of tools.

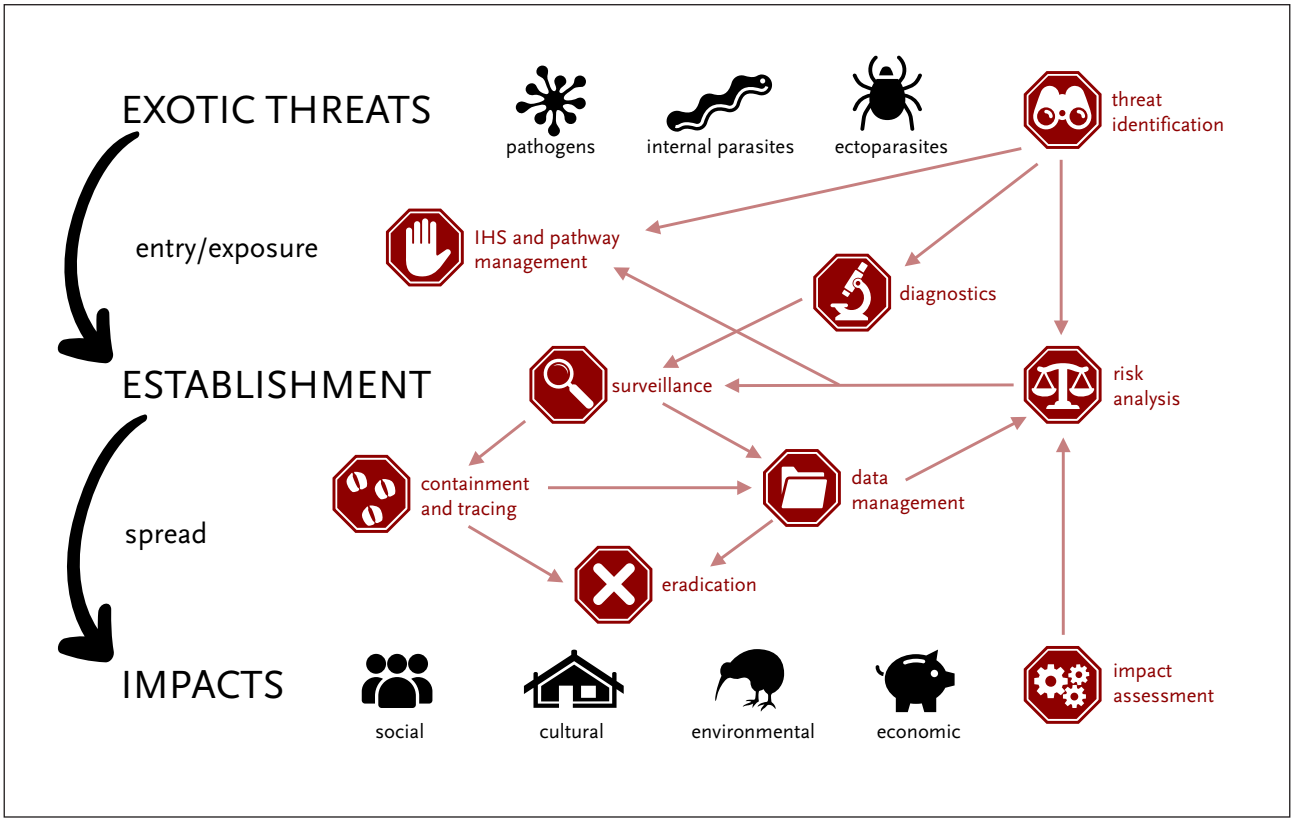

Figure 3: Areas of animal biosecurity research.

Risk analysis includes identification of threat organisms, assessment of their likelihood of entry and establishment, and estimation of their potential impacts on a range of social, cultural, environmental and economic values. This informs a range of different responses, such as targeting Import Health Standards and import pathway hygiene, and determining key targets for surveillance.

Surveillance aims to detect harmful exotic organisms sufficiently early that an effective response can be mounted to contain and, ultimately, eradicate them. This typically involves management and interpretation of substantial datasets. Surveillance data can also be used to provide mathematical proof that an unwanted organism is not present, which may be necessary to access some export markets.

Surveillance and response relies on accurate *diagnostics* to avoid false positive and false negative reports. The critical and often challenging nature of animal health diagnostics has made this a major component of past animal biosecurity research.

Effective application of a systems approach to biosecurity risk management relies on effective understanding of the *social and economic drivers* that underpin and affect each component in the system.

In 2021 we held two stakeholder workshops to review and prioritise animal biosecurity research. To facilitate conversation and synthesis, we focused on the four areas discussed above: risk analysis, surveillance and data management, diagnostics, and social science and economics. One workshop brought together researchers working in animal biosecurity and related disciplines to summarise current research. The other workshop assembled a wide range of stakeholders and end-users to prioritise future research needs. Potential research gaps were identified and discussed in small groups. Eventually the issues/research gaps were prioritised by all workshop participants using a voting system.

Current research, needs and gaps

Risk assessment

Current risk assessment research falls into four groups. First are two projects focusing on improved biosecurity risk assessment methods in general. One, funded by B3, DairyNZ and others, is developing an automated approach to rapid screening of long lists of potential biosecurity hazards to identify the highest priority organisms. The second focuses on broadening the range of values considered in biosecurity risk analysis to include stronger representation of socio-cultural, te ao Māori and environmental values alongside economics. These projects are largely focused on plant pests and pathogens but could also be applied to animal threats.

The second group of projects relate to climate change impacts on biosecurity threats, either through impacts on the organisms directly, or through changes in trade and other factors impacting their likelihood of introduction and establishment. Third are projects focusing on pathways of entry, and fourth are projects focusing on specific high-risk taxa, such as foot and mouth disease and African swine fever.

In general, current biosecurity risk research does not address the biggest priorities identified by industry end-users, leaving some significant gaps to guide future research (Table 1).

Table 1: Key risk assessment research needs identified by stakeholders

Highest priority research needs identified by stakeholders	Current research contributing to needs, from researchers	Research gaps remaining
Assessing the presence of particular organisms in Aotearoa New Zealand	Proof of freedom (absence) methods applied to bovine tuberculosis, plant pests	General methods for assessing likelihood of presence (rather than absence) given past surveillance effort. Could be trait based but needs to be rapid and robust.
Methods to assess risks to native biota	Some work on assessing risks to native flora (e.g. B3) and ecosystem function (e.g. NZBH)	Animal-specific research, potentially beginning with a review of what is currently known about impacts of exotic organisms on native fauna.
Effective communication of biosecurity risks	Sustainable Seas and NZBH projects focusing on risk communication with mana whenua. UCBI masters project on biosecurity risk communication with urban public. TMBC and B3 experience with port communities.	Understanding risk communication with other audiences

Surveillance and data management

Current research on animal biosecurity surveillance seems to be very focused on particular taxa, often directly related to animal health issues already present in New Zealand. Since much animal biosecurity surveillance relies on clinical tests for pathogens or disease, much of the emphasis in animal biosecurity has been on diagnostics, and surveillance systems rely heavily on existing veterinary health services. There has been relatively little research on how to improve and optimise animal biosecurity surveillance *systems*, as opposed to diagnostic methods, and relatively little exploration of surveillance tools that do not rely on direct animal testing (Table 2).

Diagnostics

The majority of current work in animal biosecurity is on improving, developing and quantifying diagnostic tests (Appendix B: Research workshop). However, industry stakeholders identified a key underpinning need is for guidance on the best possible tests for given target organisms (Appendix C: Industry workshop). This relates closely to a key need, mentioned by researchers, for standardised methods for performing diagnostic tests and measuring the sensitivity and specificity of operational tests so that their results can be interpreted within the context of surveillance systems. There seems to be a need for a comprehensive database of animal health diagnostic tests, that can be maintained and updated by diverse researchers in the field. Such a database would facilitate rapid response in a biosecurity incursion and help to identify critical gaps in knowledge or diagnostic capability.

Social science and economics

Current social science research for biosecurity seems concentrated in B3 and in the Aotearoa New Zealand's Biological Heritage National Science Challenge (NZBH). However, this research has focused more on plant biosecurity than animal issues. Surprising recent research in Tauranga suggests that most people have not understood the COVID-19 pandemic as a biosecurity issue at all, despite Aotearoa New Zealand's focus on border security, diagnostic tests and vaccination – all key concepts in animal biosecurity. This aligns with the high priority research needs identified by industry stakeholders, which largely concern the need to communicate biosecurity information, underpinned by sound analysis, to farmers (Table 3).

The workshops did not cover research gaps regarding non-economic consequences (impacts on socio-cultural, te ao Māori and environmental values) but current work in NZBH focuses on these values.

Table 2: Key surveillance and data management research needs identified by stakeholders

Highest priority research needs identified by stakeholders	Current research contributing to needs, from researchers	Research gaps remaining
New diagnostic technologies amenable to use in large-scale surveillance systems (e.g. pen-side tests)	New diagnostic tools being developed (see next section)	How best to organise diagnostic tools into surveillance systems, and how to collect, manage and interrogate the data they generate. New approaches may be especially important for surveillance in native fauna.
Surveillance for non-OIE-listed diseases	New diagnostic tools being developed (see next section)	See previous item
Traceability of samples, beehives, livestock		More an IT problem than a research one
Methods for mapping backyard pork, poultry, etc	Remote sensing of plant hosts (AgR, B3) could be adapted to detect backyard livestock	
Antimicrobial resistance surveillance methods		

Table 3: Key social science and economics research needs identified by stakeholders

Highest priority research needs identified by stakeholders	Current research contributing to needs, from researchers	Research gaps remaining
Understanding the economics of the impacts of poor biosecurity	CEBRA is currently valuing Aotearoa New Zealand's biosecurity system as a whole. More specific analyses have been done to estimate costs of incursions of particular taxa.	Current analyses tend to focus on direct economic impacts. More work is needed to understand indirect impacts, and on socio-cultural, te ao Māori and environmental impacts of animal biosecurity incursions.
Producers understanding the value proposition (barriers/carrots) of improved on-farm biosecurity. Why should a farmer bother implementing biosecurity measures, e.g. a footbath?		Demonstration of the value of farm-level biosecurity practices. Social science to ensure that the key messages are communicated effectively to farmers to stimulate practice change.
Who do farmers listen to? Who can change their attitudes and behaviours?	B3 research around the Port of Tauranga has looked at biosecurity behaviours in port workers, transitional facility staff, school children, the general urban public, and various horticultural industries, but not farmers	Network analysis of the flow of impactful biosecurity information

Other issues

There is a considerable range of, mostly, small research projects currently addressing animal health risks to wildlife, or wildlife as vectors of animal disease (Appendix B: Research workshop). A key gap in this area seems to be better understanding of the mechanisms of exchange of pathogens between livestock and wildlife, and between different species of wildlife. This relates to a need for better identification and quantification of pathways of spread within Aotearoa New Zealand, including across farm boundaries.

There seems to be a general need to make better use of the members of the public as sources of animal biosecurity intelligence.

The workshops also identified a concern about declining capability in certain key areas, notably morphological diagnostics. However, there are new developments recognising biosecurity as a discipline in its own right, such as the Animal Biosecurity paper included in Massey's new Bachelor of Animal Science degree.

Recommendations: Unlocking Aotearoa New Zealand's transformational biosecurity trajectory

For the last 20 years there has been co-ordination of plant biosecurity research B3 but none in animal biosecurity. This provides an opportunity to bring together experts to create an end-to-end research agenda for MPI and stakeholders around a few key case study animal biosecurity threats.

There is a need to develop MPI champions early and involve them in design of the programme. It is recommended to approach Chief Biosecurity Officer (Stu Hutchings), Chief Veterinary Officer (Mary Van Andel) and Chief Science Advisor (John Roche).

It is also recommended to nominate and fund "Theme Champions" for 3 years (Figure 4). These champions would be expected to:

- Identify and engage with appropriate stakeholder representatives.
- Create and maintain a theme strategy, reviewed and refreshed annually.
- Co-ordinate across research providers and stakeholders to encourage new bids focused on the key needs identified for their theme.

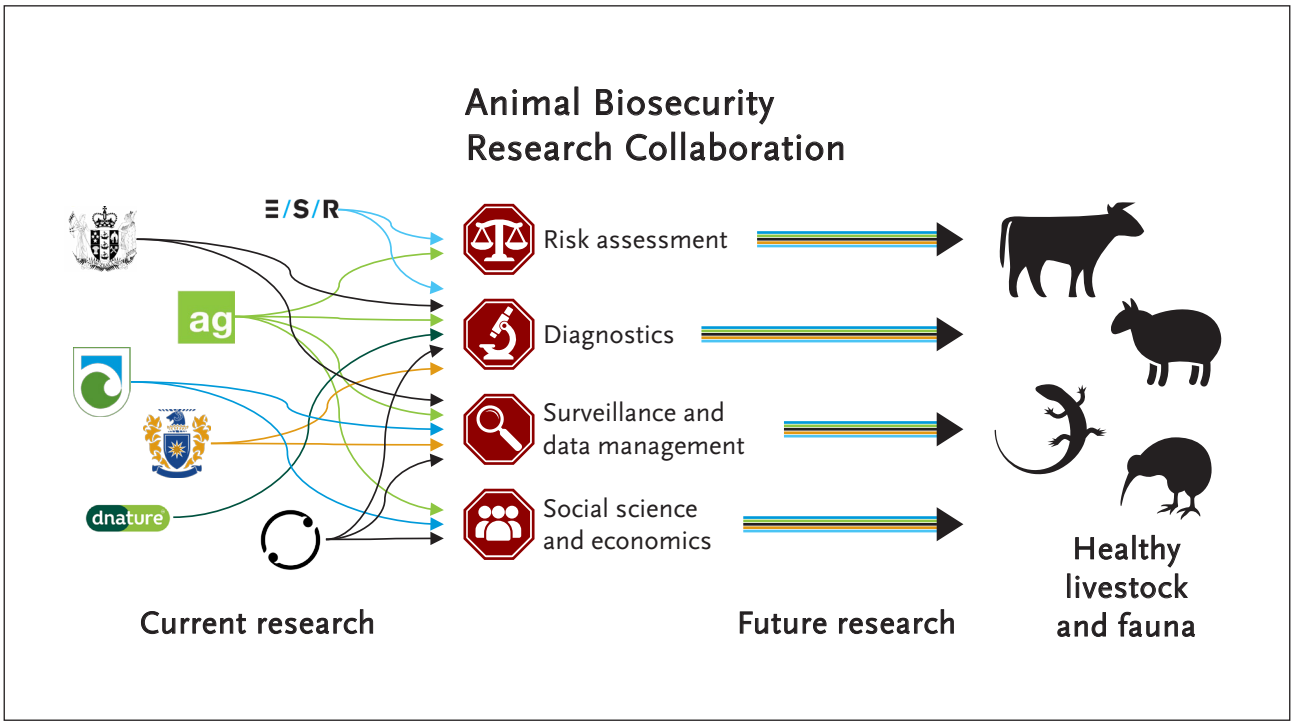

Figure 1: Four themes for future research

- Organise regular virtual seminars, where researchers can present their work to others working in the theme, champions from other themes and interested stakeholders (suggest 30 mins every 2 months).
- Support the One Biosecurity concept by interaction with COBRAS, B3 and others.
- Identify opportunities for capability development relevant to their theme.

The Theme Champions should work together to identify one or more case studies with which to develop an end-to-end collaborative research agenda, from risk assessment to pathways, diagnostics, surveillance, response, social science, and economics. During the research workshop zoonotic tick-borne diseases were identified as a potential first case study.

The concept is for a gradual, voluntary evolution towards a more coordinated and strategic approach to animal biosecurity research. The aim should be to attain enough critical mass and momentum to ensure that animal biosecurity remains a supported area of research into the future, maintaining and broadening the capabilities needed to respond to future threats and incursions like that of Mycoplasma bovis.

Acknowledgements

We are very grateful to all the researchers and stakeholders who took part in the two workshops or were unable to attend but spoke to us separately. This paper arises partly from ongoing conversations over many years, and we acknowledge our many colleagues who have participated in those. We particularly thank Chris Morley for ably facilitating the two workshops.

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Appendix A: Acronyms

Acronym	Organisation	Description	Website
B3	Better Border Biosecurity	A multi-partner, cooperative science collaboration that researches ways to reduce the entry and establishment of new plant pests and diseases in New Zealand	https://www.b3nz.org.nz
CEBRA	Australian Centre of Excellence for Biosecurity Risk Analysis,	Based at the University of Melbourne	https://cebra.unimelb.edu.au
COBRAS	Centre for One Biosecurity, Research, Analysis, and Synthesis	Based at Lincoln University	
DOC	Department of Conservation		https://www.doc.govt.nz
EPA	Environmental Protection Authority	A government body that administers the Hazardous Substances and New Organisms Act	https://www.epa.govt.nz
IHS	Import Health Standards	Documents issued under section 24A of the Biosecurity Act 1993 stating requirements that must be met before risk goods can be imported into New Zealand	https://www.mpi.govt.nz/legal/compliance-requirements/ihs-import-health-standards
MPI	Ministry for Primary Industries		https://www.mpi.govt.nz
PBRI	Australian Plant Biosecurity Research Initiative		https://www.pbri.com.au
SLMACC	Sustainable Land Management and Climate Change fund	Administered by MPI, helps the agriculture and forestry sectors with challenges arising from climate change	https://www.mpi.govt.nz/funding-rural-support/farming-funds-and-programmes/slmacc
USDA	United States Department of Agriculture		https://www.usda.gov

Appendix B: Research Workshop

Research Category	Research Topic	Key person or institution
Current and recent research that may be relevant to animal biosecurity risk analysis		
General risk assessment tools	DEBRiEF risk evaluation framework (B3, DairyNZ, EpiInteractive)	Craig Phillips (AgR)
	He Tangata, He Taiao, He Ōhanga : a values-based biosecurity risk assessment framework for Aotearoa (NZBH)	John Kean (AgR), Christine Reed (Pukaha)
Climate change impacts	Global change and NZ biosecurity (B3)	Nicolas Meurisse (Scion)
	Climate change: trade and biosecurity (SLMACC)	Nicolas Meurisse (Scion)
	Increased risk due to climate change e.g. tick distributions, parasites	David Scobie (AgR)
	Impact of climate change on diseases	Emilie Vallee (Massey)
	Modelling future disease establishment and spread capability	Mallory Ross (AgR)
Pathway specific research	Developing and testing scenarios that threaten NZ's biosecurity (e.g. social unrest in Vanuatu results in increased import risks from there)	MPI Intelligence team
	Food-borne disease risks e.g. rat lungworm disease	Chris Neibuhr (MWLR)
	Review of Import Health Standards	MPI
Taxon specific research	Foot and Mouth Disease: learning from the Asian distribution	Naomi Cogger (Massey), MPI
	South American kiwifruit fungus – simbulata? – animal vectored?	PFR, DNAture
	African swine fever modelling capability report and data	MPI (2020-2021)
Current and recent research that may be relevant to surveillance and data management		
Surveillance tools	New parasite presence detection tools (nemobiome)	Tania Waghorn (AgR)
	FMD subclinical disease (PhD)	Kelly Buckle (MPI), Wendy Row (Massey)
	COVID-19 testing in waterways	ESR
	New pathways for leptospirosis and isolation of new strain	J. Benschop (Massey)
	Campylobacter source attribution	MEpiLab

Research Category	Research Topic	Key person or institution
Surveillance systems	Proof of freedom for Tb and other diseases	Dean Anderson (MWLR), OSPRI
	Current surveillance for ticks and pathogen distributions	AgR
	Johne's disease research consortium (may be a zoonotic? Crohns link? not notifiable but trade implications)	
	Massey passive surveillance and diagnostics	
	Pacific partnership coordination project	Andy McFadden (MFAT)
	MPI bee pathogen programme, 5 year surveillance programme (operational rather than research?)	DNAture
Data Management	Antimicrobial resistance (improving use recording systems)	AgR, Massey
	Digital technologies and data management (complex legal requirements)	AgR, OSPRI
Current and recent research that may be relevant to animal biosecurity diagnositics		
New Tools	CRISPR/Cas-based tools for strain-specific diagnostics	Sandeep Gupta (AgR), NZCFPN
	MicroRNA and non-coding RNA-based diagnostics for Johne's	Sandeep Gupta (AgR)
	Non-coding RNA (except microRNA) diagnostics	
	Exosomes as a source of biomarkers for diagnostic test development	Mallory Ross (AgR)
	Point-of-care diagnostic methods development	Sandeep Gupta (AgR), DRINZ, MFAT
	Multiplex – the One Test to Rule Then All	Natalie Parlane (AgR)
	Rapid evaporative ionising mass spectrophotometry	Alistair Ross (AgR)
	Image-recognition parasite egg detection in faecal samples (e.g., Parasight, Sediview)	Tania Waghorn (AgR)
Mycoplasma Bovis	PICTOR Mycoplasma bovis ELISA	Axel Heiser (AgR)
	Exosomes for M. bovis diagnostics	MPI, AgR, Gribbles
	M. bovis reference libraries and archive analysis	Fernanda Castillo Alcala (organisation?)

Research Category	Research Topic	Key person or institution
Other	Breath/metabolite tests for Tb	Axel Heiser (AgR), Gribbles
	ApiWell epidemiology of American foul brood	John Mackay (DNAture), MPI
	Zespri avocado isothermic amplication RPAs	John Mackay (DNAture)
	Parasite resistance testing	Tania Waghorn (AgR)
	Standardising and quantifying specificity and sensitivity of tests	Natalie Parlane (AgR)
	Whole genome sequencing to track incursions/ outbreaks	Natalie Parlane (AgR)
	Alternatives to culturing	Natalie Parlane (AgR)
	Abattoir surveillance design and workflow (Tb)	Massey pathobiology group
	Breeding for disease resistance	Natalie Parlane (AgR)
	Improving E. coli host discrimination in waterways	AgR, NIWA, ESR, Massey
	Nemabiome next-generation sequencing of nematode populations	Tania Waghorn (AgR)
Current and recent research that may be relevant to social science and economics of animal biosecurity		
Social science	Adoption and practice change	Helen Percy (AgR)
	Tourist behaviour	Mark McNeill (AgR), Lincoln University, B3
	Hunting tourism risks	
	Sustainable Seas risk perception and uncertainty (2 projects)	NIWA, Waikato University
	Understanding and promoting biosecurity behaviours in port communities (Tauranga)	John Kean (AgR), B3, TMBC
Economics	Value of the biosecurity system as a whole	Mike Ormsby (MPI), CEBRA
	He Tangata, He Taiao, He Ōhanga: economics and ecosystem services (NZBH)	John Kean (AgR), Christine Reed (Pukaha)
	Rural economies	Peter Tait (Lincoln University)
Current and recent research that may be relevant to wildlife in animal biosecurity		
Vectored diseases	Bovine Tb lessons learned	OSPRI, AgR
	Vectoring of leptospirosis by rodents	Massey
	Hector's dolphin mortality by toxoplasmosis, cat vectoring	DOC, MPI, Massey
	Mycobacterial diseases in seals and sealions	Massey, AgR
	Kiwi tick as a vector for pathogens	Allen Heath (AgR)
	Managing toxoplasmosis in rats and cats	Massey
	Mosquito modelling for understanding risks of avian malaria in yellow-eyed penguins	

Research Category	Research Topic	Key person or institution
Ectoparasites	Database of records of parasitic mites and ticks	Pascal Mitchell (DOC)
	Ticks of NZ seabirds	Allen Heath (AgR)
	Tuatara tick	Allen Heath (AgR)
	Penguin and seabird ticks	Bronwyn Presswell (Otago University)
	Mites and ticks on reptiles at the border	Dylan van Winkel (MPI)
	Hedgehogs as hosts of ectoparasites	Kevin Lawrence (Massey)
Other	Remote sensing of wildlife (e.g. drones etc)	
	New species of campylobacter in NZ wildlife (e.g., possums)	Massey
	Biocontrol risks to native wildlife (e.g. RHD)	
	Viruses in invertebrates	Otago University
	Native wildlife necropsy from public submissions	Stu Hunter, Brett Gartrell (Massey), DOC
	Wallaby surveillance and management	
	Maori/Pasifika risks to tāonga	B3
	Faecal source tracking to understand role of introduced predators and avian species on water quality assessment	AgR

Appendix C: Industry workshop

In scope: international border to farm-gate continuum, legislation (e.g. IHS) (how does science inform this), international standards, social science, information/data management, response tools, macro- and micro-economics (farmer: "what is the cost of not doing this?"), cultural values, surveillance data sharing, diagnostics, pathways, zoonotic diseases (ie. human health), livestock, horses, bees, native species, vectors.

Out of scope: animal welfare (as an impact of biosecurity), biting/stinging insects (ants), aquatic, companion animals.

Participant	Position	Organisation
Allen Heath		
Angela McEwan	Farm Specialist - Animals	Pamu (Landcorp)
Angela Ravagnani	FMD Adviser	MPI
Axel Heiser	Principal Scientist	AgResearch, Animal Science
Chris Morley	Director	Chris Morley Consulting Ltd
Emil Murphy	Science and Policy Manager	DINZ
Enrico Perotti	Associate Director	MPI, Animal and Plant Health
Frances Clements	Policy and Issues Manager	NZ Pork Industry Board
Helen Beattie	Chief Veterinary Office	NZVA
John Kean	Population Ecologist	AgResearch, Forage Science
Joseph O'Keefe	Manager	MPI, Biosecurity New Zealand
Lincoln Broad	Senior Scientist	MPI, Biosecurity New Zealand
Liz Shackleton	Biosecurity Manager	DairyNZ
Petra Muellner	Director (Science and Data)	EpiInteractive
Phil Edmonds	Policy Analyst	ApicultureNZ
Richard Hall	Senior Scientist	MPI, Biosecurity New Zealand
Stu Hutchings	Chief Biosecurity Officer	MPI
Sue Leelawardana	Manager Animal Risk Assessment team	MPI
Tame Malcolm	Operations Manager	Te Tira Whakamataki, Māori Biosecurity Network
Tom Rawdon	Principal Adviser - Incursion Investigation	MPI
Trish Pearce	Veterinary Consultant	NZ Equine Health Association
Vicki Melville	Manager	MPI, Biosecurity New Zealand
Will Halliday	Senior Advisor	B+LNZ

Several organisations did not send a representative to the workshop but have expressed an interest to be involved in future activities: One Health Aotearoa (David Murdoch, Nigel French), social science, economists, tangata whenua, food safety research, mEpiLab (Jackie B), EpiCentre, animal parasitology group at University of Otago (Robert Poulin), ESR, Malaghan Research Institute, Auckland Zoo, WildBase (Brett Gartrell), DOC (Pascale Michelle or Rod Hitchmough), EpiInteractive, NZ BioHeritage, animal sector GIA group, BioResearches (Dylan Van Winkel), Cognosco

Research gaps

Challenge or issue	Research gap	Ideas for research methods	Available data/samples	Potential partners	Priority (votes)
Research gaps identified in animal biosecurity risk analysis					
We do not always know the Aotearoa New Zealand status (presence) of organisms	How can we rapidly and robustly assess likely presence (or probability of presence)?	Prioritise which organisms need more info, from looking at past cases and canvasing import/export and market access experts. Trait-based? Then develop survey plans for high priority orgs.		• MPI RA teams • MPI AHL • MPI Surveillance team • MPI Market Access and Exports • AusVet	HIGH (5)
Threats to native biota	MPI risk analysts have few resources to help them assess risks to native biota	Expert review of threats, pathways, exposure	DBRIEF methods?	• DOC • EPA • MWLR • AgR • Tangata whenua • NZBH	HIGH (4)
Decision-makers do not always understand the risks and the science	Effective communication of risk, assumptions, models etc to decision-makers and stakeholders	Sustainable Seas has current projects on risk communication. Bioheritage has a risk assessment project too		• Sustainable Seas • NZ Bioheritage • Social scientists	MEDIUM (3)
Are we over/under-managing some risks?	What is an appropriate level of risk management?	Case study approach (e.g., honey, poultry overmanaged? hitchhiker pathways undermanaged?)	AFB testing	• Importers and exporters (with care!) • Social scientists	LOW (1)
Analysts assume organisms will behave the same way in Aotearoa New Zealand as they do overseas	Do establishing organisms behave the same way in Aotearoa New Zealand as they do overseas?	Review past cases: what was expected? what eventuated?			LOW (1)
Hitchhiker pathway risks are often poorly understood e.g. TFs, travellers, smugglers	What are the risks of hitchhikers? How often are these pathways implicated in establishments?	Meta-analysis?	Incursion case studies RARs		LOW (0)

Challenge or issue	Research gap	Ideas for research methods	Available data/samples	Potential partners	Priority (votes)
Impacts of climate change on risks and risk pathways	Future risk changes, especially for mosquitoes, ticks, disease vectors	CLIMEX analysis	CLIMEX models available for some organisms; other methods developed in DBRIEF	• B3 "Global change and biosecurity" project • AgR	LOW (0)
Understanding the risks posed by non-compliers	What difference do non-compliers (e.g. farmers with poor practices, smugglers) make to outcomes?	Modelling			LOW (0)
Research gaps identified in animal biosecurity surveillance and data management					
Need more effective or efficient surveillance	New diagnostic technologies (including pen-side tests)	Prioritise diagnostics of interest	Literature	• Labs • Universities • Industry	HIGH (8)
Trade barriers and justifications	Non-OIE-listed diseases	Diagnostics: specific or species-specific Methods that cover multiple diagnostics	Surveillance magazine	• Industry	HIGH (4)
Chain of custody for identifying forward and backward risks	Traceability of samples, beehives, sheep.	AI and ASDs Survey of movements Stable isotope analysis of wool?			MEDIUM (3)
Where are the backyard herds?	Methods for mapping backyard pork, poultry, etc	High resolution satellite imagery + artificial intelligence (AI)		• B3 project mapping host plants	MEDIUM (2)
Antimicrobial resistance surveillance	Methods	Review methods overseas	Wholesalers, regional councils, ESR, industry		MEDIUM (2)
Early reporting (to reduce time between introduction and reporting)	Key motivators to report diagnostic issues	Social science methods, increased outreach	Prior study about 10-15 years ago (MPI/MAF)	• University	LOW (0)
Early reporting proof of freedom response	Novel/alternative sample types for surveillance	Prioritise diagnostics of interest	Literature	• Labs • Universities • Industry	LOW (0)
What appears to be missing here is surveillance systems (i.e. deployment of detection tools and diagnostics) or data management.					

Challenge or issue	Research gap	Ideas for research methods	Available data/samples	Potential partners	Priority (votes)
Research gaps identified in animal biosecurity diagnostics					
What is the best possible test for known targets? (see MPI website)	What are the known targets? In which order of importance? What point-of-care test adds the most value? Which is the best testing platform?	Survey. Reportable absence diseases. RA, economic impact cost/benefit.	For some industries	• Farmers • Vets • Dx labs • MPI. • Stakeholders: ref lab? other labs? public (farmers)?	HIGH (8)
Do we need advanced methods to audit current tests?					LOW (1)
Do we want non-targeted diagnostics?	Review risk of "background noise" versus value of data. We know what some technologies will find.	"Omics", biometrics			LOW (0)
Research gaps identified in animal biosecurity economics and social science					
Understanding the economics of the impacts of poor biosecurity	Some older material ie. Dairy BVD but not is a holistic multi-disease management efficiency way. Need to measure this but very complex.	Economic analysis tools (e.g. cost-benefit analysis). Surveys. Abattoir.	B+LNZ/DairyNZ work in progress. Many individual disease-specific papers. Complex due to compounding.	• Lincoln Uni Agribusiness and Economics Research Unit • CEBRA	HIGH (6)
Producers understanding the value proposition (barriers/carrots) of improved on-farm biosecurity. Why should a farmer bother implementing biosecurity measures e.g. a footbath?	Limited published data and intelligence on this.	Workshop. Community-based social marketing approaches. Survey.	None existing	• Ann Galloway • AgR social scientists	HIGH (5)

Challenge or issue	Research gap	Ideas for research methods	Available data/samples	Potential partners	Priority (votes)
Who do farmers listen to? Who can change their attitudes and behaviours?	? Not aware of published data. Penetration and reproducing.	Workshop, survey, social science, community-based social marketing	Old MWLR paper	Universities, CRIs, primary industry bodies, rural women	HIGH (4)
Are we clear on what good looks like for a particular farm system?	Not scientifically published but information is there	What is available? Resource/capability review. Gap analysis (what do we think is good vs farmers and vets?)	RBPs Industry champions International info e.g. IB	Primary industry bodies, vets, labs, rural women, rural professionals	LOW (1)
Does MPI have enough surveillance data and reports from vets and farmers?	Review of historical data would show this	Analysis of existing information			LOW (0)

For further information please contact:

Axel Heiser
Chief Scientist
06 351 8691
axel.heiser@agresearch.co.nz

John Kean
Senior Scientist
07 838 5658
john.kean@agresearch.co.nz