



CEBRA

FINAL REPORT

2013-2021



Ministry for Primary Industries
Manatū Ahu Matua



CONTENTS

CONTENTS

DIRECTORS MESSAGE

3

OVERVIEW

6

PROJECT HIGHLIGHTS

12

PEOPLE

27

COMMUNICATIONS

34

GOVERNANCE

43

FINANCIALS

49

APPENDIX

53



Director's message



It is my pleasure and privilege to welcome readers to the 2013–21 Centre of Excellence for Biosecurity Risk Analysis (CEBRA) final report.

With mid-2021 marking the end of the most recent Deed of Agreement, it is an opportune time to take stock of all that CEBRA has achieved over the past eight years. It has been a journey of maturation, both our own as an organisation, and of the relationship with our key stakeholders, Australia's Department of Agriculture, Water and the Environment (the department), New Zealand's Ministry for Primary Industries (the ministry), and the University of Melbourne.

CEBRA's mandate is to assist the department and the ministry to defend Australia and New Zealand against biosecurity threats. The risks invasive species pose to primary production, environment and human health are significant. The importance of a well-functioning biosecurity system in combatting these risks cannot be overemphasised.

CEBRA supports the department and the ministry in their vital activities by providing evidence-based tools, analyses and advice. In the past eight years, our researchers have completed almost 80 projects, documenting our work in numerous reports that are publicly available on the CEBRA website¹. We work closely with our colleagues at the department and ministry to ensure that our outputs are fit for purpose, while retaining the advantages of being an independent eye.

As an academic research institution embedded at the University of Melbourne, CEBRA highly values knowledge sharing. Over the past eight years, our staff and students have published over 220 papers in peer-reviewed journals. During this same period, we also presented at around 300 conferences, meetings, workshops and more, and contributed to many media articles.

Although we are housed in and supported by the School of BioSciences here at the university, our researchers hail from a range of disciplines and institutions. CEBRA comprises statisticians, ecologists, economists, mathematicians, and computer scientists with professional experience spanning the public, private and

Two key collectives have governed CEBRA's research and knowledge transfer activities. The CEBRA Advisory Board (CAB) meets regularly to ensure KPIs are on track and keep management accountable. I particularly wish to thank our chairs, Dr Ron Sandland and Dr Colin Grant, for their outstanding leadership throughout the life of the organisation. Members of the Scientific Advisory Committee (SAC) scrutinise draft project proposals and assess final reports. In their crucial role as successive chairs of the SAC, Professors Colin Wilks and Ian Robertson have made substantial and lasting contributions in underpinning our scientific excellence.

I am very proud of all that CEBRA has achieved over the past eight years, much of which is summarised between these pages. I want to thank all our staff – academic and professional – as well as CAB and SAC members, for their ongoing efforts. The CEBRA administration team have been simply invaluable. It has been an honour to steer CEBRA as director since 2017, and as deputy director before that under Professor Mark Burgman's directorship. We owe a huge debt to Mark for his vision, his energy, and his patience. We can't thank him enough.

I am also very grateful to the university, the Faculty of Science, and the School of BioSciences for their steadfast and warm support. Finally, I cannot emphasize enough how much we value the sustained engagement of our colleagues in the department and the ministry, most especially our day-to-day contacts in the departmental secretariat and its equivalent in the ministry. It is no exaggeration to say that without their patience, support, and camaraderie, none of this would be possible.

Biosecurity continues to be of paramount importance to the governments of Australia and New Zealand. CEBRA will forge ahead under a new Deed of Agreement, now in place until June 2025. Continuing on in my role, although now badged as CEO, I look forward to seeing the biosecurity challenges that the future will bring – and to marshalling CEBRA against them.

Professor Andrew Robinson
Managing director, CEBRA

¹ overview.cebra.unimelb.edu.au

Chair's report:

A year of challenge and change

The financial year 2020–2021 has been a time of continuing challenge and of change. Like many organisations, CEBRA has faced the challenge of how to maintain operations under COVID restrictions. This has necessitated holding all CEBRA Board meetings via visual online technology. The board has not met face-to-face since February 2020, and board members who were recruited in late 2019 have had limited in-person contact with their fellow members. The board was also not able to hold its bi-annual meeting in New Zealand. Despite this, board meetings have been effective, and I thank all members for maintaining their commitment and enthusiasm during this difficult year.

CEBRA staff have also been affected, with most of the organisation's multidisciplinary analytical research being undertaken remotely. Under such constraints it is a credit to staff that they have been able to maintain a high level of connectivity and productivity, including with New Zealand colleagues. Many excellent research outputs have been produced over the year, including assessing the value of Australia's biosecurity system and estimating trade-related pest and disease risk. We all hope the current situation will change in 2021–2022, once community vaccination levels allow a return to safe travel.

Inclusive of the period of existence of its antecedent, ACERA, CEBRA approached its 16th birthday in 2021. This was a significant milestone. It was also one of considerable satisfaction as it was recognition that the governments of Australia and New Zealand value the capacity of CEBRA to provide biosecurity analytical services in support of biosecurity management in both countries.

This year, following a recent comprehensive review of CEBRA's performance conducted by ACIL Allen Consulting on behalf of the Australian Government, a new Deed of Agreement for biosecurity analytical services was established with the University of Melbourne. The deed runs for four years until June 2025. The New Zealand Government also renewed its

Memorandum of Understanding with the university for a similar period. This is a pleasing outcome that reflects ongoing government satisfaction with CEBRA's performance. Government intends to make a public call for the continued provision of these services post-2025.

Under the new deed, there is a requirement that, in keeping with best-practice governance, membership of the board will be limited to two funding terms of four years. As a result, Professor Pauline Ladiges, who was a foundation board member of ACERA, and is the only member to have maintained her board position over the life of both ACERA and CEBRA, has stepped down from the board. I thank Pauline for her long and generous service. Her contributions to board discussions were always insightful and provided wise counsel to both board and staff members.

I have also decided to step down as chair of the board. My decision is guided by the fact that I have been chair for the past four years and, in keeping with the new deed, I would not be eligible to continue in that role past 2025. Accordingly, I believe it is in the best interests of CEBRA that it be able to put forward its 2025 competitive bid proposal inclusive of a board chair known to both governments and available to lead CEBRA into the future. I have had a long and, I believe, very productive relationship with ACERA/CEBRA having overseen ACERA's establishment in 2005, and its expansion and name change, to include New Zealand, in 2013.

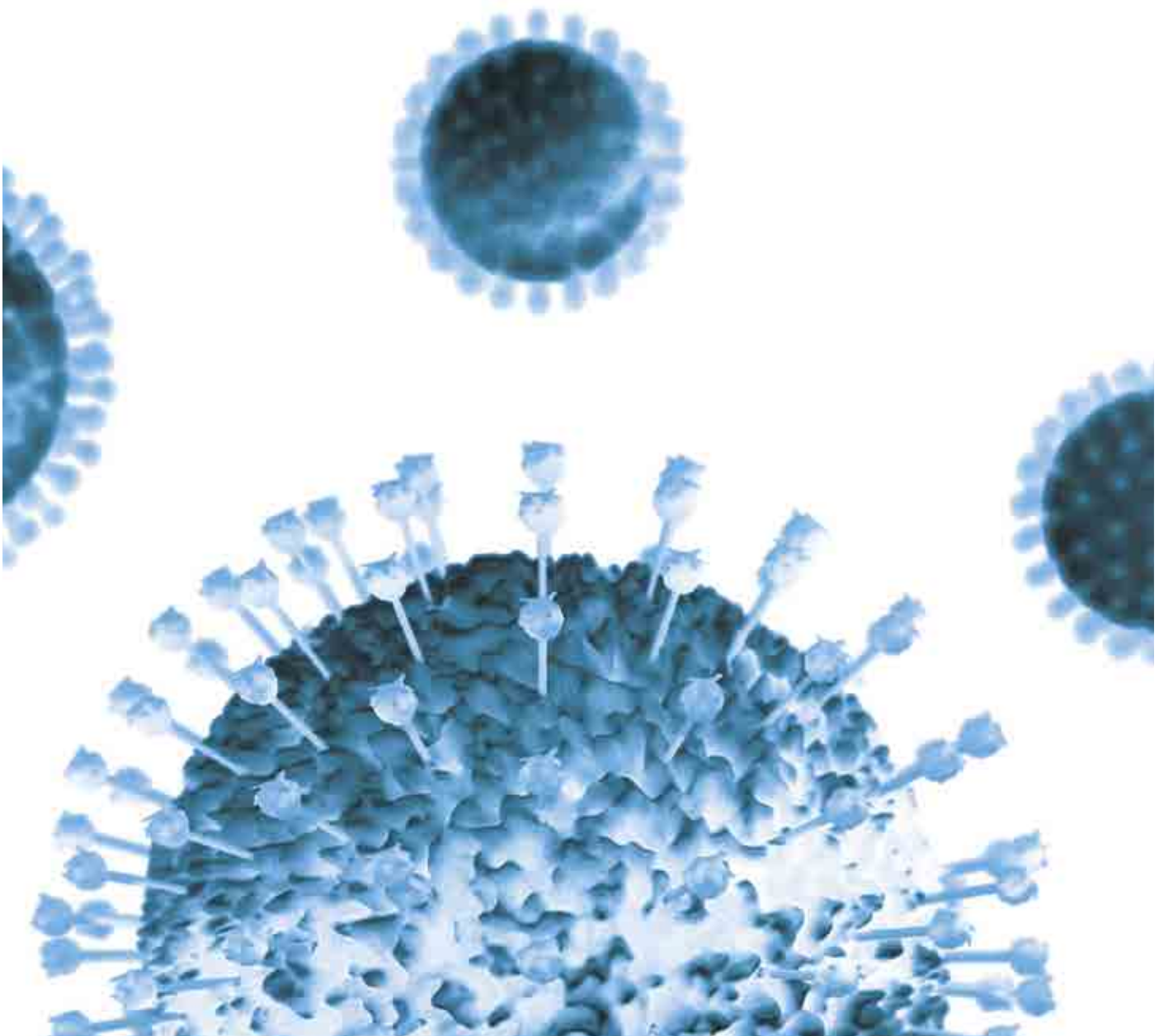
In keeping with my decision, the board conducted an extensive search for a replacement chair, and I am pleased to advise that Ms Lindy Hyam has agreed to take up the role from July 2021. Lindy has impressive credentials, including a Master of Business Administration, fellowship of the Australian Institute of Company Directors and substantial experience as a former board member and board chair in several organisations in the agricultural domain. I am delighted to hand over the responsibility of chair to Lindy.

There will inevitably be more challenges and changes that confront CEBRA. However, CEBRA has established itself as an acknowledged centre of excellence in biosecurity risk analysis. It is valued by national and state governments and agricultural industries, and it has a highly qualified board and staff who are passionate about their work. These attributes stand it

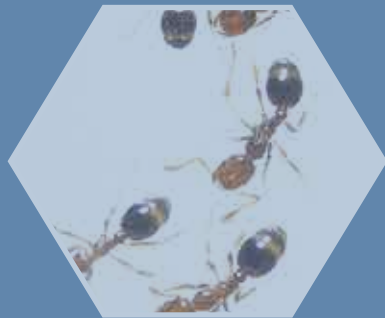
in good stead for the future. I am proud to have been involved in the journey that has enabled CEBRA to achieve this standing, and I wish it every success as it navigates the future.

Dr Colin J Grant

BSc (Hons), PhD, JCU OA



Overview



CEBRA at a glance: 2013–2021

79

research
projects

30

researchers

200+

journal
articles

19

PhD
students

300+

presentations
and
workshops

29

media
engagements

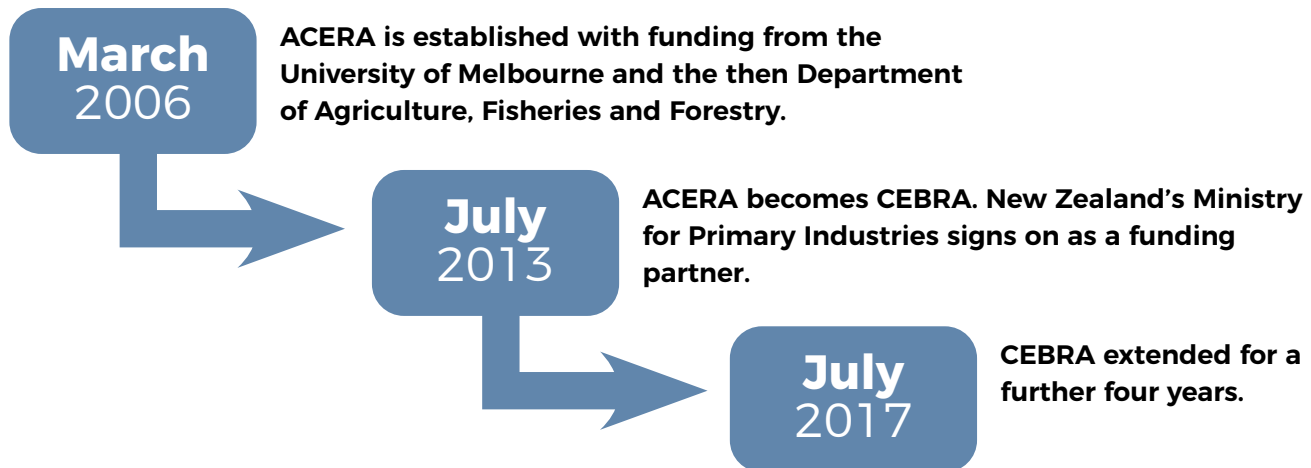
64

reports

History of CEBRA

The Centre of Excellence for Biosecurity Risk Analysis (CEBRA) is a longstanding biosecurity research initiative of the Australian Government. CEBRA's research findings and outputs inform the Department of Agriculture, Water and the Environment and New Zealand's Ministry for Primary Industries in responding to biosecurity risks.

CEBRA began as the Australian Centre of Excellence for Risk Analysis (ACERA), housed in the School of Botany (now BioSciences) at the University of Melbourne.



The core objective of CEBRA is to deliver rigorous solutions and strategic advice related to biosecurity risk. We do this by providing collaborative, world-class research and analysis underpinned by an understanding of the relevant issues, risks and response mechanisms.

Our work informs a range of regulatory activities including risk assessment and communication, interventions, inspection activities, surveillance and pest management. This assists the Australian and New Zealand governments to remain at the forefront of biosecurity risk analysis.



Strategic pillars

CEBRA's mission is to produce innovative, effective and practical research in risk analysis to address the biosecurity challenges facing Australia and New Zealand.

Our mission is supported by five objectives:



research and develop methods relevant to biosecurity risk



engage a range of disciplines to ensure governments remain at the forefront of practical risk analysis



collaborate with end users to improve adoption and increase the impact of research



document and communicate research findings to government and others



promote excellence in risk analysis

Strategic pillars:

Commitment to innovation

Our research challenges biosecurity thinking by developing and introducing new tools and perspectives that provide more efficient, effective and useful solutions. We seek projects that allow our people to innovate, adapt and excel. We respond flexibly and creatively to the challenges presented by our research partners.

Commitment to impact

We provide solutions that connect directly to concrete problems. We focus on a balanced portfolio of challenges, from developing clear and simple solutions to straightforward problems to thinking deeply about how to approach and resolve richer and more complex problems.

Commitment to global reach

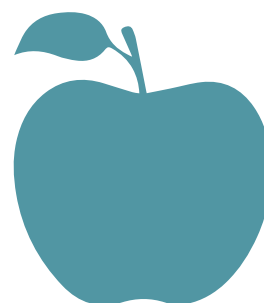
We build networks, champion risk analysis and share the knowledge that we create with the wider world. We work with global partners to find solutions to global biosecurity challenges. We focus on biosecurity regulatory undertakings, but our outcomes often have broader regulatory relevance.

CEBRA research insights



**\$314
billion**

value of Australia's
biosecurity
system

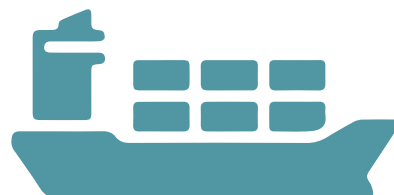


30:1

estimated return
on investment in
biosecurity

AADIS

worldwide interest
for the Australian
animal disease
(AADIS) model



**Improved
surveillance
for invasives**

80%+

accuracy for
automated biofouling
identification

**Framework
for evaluating
the Health
of Australia's
biosecurity
system**



**Improved
KPIs
and profiling for
travellers and
mail**



Future outlook

Invasive species continue to pose a major threat to Australia's and New Zealand's agricultural industries, native fauna and flora, and human health – and the prognosis is grim. Long-term trends point to increasing movements of people and goods, which bring with them biosecurity risk material. However, with the impacts of COVID-19 becoming clear, many people and governments of the world, now more than ever, appreciate the value of a healthy biosecurity system.

In the short term, traveller volumes remain impacted by COVID-19 restrictions. In their April quarterly business outlook, Deloitte Access Economics predicted that rates of Australian air travel will not return to pre-pandemic levels until 2024¹. However, the historical long-term trend in air and sea passenger arrivals during the period 2013–19 showed growth of approximately 5.2% per annum, according to the Australian Department of Home Affairs².

Mail and freight volumes also continue to be affected. According to the ABS, imports have been rising since mid-2020³. At the start of the pandemic, demand for shipping services dropped dramatically; however, once initial trade lockdowns eased, demand on imports increased rapidly, leading to a stockpiling of empty freight containers in Australia⁴. With an increase in freight, the magnitude of hitchhiker and other pest risk faced by Australia and New Zealand's biosecurity systems has also increased. The number of border and post-border interceptions of the very damaging khapra beetle, for example, increased markedly in 2020⁵.

Earlier this year, Australia's federal government pledged \$370 million to biosecurity. Almost \$100 million of this budget is allocated for freight container intervention. Also ear-marked are \$35 million for research about how pests can enter Australia, \$20 million for a pre-border passenger screening trial, \$67.4 million for a national surveillance information system for Australia's animal sector, \$30m to improve biosecurity management of international mail and \$3.9m to improve community and business biosecurity awareness. CEBRA recently estimated that every dollar invested by the Australian Government into biosecurity returns approximately \$30 in value, making biosecurity a very sound investment. We estimated the total value of Australia's biosecurity system at \$314 billion, protecting assets valued at over \$5.7 trillion (over a 50-year timeframe).

With the contributions of CEBRA 2013–21 cemented and a thorough audit of activities conducted, we are looking ahead. A new deed between CEBRA, the University of Melbourne and the Department of Agriculture, Water and the Environment is now in place for the period 2021–25. This ensures that CEBRA can continue to provide quality research and excellence in biosecurity risk analysis into the future.

1 deloitte.com/au/en/pages/media-releases/articles/dae-business-outlook-bump-become-grind-120421.html

2 homeaffairs.gov.au/research-and-statistics/statistics/visa-statistics/live/overseas-arrivals-and-departures

3 abs.gov.au/statistics/economy/international-trade/international-trade-goods-and-services-australia/latest-release

4 globaltrademag.com/australia-shipping-trade-insights-what-is-really-going-on-down-under/

5 agriculture.gov.au/pests-diseases-weeds/plant/khapra-beetle/khapra-beetle-story

Project highlights



Themes 2013-17

Spatial analysis

7 projects

Spatial analyses apply scientific tools such as spatial distribution models to identify high- risk pathways, and predict the spread of current and future biosecurity incursions

Intelligence

4 projects

Intelligence research develops and tests tools to assist biosecurity managers to foresee new threats

Data mining

7 projects

Data mining can be applied to develop, test and implement tools that provide effective use of large volumes of biosecurity data

Building scientific capability

2 projects

Building scientific capability increases understanding and encourages uptake of scientific research

Pathways

7 projects

Understanding the pathways invasive species use to arrive at our shores – including passenger movements, traded commodities and natural dispersal – is key to managing the associated risk

Benefit-cost

8 projects

Benefit-cost analysis is an economic technique that can be applied in biosecurity contexts to predict decision trade-offs and importer behaviour

Data and information

6 projects

Optimal use of data to develop decision-making tools leads to better allocation of limited resources

Strengthening surveillance

5 projects

Effective surveillance reduces the risk of entry and establishment of invasive species by stronger targeting of higher risk pathways

Data mining

Analytical assessment of endpoint surveys

Project number: 1301B

Years: 2013-15

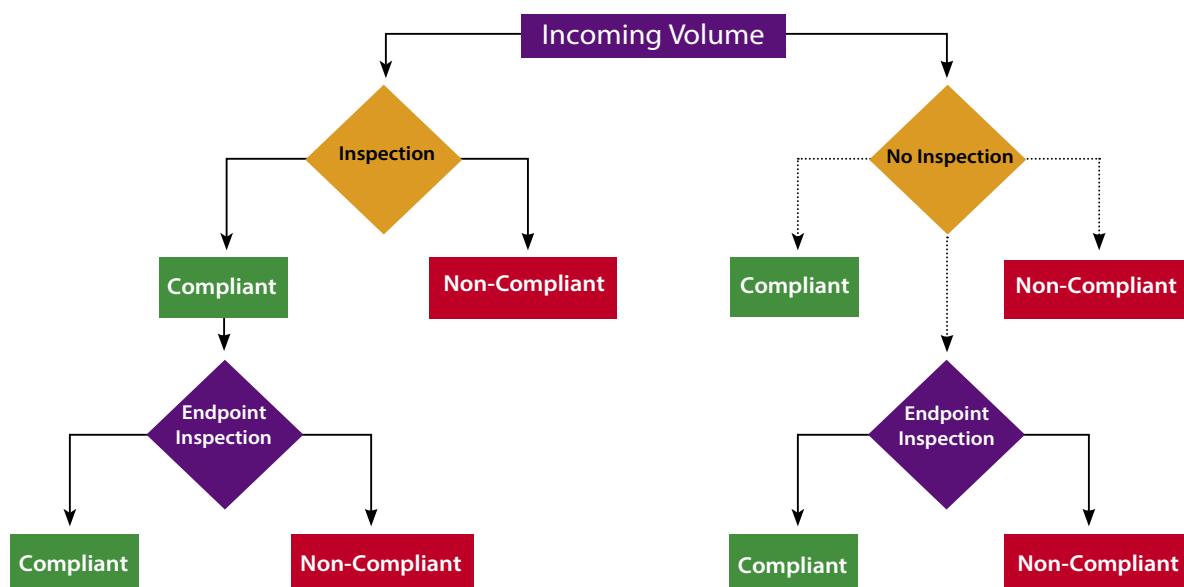
Endpoint surveys are applied in the traveller and mail pathways to estimate the prevalence of any remaining undetected actionable biosecurity material (ABM) after all other interventions have been completed. This information is used to develop cohort profiles and key performance indicators.

CEBRA investigated the design, methods, execution and analysis of these endpoint surveys through interviews with staff at mail facilities and airports, literature reviews, data analysis and simulation experiments. The project identified several issues and made recommendations on how to improve survey design and execution for greater data accuracy. These related to bias in the sampling technique, inspection quality inconsistencies and data recording and analysis.

Analysis and Intelligence (A&I), together with Travellers and Vessels, Cargo and Mail and Inspection Services Group, implemented several of the report's recommendations, including improvements to the calculation of KPIs for quarterly executive reports and cohort profiles.

CEBRA project lead: Andrew Robinson

Report: Chisholm, M, Hoffmann, M, Kuffer, A, Robinson, A & Callis, S (2015) *Analytical assessment of endpoint surveys*



'CEBRA played a vital role in supporting the Department of Agriculture, Water and the Environment implementation of risk-based intervention to more efficiently and effectively manage the biosecurity risks associated with international passengers, mail and cargo.'

Tim Chapman, Department of Agriculture, Water and the Environment

Intelligence

IBIS

Project numbers: 1303A, 1403A, 1503A

Years: 2013-15

The international biosecurity intelligence system (IBIS) was developed by CEBRA as an intelligence network for plant and animal (aquatic and terrestrial) biosecurity surveillance.

IBIS has two parts: automated information gathering and a crowdsourcing aspect for data classification and quality control, incorporating a worldwide network of members. IBIS allows the department to have early warning and better planning and response mechanisms to deal with emerging biosecurity threats, as well as monitoring animal welfare and trade issues.

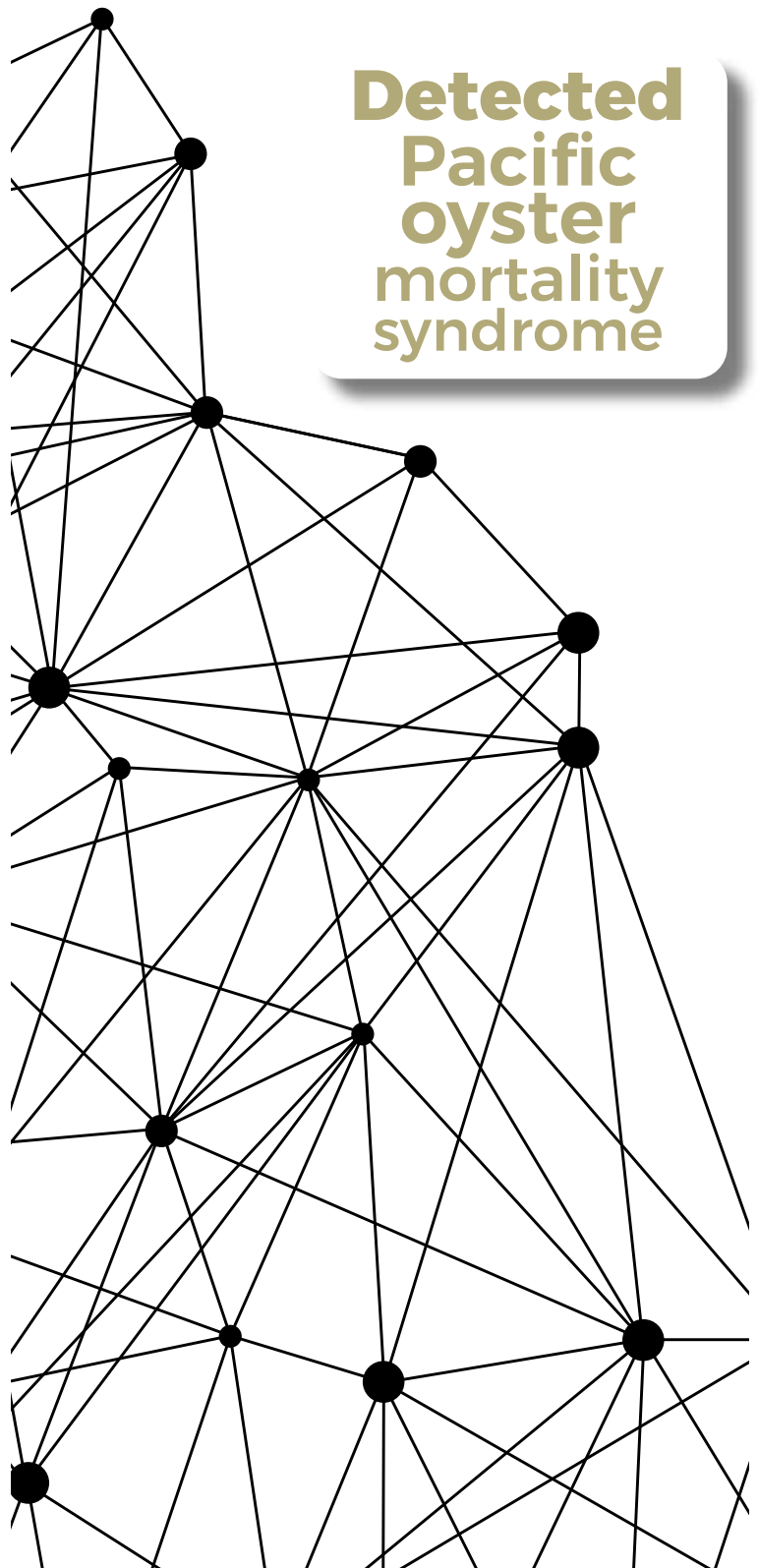
CEBRA project lead: Mark Burgman

Report: Burgman, M, Cupit, A, Reed, C & Mogosanu, H (2015) *Intelligence gathering and analysis: International biosecurity intelligence system (IBIS)*

'We wanted to be an international leader in modern biosecurity intelligence, especially for plant and marine aquatic pests and diseases. Working with CEBRA, we believe we have that system (IBIS). Getting the right information to the right people in a timely way is a key part of managing biosecurity for the department and we use IBIS every day.'

Matt Koval, Department of Agriculture, Water and the Environment

**Detected
Pacific
oyster
mortality
syndrome**



Benefit-cost/Data and information

Testing incentive-based drivers for importer compliance

Project numbers: 1608C, 1504C, 1404C, 1304C

Years: 2013–17

The suite of carrots and sticks (1608C, 1504C, 1404C, 1304C) projects tested whether an import-chain participant's behaviour changes in response to incentives around intervention protocols. The projects involved setting up a theoretical framework, testing this framework via a computer simulation experiment and finally, running a field trial.

Under the trial, participants (e.g. importers and competent authorities) were provided with regular feedback on their imports performance, assisting them to recognise patterns of their own compliance. Importers' behavioural responses to the feedback were assessed using both quantitative (data analysis) and qualitative (stakeholder interviews) methods.

As a result of these projects, increased feedback on inspection performance is now being made available to import-chain participants. Output from these projects is also informing the roll out of incentive-based approaches to additional commodities. CEBRA's research in this area has placed the department as a world leader in explicitly designing rules to harness incentives inherent in the pathway and has prompted interest from the North American Plant Protection Organization.

CEBRA project lead: Susie Hester

Collaborators: DAWE

Reports: Rossiter, A, Mody, F, Whyte, J, Wang, B, Brent, C, Vandenbroek, J, Miech, E, Ryan, S & Hester, S (2019) *Testing incentive-based drivers for importer compliance*

Rossiter, A, Leibbrandt, A, Wang, B, Woodhams, F & Hester, S (2018) *Testing compliance-based inspection protocols – Final report*

Rossiter, A, Hester, S, Aston, C, Sibley, J, Stoneham, G & Woodhams, F (2016) *Incentives for importer choices*

'The work that Plant Import Operations and CEBRA researchers have done together on the CBIS has produced practical, real-world benefits, not only for the department, but directly for importers.'

Brendan Woolcott, Department of Agriculture, Water and the Environment

Spatial analysis

Exposure pathway model for forest surveillance

Project number: 1502E

Years: 2015-16

This project involved developing a spatially explicit Bayesian network approach to allocate surveillance effort based on risk and a pathway map. The approach used a combination of empirical data (where available) and expert elicitation (where data was not available) to support an assessment of risk factors. The overall aim was to identify levels of risk along pathways into any country, including Australia and New Zealand, and designated high-risk sites where surveillance is more likely to detect invasive organisms.

The New Zealand forestry industry rolled out the full system and the software developed under this project, and has implemented it to plan their annual surveillance program. Furthermore, the ministry also used the model to update risk mapping for its high-risk site surveillance program. Both MPI and the New Zealand forest industry were very happy with the output of the project.

CEBRA project lead: Tom Kompas

Report: Mascaro, S & Thiruvady, D (2017) *Exposure pathway model for forest surveillance: Stage 2*



Strengthening surveillance

Sample size calculations for phytosanitary testing of small lots of seed

Project number: 1606A

Years: 2016–17

To meet phytosanitary requirements, the Ministry for Primary Industries established procedures for the documentation, sampling and testing of imported viable seeds to ensure that weed seeds and seedborne diseases are not incidentally present in consignments. Inspection of imported plant seeds is usually destructive and often requires large sample sizes, making importation of small seed lots (fewer than 2500 seeds) unfeasible. Seed importers in New Zealand have the option to source bigger seeds lots, but only from countries that are declared free from the regulated diseases listed in the Import Health Standard.

In this project CEBRA investigated an alternative testing protocol, considering biosecurity risk for the whole pathway. The study demonstrated the impact of lot size on the leakage rate, which is the proportion of contaminated seeds in the lot that are not detected. An output of this project was the development of a web-based application (an R shiny app) for convenient calculation of sample size based on species and lot size. USDA APHIS showed great interest in this research and asked to see the code developed during this project.

CEBRA project lead: Stephen Lane

Report: Lane, S, Souza Richards, R, McDonald, C & Robinson, A (2018) *Sample size calculations for phytosanitary testing of small lots of seed*



Themes 2017-21

Data and intelligence

3 projects

Innovative use of data and intelligence underpins better management of biosecurity risk

Surveillance, diagnostics and screening

2 projects

These tools are vital to identifying biosecurity threats and understanding their spread mechanics

Building scientific capability

3 projects

Building scientific capability increases understanding and encourages uptake of scientific research

NZ MPI

5 projects

A range of analyses relevant to NZ MPI

Risk analysis

(assessment, management and communication)

3 projects

Applying a scientific lens to risk analysis leads to improved risk assessments and decision-making

Data and information

7 projects

Optimal use of data to develop decision-making tools leads to better allocation of limited resources

Strengthening surveillance

10 projects

Effective surveillance reduces the risk of entry and establishment of invasive species by stronger targeting of higher risk pathways

Data and information

Automated image analysis for identifying biofouling risk on vessels

Project number: 190801

Years: 2019-20

Biofouling is the accumulation of organisms on solid surfaces immersed in water, particularly on the hulls of vessels, and is a major pathway for invasive marine organisms. However, conducting in-water inspections and analysing hull footage is expensive and time consuming.

CEBRA project 190801 developed a method to automate the assessment of footage from in-water inspections for biofouling, using deep convolutional neural networks, a method which has achieved widespread success in the field of automated image recognition.

Images gathered by DAWE, MPI and the California State Lands Commission were manually graded by online crowd-sourcing platforms into three levels: no biofouling present, a small amount of biofouling present and a large amount of biofouling present. Aggregating many scores achieved accuracy comparable to a set of three experts who have experience with biofouling and qualifications in marine biology.

Next, we trained our neural networks. The resulting networks obtained better than 80% accuracy for identifying clean and heavily fouled images, performing almost as well as our experts. This could be used with data collected from remotely operated underwater vehicles or automated drones to allow in-water inspections to be conducted much more easily.

CEBRA project lead: Nathaniel Bloomfield

Report: Bloomfield, N, Wei, S, Woodham, B, Wilkinson, P & Robinson, A (2020) *Automated image analysis for identifying biofouling risk on vessels*



Building scientific capability/Data and intelligence

The value of Australia's biosecurity system

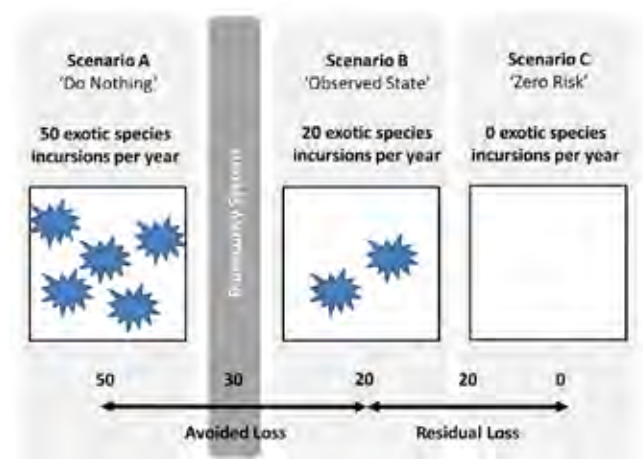
Project numbers: 20100401, 170713, 1607A

Years: 2016–21

Australia's biosecurity system provides a substantial benefit by avoiding or minimising the harm caused by invasive pests and diseases. This value is difficult to quantify. This is because the system has a complex interplay of parts across supply chains, geographies, jurisdictions and stakeholders.

CEBRA's approach to valuing Australia's biosecurity system involved:

- clearly defining Australia's biosecurity system
- determining the value and geographic distribution of assets protected by the biosecurity system
- identifying the key classes of pests and diseases at risk of entering Australia, estimating their capacity for spread, and the associated asset-specific damages
- modelling the arrival, spread, and damages caused by forty classes of pests and diseases across Australia, both with and without a biosecurity system in place.



The project estimated the value of the biosecurity system at \$314 billion over a 50-year timeframe, protecting assets valued at over \$5.7 trillion. For every dollar invested by the Australian Government, the average return was estimated at \$30. The results were reported in the Minister for Agriculture, Drought and Emergency Management's press release: [minister. awe.gov.au/littleproud/media-releases/cebra-value-biosecurity-system](https://www.minister.awe.gov.au/littleproud/media-releases/cebra-value-biosecurity-system)

CEBRA project leads: Tom Kompas and Aaron Dodd

Reports: Dodd, A, Stoeckl, N, Baumgartner, J & Kompas, T (2020) *Key result summary: Valuing Australia's biosecurity system*

Dodd, A, Spring, D, Schneider, K, Hafi, A, Fraser, H & Kompas, T (2017) *Valuing Australia's biosecurity system – Year One report*

"The model demonstrates the benefits of the Australian Government's investment in biosecurity."

The Hon David Littleproud MP, Minister for Agriculture and Northern Australia

Surveillance, diagnostics and screening

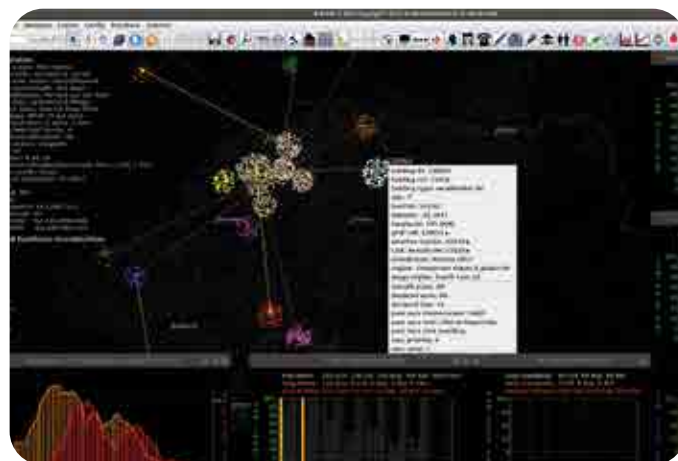
Modelling the spread and control of African swine fever in domestic and feral pigs

Project number: 20121501

Years: 2020-21

African swine fever (ASF) represents a significant threat to the pork sector and the Australian economy in general. ASF outbreaks are widespread and increasing in Asia and Europe. Detections of ASF viral fragments in undeclared pork products intercepted at the Australian border have increased in recent years.

For this project, CEBRA applied the Australian animal disease model (AADIS), which was originally developed to model the spread of foot-and-mouth disease. AADIS incorporates spread pathways and the current locations of farms, with disease spread being modelled both within and between herds. In this case, the modelling was also expanded to include wild populations.



This research allows decision-makers to flexibly allocate resources for disease control and model the outcome. The ability to experiment with outbreak scenarios – and trial various control measures – assists the development of animal health policy, preparedness and planning, including application of disease control zones and movement controls.

AADIS has been adapted for several livestock diseases, vector-borne diseases and plant pests. The model has drawn international attention from organisations including the European Commission for the Control of Foot-and-mouth Disease, United States Department of Agriculture: Centre of Epidemiology and Animal Health and the Malaysian Department of Veterinary Services.

CEBRA project lead: Richard Bradhurst

Report: Bradhurst, R, Garner, G, Roche, S, Iglesias, R, Kung, N, Robinson, B, Willis, S, Cozens, M, Richards, K, Cowled, B, Oberin, M, Tharle, C, Firestone, S & Stevenson, M (2021) *Modelling the spread and control of African swine fever in domestic and feral pigs*

Surveillance, diagnostics and screening

Using edmaps and Zonation to inform multi-pest early detection surveillance designs

Project number: 20121001

Years: 2020-21

Surveillance of exotic pests and diseases for the purposes of early detection is a critical component of any effective and efficient biosecurity system. Under this project, CEBRA developed a framework for estimating post-border establishment potential of priority plant pests and diseases. This framework, now compiled into an R package called edmaps, estimates post-border establishment potential as a function of three fundamental barriers to establishment: propagule pressure, climate suitability and host availability. This framework can be used to identify areas of high establishment potential across pests and examine whether early detection programs can be consolidated to reduce costs.

CEBRA used edmaps in conjunction with R package Zonation to produce post-border establishment potential maps for ten plant pests, four plant pathogens and nine exotic pathogen vectors identified by the department as priority threats.

The latest version of edmaps, developed under this project is currently being incorporated into Biosecurity Commons to allow greater accessibility to state and federal practitioners. The work was presented to the National Citrus Surveillance Steering Committee and was well received.

CEBRA project lead: James Camac

Report: Camac, J, Baumgartner, J, Hester, S, Subasinghe, R & Collins, S (2021) *Using edmaps and Zonation to inform multi-pest early detection surveillance designs*



Building scientific capability

The health of Australia's biosecurity system

Project number/s: 170714, 1607B

Years: 2016–19

Performance reporting is part of the accountability responsibilities of any government agency. Prior to these projects, performance evaluation of biosecurity activities had not been done at a national level. To fill this gap, CEBRA developed a performance evaluation framework that can be repeatedly used to evaluate the health or performance of the national biosecurity system against agreed performance criteria and indicators. The framework provides an objective basis on which to identify shortcomings of Australia's biosecurity system and to guide evidence-based investment decision-making.

Main project outputs:

- comprehensive description of the national biosecurity system and logic model
- seven-step performance evaluation approach
- indicator framework for collecting quantitative and qualitative information.

The approach used rubrics. A rubric is a table that presents and captures qualitative information about performance. It requires evaluative criteria and a defined number of performance standards with a description of expected performance. Rubrics are widely used in the education sector, and are increasingly being adopted by program evaluators. CEBRA has integrated rubrics into the indicator framework, to assemble experts' judgements in a robust and transparent way.

CEBRA project lead: Karen Schneider and Edith Arndt

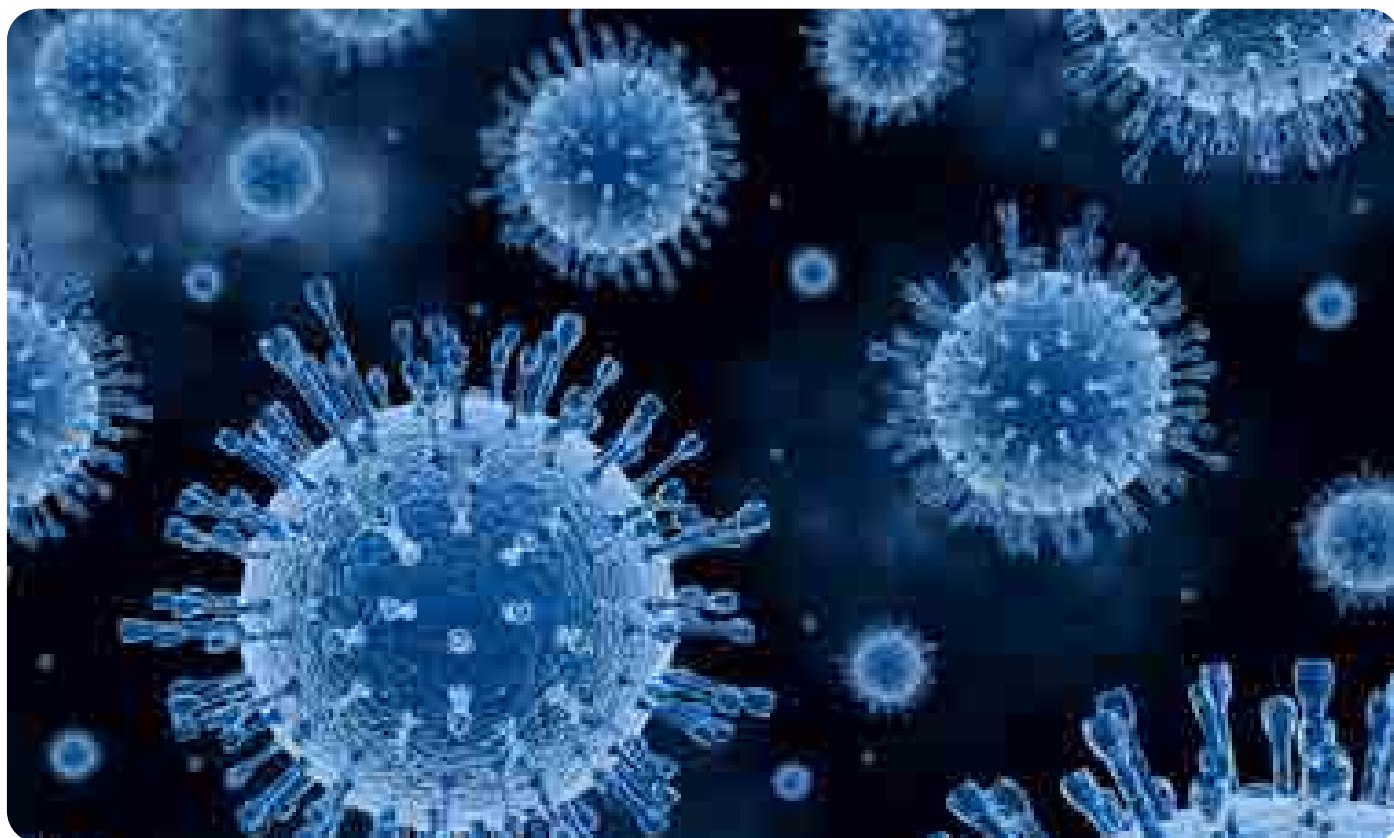
Report: Schneider, K & Arndt, E (2020) *Evaluating the health of Australia's biosecurity system*



Project reports

A complete list of CEBRA projects completed during the period 2013–21 is provided in Appendix Table A. For more information about our research, and to access reports, please visit:

overview.cebraz.unimelb.edu.au



Publications

As a member of the academic community, CEBRA endeavours to share research through peer-reviewed papers, where practical. This ensures our contribution is accessible to – and scrutinised by – a wide range of interested parties, via academic journals.

H-index

CEBRA's h-index is **45**.

The h-index aims to measure the cumulative impact of a researcher or organisation's output.

The advantage of the h-index is that it combines an assessment of both quantity (number of papers published) and quality (impact, or paper citations).

Impact factor

The impact factor is a measure of the frequency with which the average article in a journal has been cited in a particular year or period. The InCites impact factor in Table 1 is calculated as the number of current year citations of items published in a journal, divided by the number of items published in that journal during the previous two years.

A list of CEBRA publications can also be accessed at: cebra.unimelb.edu.au/engage/journal-articles

Table 1: CEBRA publications summary with average citations and InCites impact factor as at 21/07/2021

Calendar year	Total publications	Total citations	Average citations	Average InCites impact factor	CEBRA project-specific publications
2020	20	91	4.55	3.87	2
2019	19	525	27.63	5.16	6
2018	26	575	22.12	4.53	8
2017	37	1398	37.78	4.32	14
2016	29	1241	42.79	4.47	8
2015	29	1694	58.41	6.20	12
2014	16	949	59.31	6.53	3
2013	27	7615	282.04	6.20	11
Total	203	14088	-	-	64

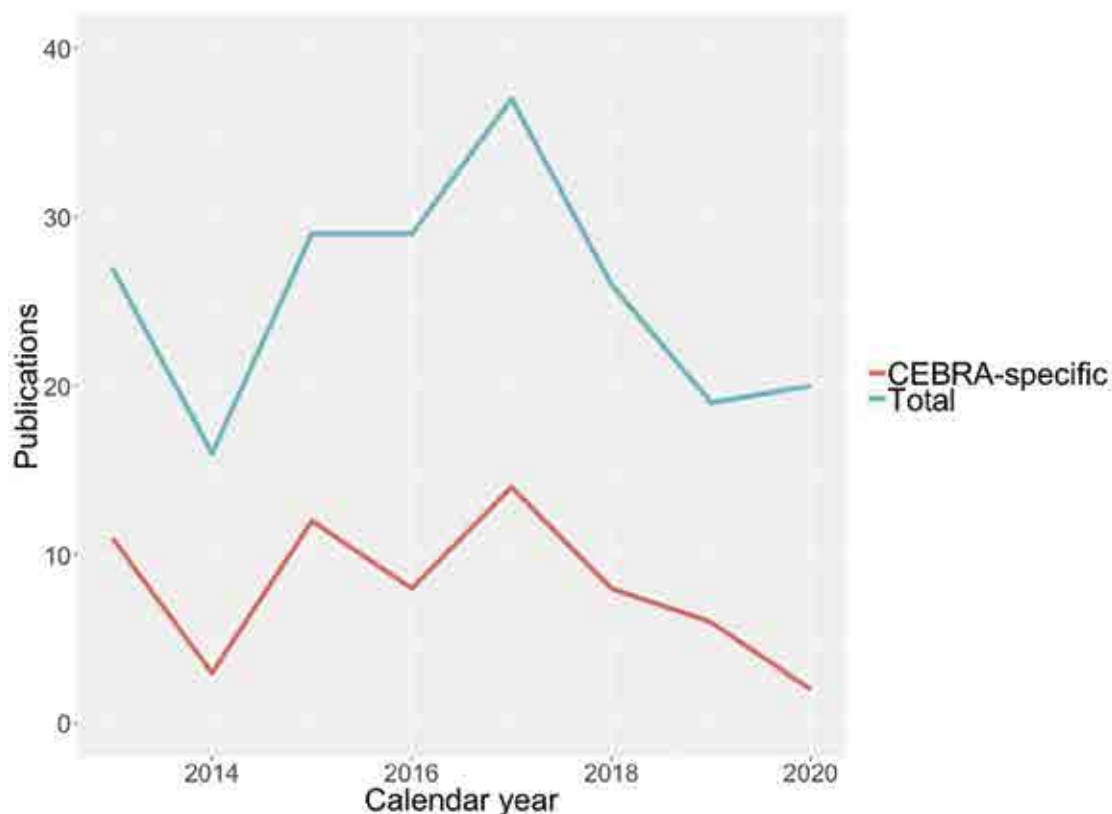


Chart 1: Total and CEBRA-specific publications by CEBRA researchers, across the 2013–20 calendar years

People

People



Key CEBRA personnel

CEBRA engages academics and practitioners across a range of specialties. Our expertise span statistics, ecology, economics, mathematics, decision science and more. Many of our researchers have also previously worked in other biosecurity-related organisations.

Director (2017-21)

Professor Andrew Robinson



PhD, MSc, BSc (Hons)

Specialty: Definition and statistical properties of performance indicators for inspectorates, use of applied statistics and risk analysis to support biosecurity management

Deputy Director (2017-21)

Dr Aaron Dodd



PhD, BSc (Hons), Cert III Public Safety (Biosecurity Operations)

Specialty: Biosecurity practice, system design and evaluation, bioeconomic modelling, invasive species ecology

Chief Investigator Dr Susie Hester



PhD, BEc (Hons)

Specialty: Biosecurity economics, incentive-compatible biosecurity policy, post-border surveillance, bioeconomic modelling

Chief investigator Professor Tom Kompas



PhD, MSc, BSc

Specialty: Economic dynamics, agricultural economics, natural resource economics and environmental economics

Past senior personnel

Director (2013–16)
Professor Mark Burgman



PhD, MSc (Hons), BSc (Hons)

Specialty: Ecological modelling, conservation biology and risk assessment

Deputy Director (2017–19)
Dr Stephen Lane



PhD

Specialty: Effective data communication, and the preparation, collation and management of complex datasets.

Research fellows (as of mid-2021)

Dr Edith Arndt



PhD, MSc

Specialty: Soil biogeochemistry of alpine and subalpine environments, science-policy interface, marine vessel biofouling, surveillance

Dr John Baumgartner



PhD, BSc (Hons)

Specialty: Ecological modelling, habitat suitability modelling, population dynamics modelling, climate change impacts

Nathaniel Bloomfield



BPhil (Hons)

Specialty: Mathematical modelling, machine learning, statistical analysis, high-performance computing

Dr Richard Bradhurst



PhD, MCompSc, BSc

Specialty: Computational modelling, software engineering, computer science, veterinary epidemiology

Dr James Camac



PhD, BBioSc (Hons)

Specialty: Ecological modelling, climate change and fire impacts on biodiversity, invasive species risk mapping, surveillance

Professor Jane Elith



PhD, BAgSc (Hons)

Specialty: Spatially explicit models of species distributions

Associate Professor Anca Hanea



PhD, MSc, BSc

Specialty: Probabilistic modelling, risk analysis, decision theory, structured expert judgement, Bayesian modelling

Martina Hoffmann



BSc, BActStud

Specialty: Statistics, airport passenger profiling, continuous sampling plans, spatial spread models, performance indicators

Natasha Page



MSc, BSc

Specialty: Data science and optimisation, computer science

Karen Schneider



BSc (Hons)

Specialty: Economics (agriculture, energy and natural resource management), biosecurity public policy

Dr Daniel Spring



PhD, MEcon, BEcon

Specialty: Environmental economics, invasive species eradication, regulatory economics, cost-benefit analysis

Dr Raphael Trouvé



PhD, MSc, BBioSc

Specialty: Ecological modelling, population dynamics, statistical sampling and inference, optimisation, remote sensing, climate change

Dr Terry Walshe



PhD, Grad Cert University Teaching,
BForSc (Hons)

Specialty: Decision analysis, bioeconomic
modelling

Dr Jason Whyte



PhD, BSc (Hons)

Specialty: Experimental design, optimisation,
mathematical modelling, scientific
communication, data visualisation

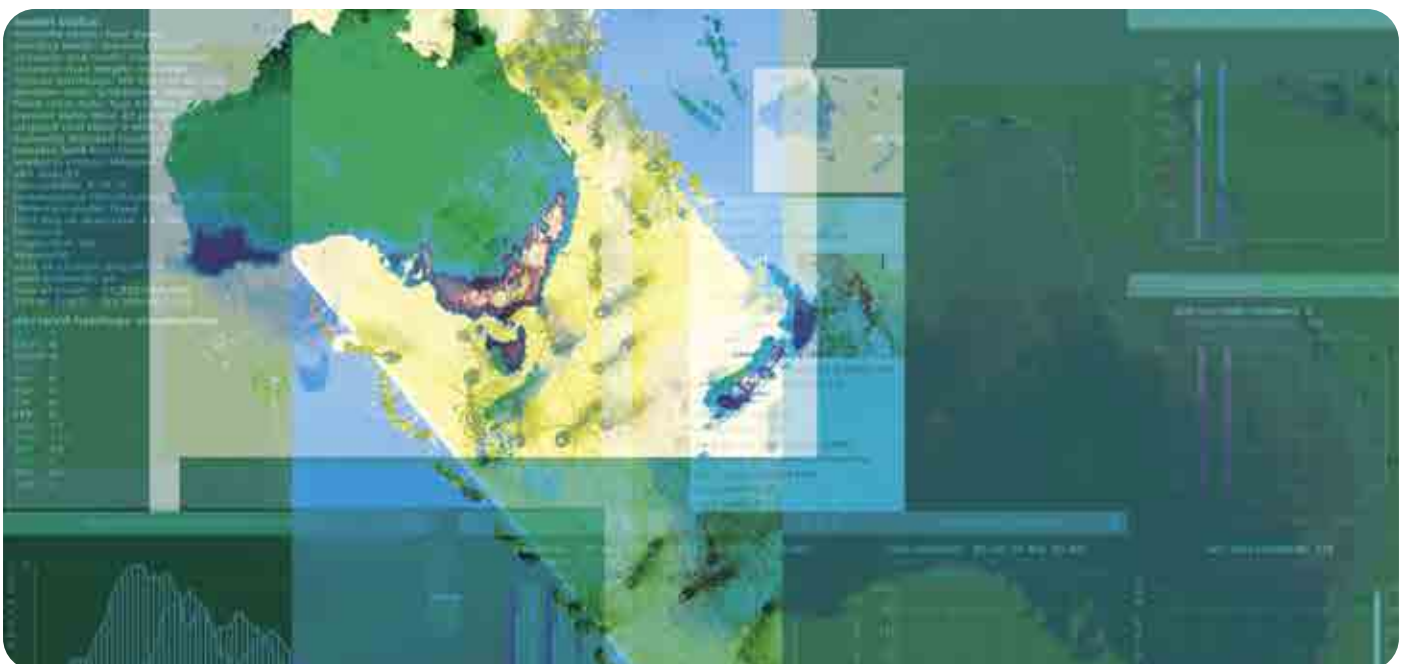
Professional staff

**Business Manager
Cassie Watts**



BBus

**Administrator
Erica Kecorius**



Past personnel

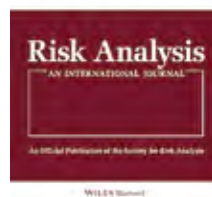
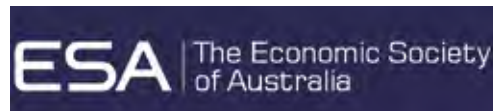
Table 2: CEBRA associates and past personnel

Name	Professional qualifications	Speciality
Dr Jan Carey	PhD, BSc	Marine ecology
Matthew Chisholm	BSc, BA	Data curation, data engineering and performance measurement of regulatory activities related to the Biosecurity Act 2015 and Export Control Act 2020
Dr Rezvan Hatami	PhD, MSc	Various aspects of natural resources, water management, environmental science, statistics and ecology
Dr Cindy Hauser	PhD, BAppSc (Hons)	Quantitative ecological modelling
Jessica Holliday	BSc (Hons)	Environmental science, quantitative risk analysis, biosecurity stakeholder liaison
Dr Tracey Hollings	PhD, MConBio, BCom, BSc	Wildlife disease ecology, biosecurity risk analysis, species distribution modelling, threatened species conservation
Anthony Rossiter	BEcon (Hons), BSc (Hons)	Applied game theory, economics of regulation, behavioural economics, statistical and mathematical modelling, public policy research translation



Professional and academic links

CEBRA staff are members of many societies and advisory councils. We also regularly act as reviewers and editors for numerous journals. The organisations/publications we have connections to include:



Communications

Communications



Communication activities

CEBRA actively engages with a broad domestic and international audience across a range of media. We use online platforms to promote papers that we've published and conferences at which CEBRA researchers present project outcomes, as well as sharing biosecurity-related news. CEBRA newsletters – which contain CEBRA-focused updates from the director, researcher profiles and project spotlights – are sent out to an e-mail list. CEBRA researchers also communicate to the wider public via media articles. Two further communication initiatives that CEBRA has undertaken recently include a booklet outlining CEBRA's research focus and activities and a set of biosecurity playing cards to encourage community identification and knowledge of invasive species.

Our engagement channels:

CEBRA website: cebra.unimelb.edu.au

Facebook: facebook.com/cebrauom

Twitter: twitter.com/CEBRA_UoM

CEBRA e-newsletter: cebra.unimelb.edu.au/news#e-newsletters

All endorsed CEBRA reports are published on the CEBRA website at:
cebra.unimelb.edu.au/engage/reports

The booklet outlining the objectives of CEBRA and its recent activities can be referenced at:
cebra.unimelb.edu.au/news/news/cebra-at-a-glance

CEBRA has also produced an overview report and website which summarises ACERA and CEBRA project outputs and outcomes:
overview.cebra.unimelb.edu.au

Communication and engagement activities are reported in detail to the CEBRA Advisory Board, the department and the ministry via quarterly progress reports, as well as in annual final reports.



Presentations

CEBRA work is regularly shared and communicated at domestic and international conferences, symposiums and other meetings. During the period 2013–21, CEBRA staff members gave presentations, ran workshops, chaired sessions, presented posters, joined roundtables, recorded webinars and more. CEBRA researchers also shared insights with a wider audience through media engagements. These engagements have become more important in recent years, with the rise of online media and COVID-19 restrictions on travel. Note that some activities were restricted during 2019–21 due to the pandemic.

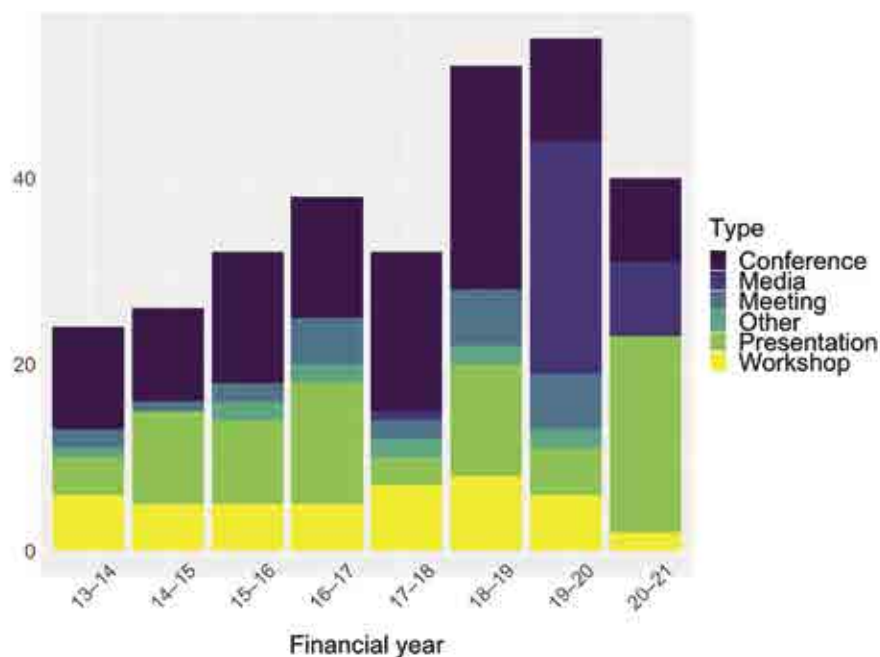


Chart 2: A summary of CEBRA's engagements across the period 2013–21, segmented by event type

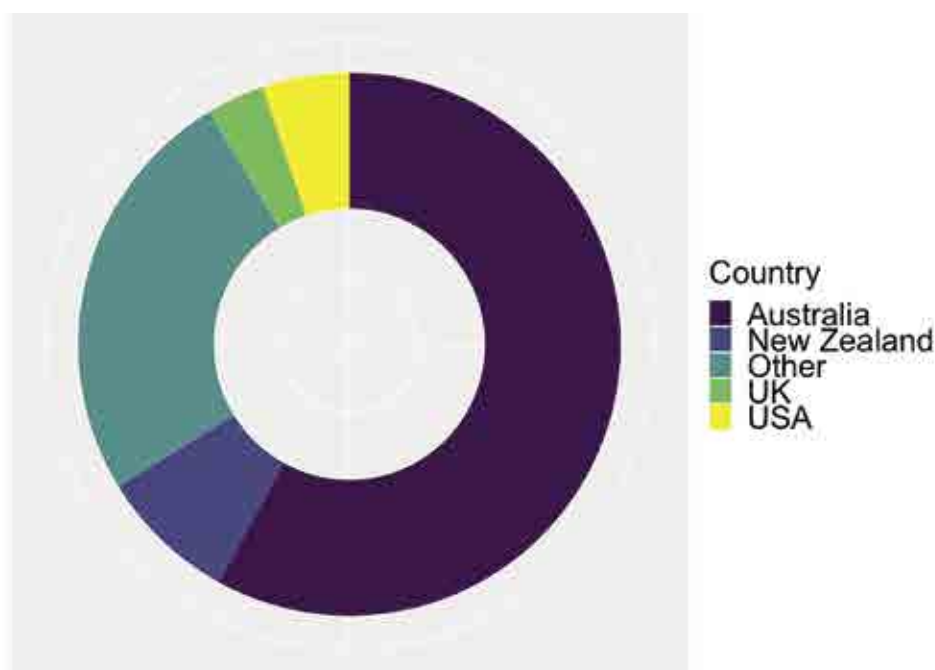


Chart 3: A summary of CEBRA's engagements across the period 2013–21, segmented by location (excludes virtual events and media)

Event spotlight: SRA-ANZ Conference 2017

100
attendees

In November 2017, CEBRA hosted the tenth annual conference for the Society of Risk Analysis – Australia and New Zealand at the University of Melbourne, held in conjunction with the annual conference of the Australasian Bayesian Modelling Society.

The meeting brought together risk researchers and stakeholders across academia, government and industry. Held over four days, the conference featured a number of presentations, panel discussions, workshops and networking events.

The theme of the conference was *risk in an interconnected world*, with talks covering a range of fields including biosecurity, epidemiology and ecology. University of Melbourne Vice-Chancellor Professor Glyn Davis provided an opening address and keynote speakers included Professor Mark Burgman and Dr Emily Nicholson.

Also in attendance were President of SRA-International, Dr Margaret MacDonell from Argonne National Laboratory and President of SRA-ANZ, Dr Sandra Seno-Alday from the University of Sydney.

Talks from CEBRA researchers presented at the SRA-ANZ conference included:

- *Does size matter to biosecurity risk?* by Professor Andrew Robinson
- *The 'curse of dimensionality' resolved! Optimal surveillance measures in large dimensional settings for the early detection of pests and diseases* by Professor Tom Kompas
- *Plant invasions in Australia: How can decision-theory inform management?* by Dr Aaron Dodd
- *Simple rules for protecting islands from biological invasions* by Dr Danny Spring
- *Does structured expert elicitation improve judgements?* by Victoria Hemming
- *Naturalised exotic species from the tropical botanic gardens: trait-based assessment* by Decky Junaedi

A welcome drinks also included a book launch for *Invasive Species: Risk Assessment and Management*, edited by Professor Andrew Robinson, Dr Terry Walshe et al.



Support for the Society for Risk Analysis

The Australia and New Zealand chapter of the International Society for Risk Analysis provides an opportunity for an inclusive, broad-based society that promotes communication between disciplines, a breadth of tools and viewpoints, and platforms for training, workshops, and conferences. CEBRA acts as secretariat to the society providing administration of accounts, executive support and assistance in organisation of its annual conference.

NRMT90002 BIOSECURITY:

Managing invasive species

For the past two years, CEBRA has been coordinating the University of Melbourne subject NRMT90002 Biosecurity: Managing invasive species. An overview of this course is provided below.

Changing climate and increasing globalisation of human movement and trade has dramatically increased the exposure of countries to new pests and diseases that can have devastating economic, environmental and social impacts. We need only look at the recent COVID-19 pandemic to see how quickly an emerging threat can spread and cause large-scale impacts on both social values and global economies. The difficulty faced by governments, industry and environmental practitioners is how to foster a strong and efficient biosecurity system that can mitigate the risk of new pests and diseases entering, establishing and spreading while also allowing for increased global trade and human movement.

To prepare the next generation of biosecurity practitioners to face this mounting challenge, CEBRA has developed a postgraduate subject, Biosecurity: Managing invasive species.

This subject aims to expose students to what biosecurity is, what components it is comprised of, and what the various actions, decisions and trade-offs are that governments, industry and environmental stakeholders must consider when trying to manage the risks posed to the environment, agricultural assets and social values.

To guide students through this process, CEBRA has developed a series of lectures that step through the processes and actions used in an efficient and effective biosecurity system – from how to anticipate incoming risk through to how to prepare and respond to incursions. To ensure students have a thorough understanding of the practical challenges in implementing biosecurity measures, we also have guest lectures from world-leading biosecurity experts from industry, government and the environmental sector.



Postgraduate research students

CEBRA has made substantial investments in postgraduate research training. Our students research, apply and develop specialist techniques to tackle real-world problems, building biosecurity risk analysis capacity and capability in Australia and around the world.

Table 3: CEBRA postgraduate research students 2013–21

Student	Year completed	Title	Supervisor
Prue Addison	2013	PhD: Control charts for marine monitoring	Dr Jan Carey
Shumoos Al-Riyami	2021	PhD: Decision-support tools for vector-borne spread of animal disease	Dr Richard Bradhurst
Raquel Ashton	Withdrawn 2015	PhD: Facilitation and expert judgement	Professor Mark Burgman
Nayomi Attanyake	2020	PhD: Efficient estimation of hazard cut-points for risk-based fleet management	Professor Andrew Robinson
Indriati Bisono	2017	PhD: Modelling spatial extremes	Professor Andrew Robinson
Gayan Dharmarathne	2019	PhD: Exploring the statistical aspects of expert elicited experiments	Professor Andrew Robinson
Aaron Dodd	2016	PhD: Predicting invasion success	Professor Mark Burgman
Rodrigo Estevez	2013	PhD: Social and amenity value in risk analysis	Professor Mark Burgman
Emma Gorrod	2013	PhD: Measures and habitat condition	Professor Mark Burgman
Victoria Hemming	2019	PhD: Selection of experts for judgement using test questions	Professor Mark Burgman
John Hicks	2016	MPhil: Robust optimal decision making in traditional Aboriginal culture	Professor Mark Burgman
Stuart Jones	Withdrawn 2015	PhD: Numerical methods for biosecurity risk analysis	Professor Mark Burgman
Decky Junaedi	2018	PhD: Trait-based approach of the management of invasive exotic species from botanic gardens in the tropical ecosystem	Professor Mark Burgman

Natalie Karavarsamis	2014	PhD: Methods for estimating occupancy	Professor Andrew Robinson
David Lazaridis	2014	PhD: Regularised mixed-effects models	Professor Andrew Robinson
Matthew Malishev	2018	PhD: Feeding ecology and behaviour	Professor Mark Burgman
Lucy Rose	Currently enrolled	PhD: Managing Melbourne water for biodiversity	Professor Mark Burgman (co-supervisor)
Thiripura Vino	2019	PhD: Human mobility models with imperfect data	Professor Andrew Robinson
Peixin Yuan	2016	MSc: Performance of CSP algorithms under incomplete inspection	Professor Andrew Robinson

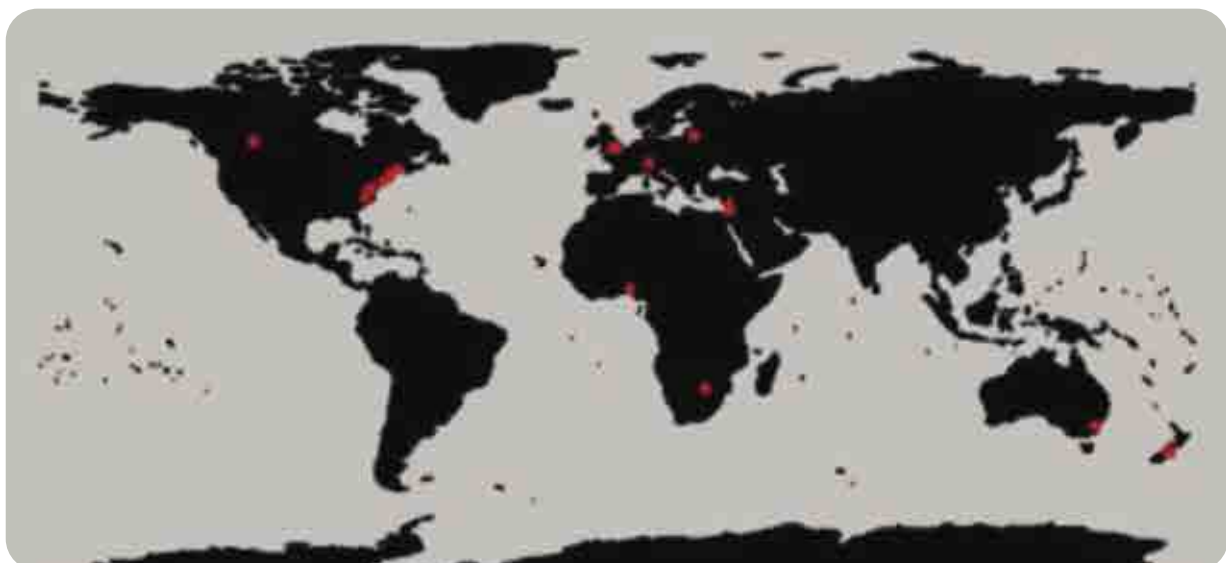
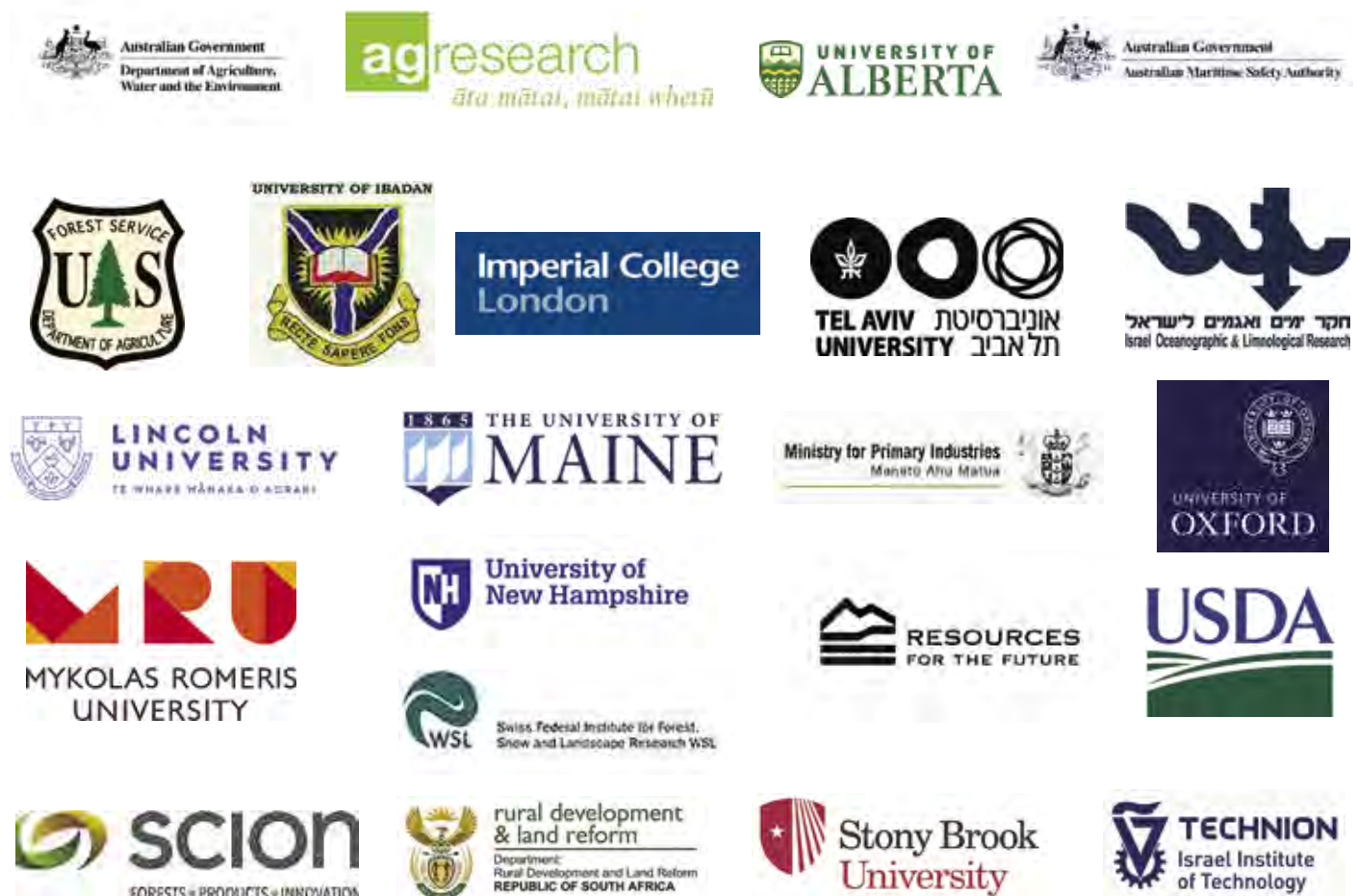
Research collaboration partners

CEBRA maintains collaborative research links with the following industry partners:

- Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
- The Australian National University
- Bayesian Intelligence
- Centre for Market Design, University of Melbourne
- CSIRO
- Imperial College, UK
- Lincoln University, NZ
- Massey University, NZ
- Monash University
- Scion Research, NZ
- Technocrat
- University of New South Wales
- Universal Biosecurity Limited
- University of New England

Visiting academics and practitioners

CEBRA fosters connections with overseas organisations and individuals working in risk analysis. By sharing knowledge and research, we advance the field and identify opportunities for mutually beneficial collaboration. Below is a summary of the organisations from which we hosted academics and practitioners during the period 2013–21.



Visitor spotlight:

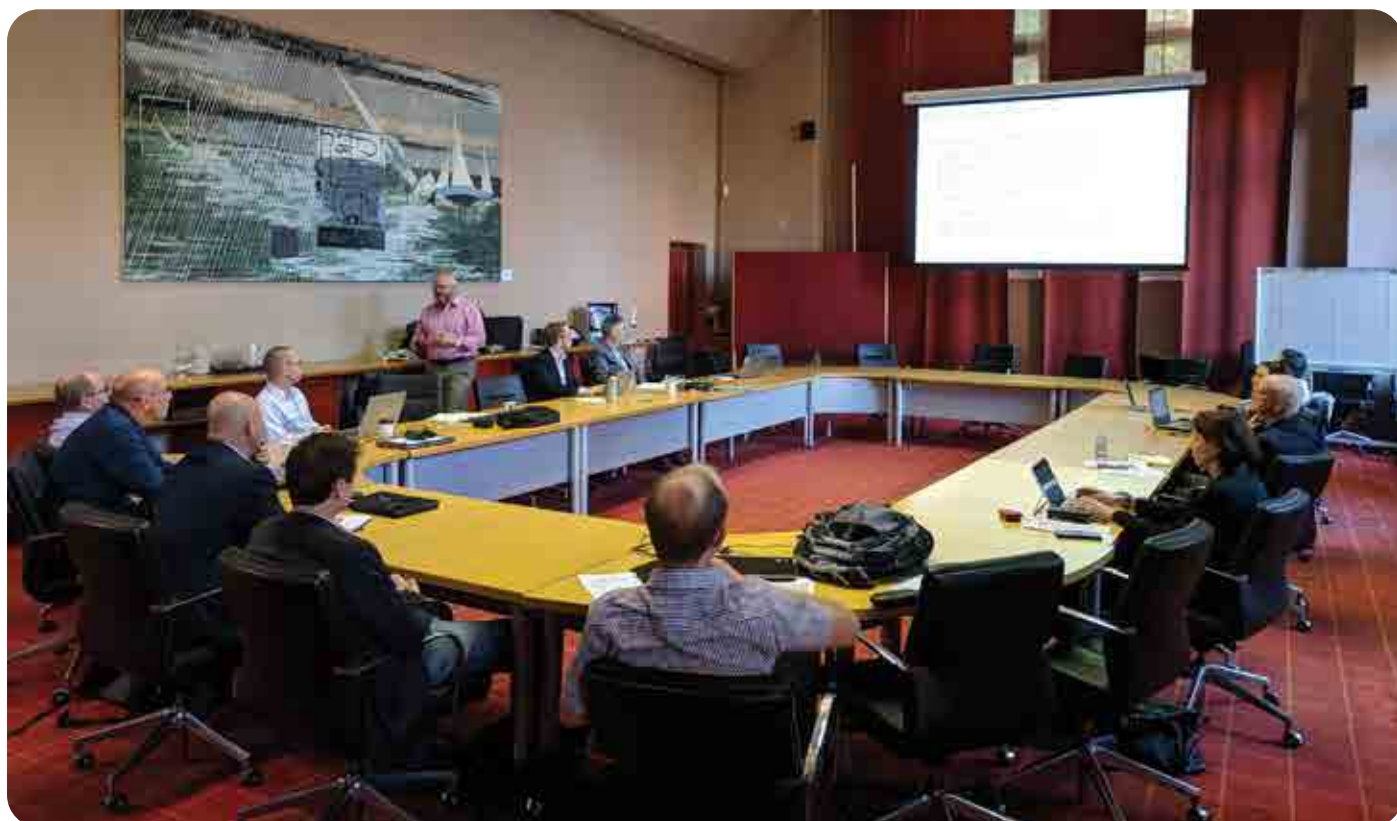
International Biosecurity Data Analytics Working Group

In April 2018, CEBRA hosted the first International Biosecurity Data Analytics Working Group meeting at the University of Melbourne. The week-long program was attended by academics and government representatives from four corners of the world: the USA, Canada, New Zealand and Australia. Talks covered a range of topics relating to biosecurity, from big data to sampling, with an overview of analytics in Australia, New Zealand, Canada and the USA given.

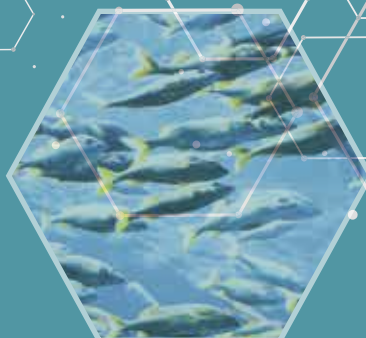
CEBRA Director Andrew Robinson spoke about CEBRA's role, as well as leading the discussion on lab seed testing and models for profiling. CEBRA researchers Steve Lane and Matthew Chisholm led the discussion on international passengers. The gathering provided a platform for attendees to network and exchange ideas, and also included a field trip to:

- the Victorian Department of Economic Development, Jobs, Transport and Resources campus in Attwood
- DAWE's post-entry quarantine facility in Mickleham
- the Yarra Valley, to study the impacts of phylloxera on grapevines

It was a very successful meeting and catalysed a bimonthly conference call discussion among the analytics teams of the regulators and other stakeholders.



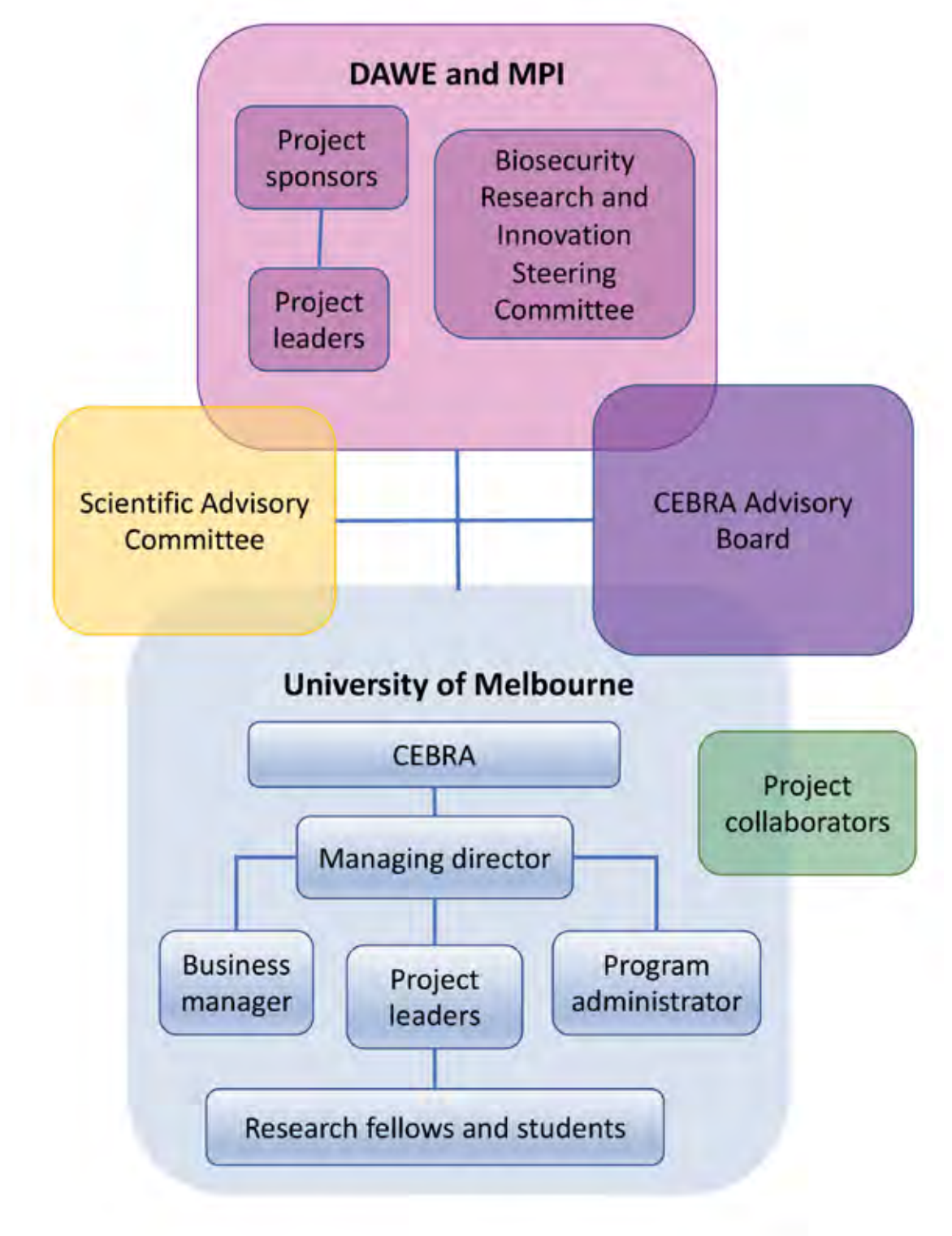
Governance



Governance at CEBRA

CEBRA functions under the oversight of two important committees: the CEBRA Advisory Board (CAB) and the Scientific Advisory Committee (SAC).

CEBRA governance and operational model



CEBRA Advisory Board

The CEBRA Advisory Board was established to monitor and provide advice on CEBRA's:

- research policy framework
- work plans
- progress and performance
- research dissemination and promotion
- application of relevant professional standards

The board includes representatives from the Australian Government, the New Zealand Government and the University of Melbourne, as well as third party representatives across industry, academia and government. A list of board members is provided in Table 4. The board meets four times per year and is overseen by an independent chair.

CAB chair: Dr Colin Grant (2017-21)
Dr Ron Sandland (2013-16)

CEBRA Advisory Board members 2013-21

Table 4: CAB members 2013–2021

Name	Position	Years	Organisation
Professor Peter Bardsley	Board member (host)	2013–14	Department of Economics, The University of Melbourne
Professor Mark Burgman	Board member (ex officio)	2013–16	Director, CEBRA, The University of Melbourne
Ms Sarah Corcoran	Board member	2019–21	Chief executive officer, Plant Health Australia
Dr Vanessa Findlay	Board member	2013–14	Plant Division, Department of Agriculture
Mr Peter Gooday	Board member	2020–21, 2016–17	Assistant secretary, Australian Bureau of Agricultural and Resource Economics and Sciences, Department of Agriculture, Water and the Environment
Dr Colin Grant	Chair	2017–21	Independent
Dr Steve Hatfield-Dodds	Board member	2017–19	Executive director, Australian Bureau of Agricultural and Resource Economics and Sciences, Department of Agriculture, Water and the Environment

Name	Position	Years	Organisation
Dr Marion Healy	Board member	2016–19	First assistant secretary, Biosecurity Plant Division, Department of Agriculture, Water and the Environment
Professor Tom Kompas	Board member (ex officio)	2015–21	CEBRA, The University of Melbourne
Professor Pauline Ladiges	Board member (host)	2013–21	Professor emeritus, Botany, School of BioSciences. The University of Melbourne
Dr Robyn Martin	Board member	2020–21	First assistant secretary, Biosecurity Animal Division, Department of Agriculture, Water and the Environment
Professor Jodie McVernon	Board member (host)	2020–21	Director, Peter Doherty Epidemiology Institute for Infection and Immunity
Professor Anna Meredith	Board member (host)	2020–21	Head, Melbourne Veterinary School, The University of Melbourne
Dr Michael Ormsby	Board member	2019–21	Biosecurity Science and Risk Assessment, Ministry for Primary Industries New Zealand
Professor Aleks Owczarek	Board member (host)	2014–16	Mathematics and Statistics, The University of Melbourne
Associate Professor Roger Paskin	Board member	2013–18	Chief Veterinary Officer, Biosecurity South Australia, Primary Industries and Regions South Australia
Ms Christine Reed	Board member	2013–19	Biosecurity Science and Risk Assessment, Ministry for Primary Industries New Zealand
Dr Kim Ritman	Board member	2014–15	Plant Division, Department of Agriculture
Professor Ian Robertson	Board member (SAC chair)	2017–21	Professor emeritus, Veterinary Epidemiology, College of Veterinary Medicine, Murdoch University
Professor Andrew Robinson	Board member (ex officio)	2013–21	Director, CEBRA, The University of Melbourne
Dr Ron Sandland	Chair	2013–16	Independent
Ms Karen Schneider	Board member	2013–16	ABARES, Department of Agriculture
Professor Helen Sullivan	Board member	2016–19	Director, Crawford School of Public Policy, The Australian National University

Scientific Advisory Committee

The Scientific Advisory Committee (SAC) reviews and approves all draft project plans and provides an assessment of all final reports.

The role of the SAC is to:

- assist the director in evaluating research proposals
- review CEBRA reports
- advise researchers conducting CEBRA projects

SAC reviewers hail from a broad range of fields including environmental, animal and plant sciences; biosecurity; physical, mathematical and social sciences; psychology; philosophy; and statistics.

A breakdown of reviewer attributes is provided in Chart 4.

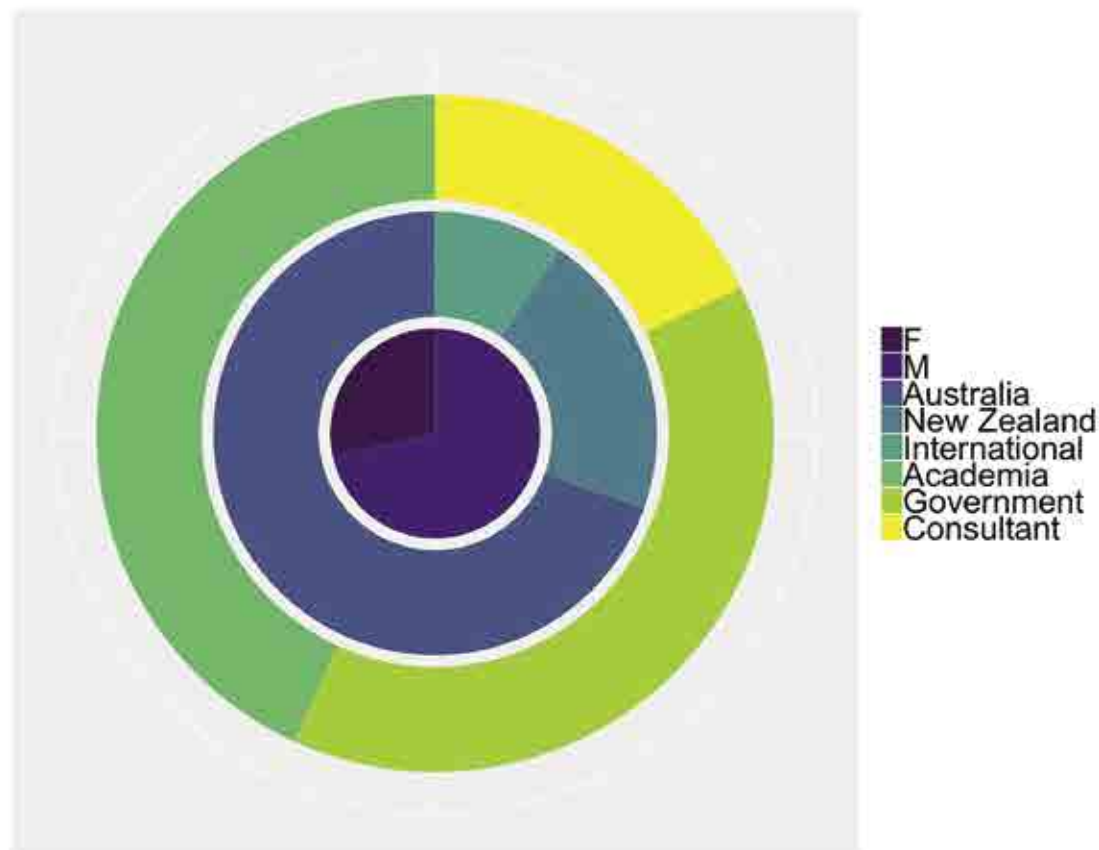


Chart 4: SAC reviewers segmented by sex, location and sector

SAC chair: Professor Ian Robertson (2017-21)
Professor Colin Wilks (2013-17)

ACIL Allen review outcomes

ACIL Allen Consulting was engaged by the Department of Agriculture, Water and the Environment (DAWE) to conduct an independent evaluation of the Centre of Excellence for Biosecurity Risk Analysis (CEBRA) over the period 1 July 2013 to 30 June 2019.

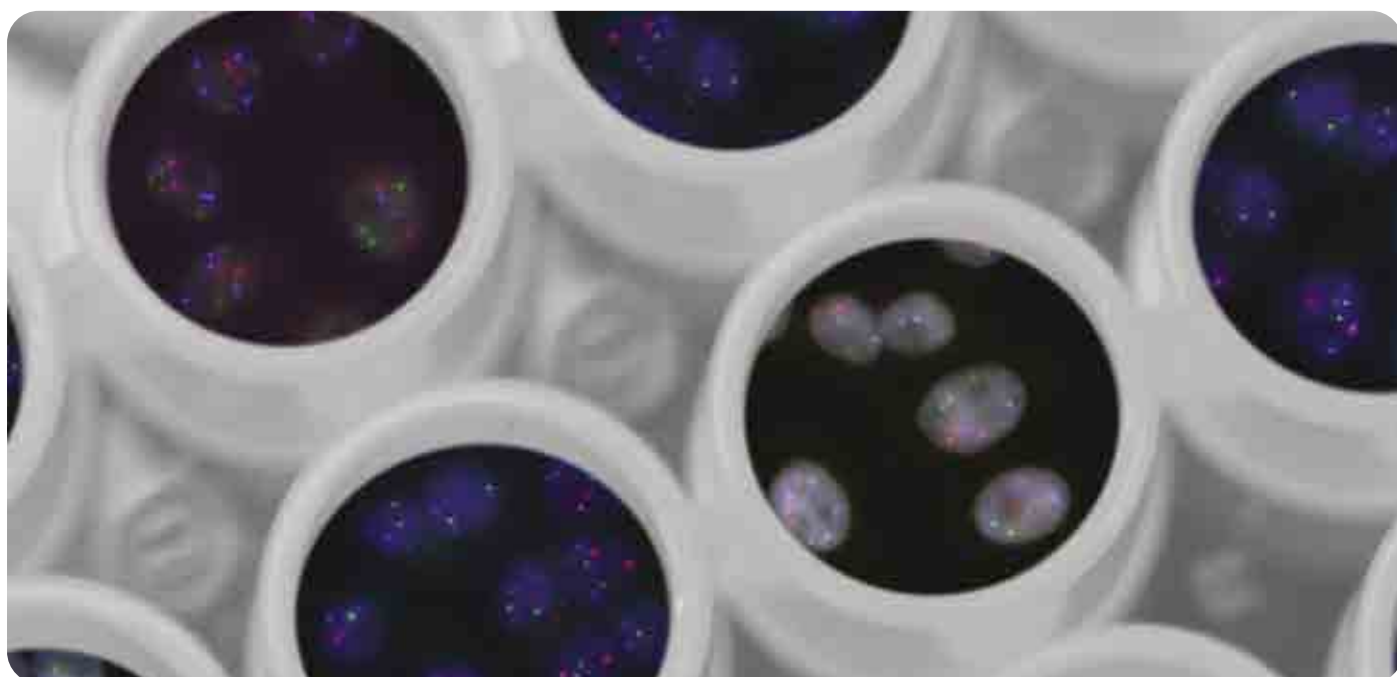
CEBRA provides biosecurity risk research and analysis under a Deed of Agreement with DAWE. It receives funding from both the Australian and New Zealand governments, which are partners in the research process as well as end-users of the centre's research outputs.

Since its establishment, CEBRA's work has grown and its arrangements have evolved. This evaluation considered six key Terms of Reference (ToR) that required consideration of the centre's day-to-day activities as well as its relationships with key stakeholders, its governance arrangements, administration, and research quality. The ToR also required consideration of other models for delivering biosecurity risk research to government.

The ToR were analysed using a combination of standard program evaluation (logic) techniques, best practice principles for governance and grant administration and citation analysis. The evidence used for the evaluation included data held by CEBRA and government, as well as consultation feedback from key stakeholders.

The findings of this review were very positive overall and suggest that CEBRA is meeting the needs of the DAWE and MPI (NZ). The evaluation outcomes suggested that CEBRA is performing against its objectives, and the centre's core activities are being conducted in an efficient and effective manner.

ACIL Allen produced a final report that made a series of recommendations that addressed the ToR of this review. Many of the recommendations were agreed to by DAWE and will be progressed under a new round of grant funding from July 2021 for the continuation of the CEBRA with the University of Melbourne for a further four years, to June 2025.



Financials



Financial summary

During the period 2013–21, CEBRA was primarily funded by the Department of Agriculture, Water and the Environment, the Ministry for Primary Industries and our host, the University of Melbourne. Our expenses included business development, operations, research contracts and salaries.

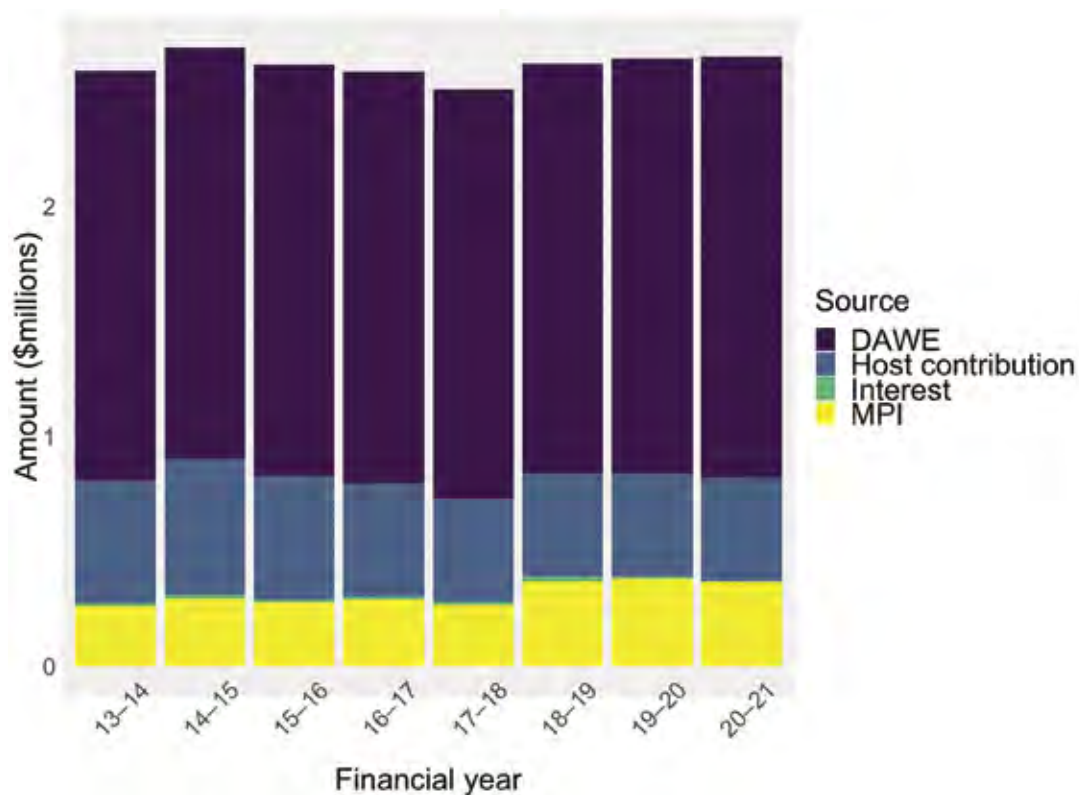


Chart 5: Income by source

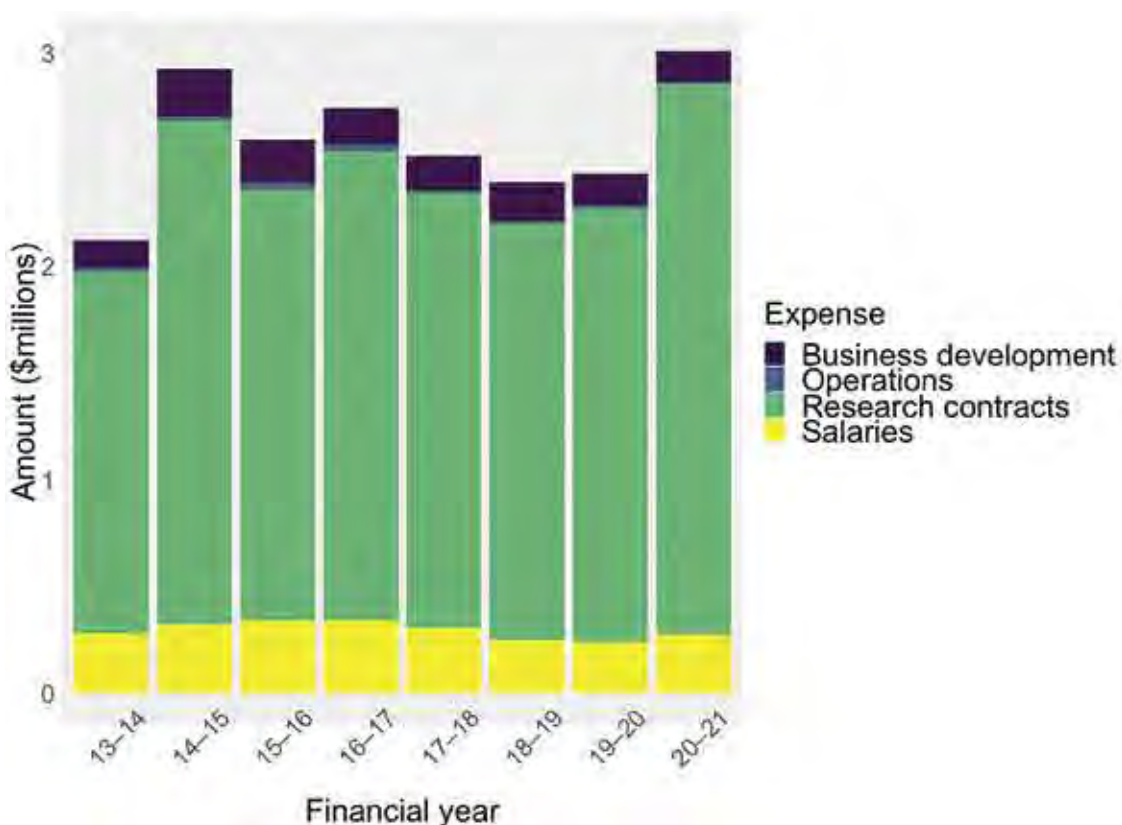


Chart 6: Expenses by type

Institutional grants, contracts and consultancies

CEBRA's important work is recognised and supported by a range of stakeholders and funding bodies. During the period 2013-21, we were awarded a number of grants, contracts and consultancies totalling approximately \$15.5 million.

This additional funding was used for knowledge-building, for the benefit of biosecurity, across Australia, New Zealand and internationally. Our ability to attract this funding indicates the value that many organisations place in CEBRA.

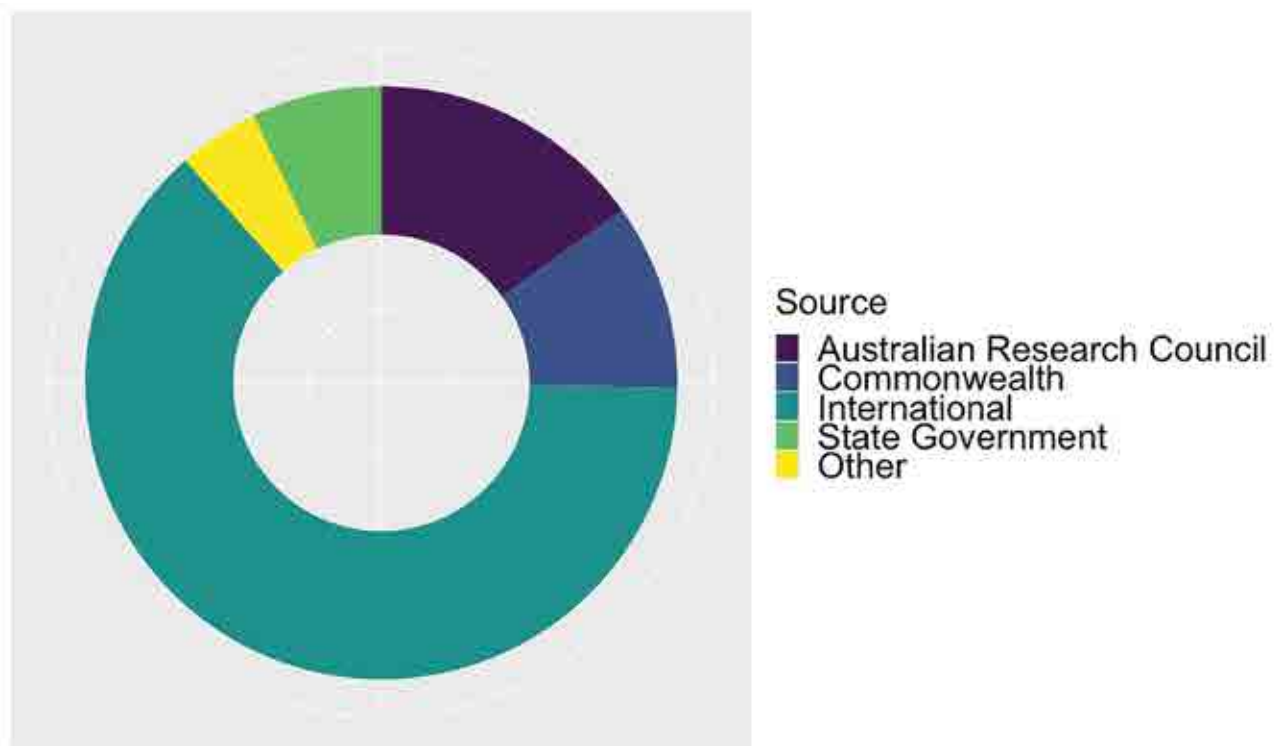
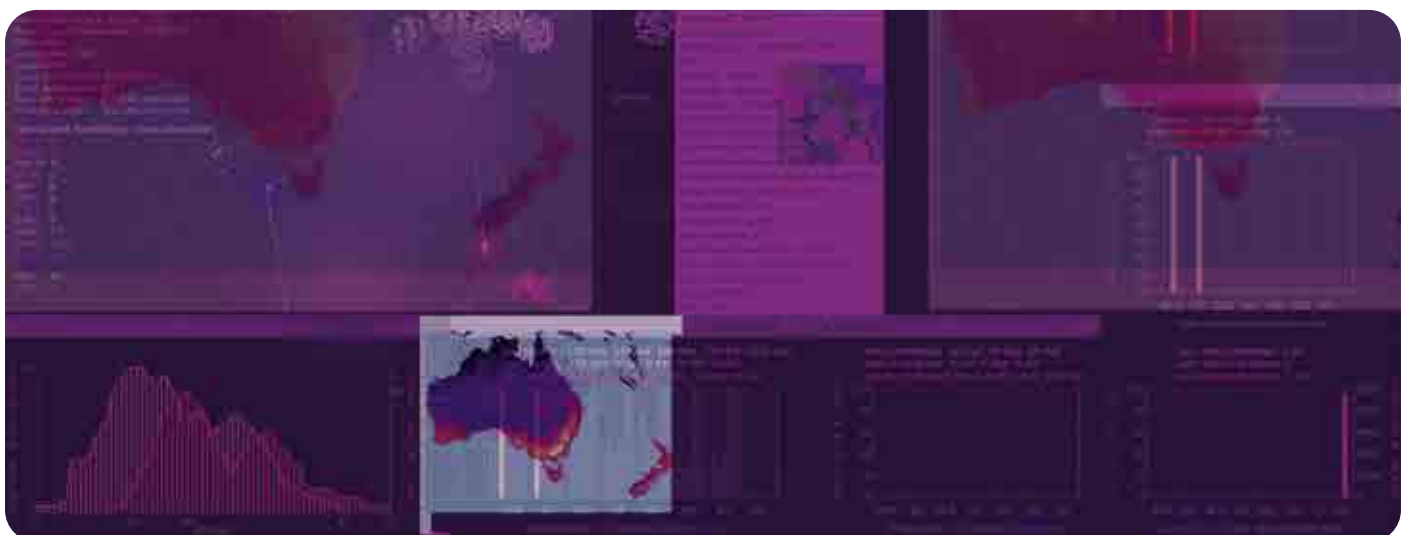


Chart 7: Institutional grants, contracts and consultancies awarded during the period 2013-21.



23 August 2021

INDEPENDENT AUDIT REPORT

TO COMMONWEALTH OF AUSTRALIA – DEPARTMENT OF AGRICULTURE, WATER AND THE ENVIRONMENT(DAWE) IN RELATION TO THE FUNDING AGREEMENT FOR THE CENTRE OF EXCELLENCE FOR BIOSECURITY RISK ANALYSIS (CEBRA)

I advise that an audit has been conducted of the Financial Statement and In-kind Support Statement for the Centre of Excellences for Biosecurity Risk Analysis (CEBRA) the period 1 July 2020 to 30 June 2021.

AUDIT OBJECTIVE

The objective of the audit was to provide an auditor's report in accordance with clause 20.4 of the Funding Deed dated 20 May 2013. Specifically, this includes forming an opinion on whether the financial reports provided under this clause are true and fair and the University of Melbourne has complied with its obligations to expend grant payments in accordance with the Agreement.

AUDIT SCOPE

The audit was conducted in accordance with Australian Auditing Standards to provide reasonable assurance as to whether the financial statements are free of material misstatement. The audit procedures included an examination, on a test basis, of evidence supporting the amounts in the financial statements. The funds form part of the University's overall accounts, which have been audited and signed off by the Victorian Auditor-General's Office.

The prevention and detection of fraudulent activity is the responsibility of University of Melbourne management. Our audit procedures were conducted with a focus on addressing specific objectives from a control systems design perspective. We did not examine all transactions over the defined review period, and while an outcome of these procedures may be the detection of fraud, this was not the objective of the review. As a consequence, we do not provide a guarantee that all errors or omissions, whether intentional or otherwise were detected.

AUDIT OPINION

I confirm that in my opinion:

- the University has incurred \$3,012,106 expenditure on the Project; and
- the contributions of the University are \$450,312 in cash and \$1,198,446 in-kind in accordance with the terms of the Agreement.

The Financial Statement and Summary of In-kind Support Statement signed by the Director of the Centre of Excellence for Biosecurity Risk Analysis (CEBRA), in accordance with the Agreement are attached.



Craig Geddes
Partner
Dench McClean Carlson Pty Ltd

Dench McClean Carlson Pty Ltd ACN 050 237 315 / ABN 42 050 237 315
Level 5, 171 Collins Street, Melbourne Victoria 3000 Australia
Phone: (613) 8617 8141 Mobile 0418 349 570
E-Mail: admin@dmcca.com.au
Website: www.dmcca.com.au

Appendix

Appendix



CEBRA research projects

CEBRA has undertaken a plethora of projects across a range of themes relating to biosecurity risk analysis. Table A provides a list of these projects, together with the final report title and chief investigator.

Table A: CEBRA research projects during the period 2013–21, by theme

Project number	Title	Chief investigator
Theme: Benefit-cost		
1504C	Testing incentive-based drivers for importer compliance	Susie Hester
1504D	Using decision-support tools in emergency animal disease planning and response: Foot-and-mouth disease	Tom Kompas
1404A	Optimal surveillance against foot-and-mouth disease: The case of bulk milk testing in Australia	Tom Kompas
1404C	Testing compliance-based inspection protocols	Susie Hester
1404D	Using decision-support tools in emergency animal disease planning and response: Foot-and-mouth disease	Tom Kompas
1304A	The value of 'early detection' and cost-effective surveillance measures against foot-and-mouth disease	Tom Kompas and Susie Hester
1304B	Making robust decisions with a model subject to severe uncertainty	Mark Burgman
1304C	Incentives for importer choices	Susie Hester
Theme: Building scientific capability		
180702	CEBRA research: Harnessing past and new work to improve uptake and impact of best practice risk analysis approaches in MPI analysis	Susie Hester
170713	Valuing Australia's biosecurity system	Tom Kompas
170714	Evaluating the health of Australia's biosecurity system	Karen Schneider
1607A	Valuing Australia's biosecurity system	Tom Kompas
1607B	Evaluating the health of Australia's biosecurity system	Edith Arndt
Theme: Data and information		
190801	Automated image analysis for identifying biofouling risk on vessels	Nathaniel Bloomfield
190803	Factors that influence vessel biofouling and its prevention and management	Edith Arndt
190804	Re-evaluating management of established pests including the European wasp, <i>Vespula germanica</i> , using biocontrol agents	Susie Hester
190808	Prioritisation of biosecurity risk	Andrew Robinson
190810	Advanced profiling for travellers and mail	Andrew Robinson

170805	The value of passive surveillance and portfolio budget allocations for active surveillance against selected animal diseases in Victoria	Tom Kompas
170820 NZ	Biosecurity response decision-support framework	Susie Hester
1608A	Defensible resource allocation for plant health surveillance: Optimal border and post-border surveillance expenditures	Tom Kompas
1608B	Vector-borne spread of animal disease	Tom Kompas
1608C	Testing incentive-based drivers for importer compliance	Susie Hester
1608D	Incorporating economic components in Australia's FMD modelling capability and evaluating post-outbreak management to support return to trade	Tom Kompas
1608E	Methodology to guide responses to marine pest incursions under the National Environmental Biosecurity Response Agreement	Susie Hester
1608F NZ	Biosecurity response decision-support framework	Susie Hester
Theme: Data and intelligence		
19081002	Advanced profiling	Andrew Robinson
20100201	Review of document assessment processes in relation to their management of biosecurity risk	Nathaniel Bloomfield
20100401	Pathways to adoption for the CEBRA 'value' modelling framework within DAWE	Aaron Dodd
Theme: Data mining		
1501C	Ballast water risk assessment: Exploring new methods for estimating risk using satellite sea surface temperature data and incorporating vessel voyage data	Andrew Robinson
1501E	Compliance and risk-based sampling for horticulture exports	Andrew Robinson
1501F	Performance indicators for border compliance	Andrew Robinson
1401D	AIMS and SAC text mining (scoping study)	Andrew Robinson
1301A	Data mining to improve biosecurity risk profiling	Andrew Robinson
1301B	Analytical assessment of endpoint surveys	Andrew Robinson
1301C	Updating the methods for ballast water risk table construction	Andrew Robinson
Theme: Intelligence		
1503A	Intelligence gathering and analysis: International Biosecurity Intelligence System	Mark Burgman
1503B	Intelligence tools for regulated goods traded via ecommerce	Mark Burgman
1403A	Intelligence gathering and analysis: International Biosecurity Intelligence System	Mark Burgman
1303A	Intelligence gathering and analysis: International Biosecurity Intelligence System (IBIS)	Mark Burgman

Theme: NZ MPI		
20NZ01	Design a statistically valid pathway slippage audit system	Andrew Robinson
20NZ02	Design a framework for responding to inspection success or failure	Andrew Robinson
17062102	Marine pest structural risk model	Andrew Robinson
19NZ02	Impact of evidence on decision-making	Tim van Gelder
19NZ03	Proportional return of interventions: Cost-effective surveillance for the early detection of Gypsy Moth	Tom Kompas
Theme: Pathways		
1505A	Ornamental fish import reform: Risk-based on-arrival fish health surveillance and pathway analysis system	Andrew Robinson
1405A	Ornamental fish import reform – health monitoring program	Andrew Robinson
1405C	Baseline consequence measures for Australia from the Torres Strait Islands pathway to Queensland: Papaya fruit fly, citrus canker and rabies	Tom Kompas
1405D	Illegal logging sampling strategy	Andrew Robinson
1405E NZ	Use of unmanned aerial vehicles for biosecurity surveillance, incursions and response (scoping study)	Susie Hester
1305A	Risk-based management for imported ornamental finfish	Andrew Robinson
1305B	Plant-product pathways and the continuous sampling plan	Andrew Robinson
Theme: Risk analysis (assessment, management and communication)		
20110801	Improving the methodology for rapid consequence assessment of amenity and environmental pests	Susie Hester
20110901	Improved profiling of risks associated with seed interceptions in the international mail pathway	Raphael Trouvé
20111101	Environmental biosecurity risk assessment for conservation areas	Terry Walshe
Theme: Spatial analysis		
1502C NZ	National-level farm demographic data for preparedness of highly infectious livestock disease epidemics	Mark Burgman
1502D	A framework for prioritising plant pests	Susie Hester
1502E	Exposure pathway model for forest surveillance	Tom Kompas
1402A	Development of an expert-based model for improved biofouling risk assessment	Mark Burgman
1402B	Tools and approaches for invasive species distribution modelling for surveillance	Mark Burgman
1402C NZ	National-level farm demographic data for preparedness of highly infectious livestock disease epidemics	Mark Burgman
1302A	Evaluating spatial analysis tools for surveillance and monitoring in marine and terrestrial environments	Mark Burgman

Theme: Strengthening surveillance		
190606	Estimating trading partner exposure risk to new pests or diseases	James Camac
180601 NZ	Alternative approaches to developing assurance about the regulatory compliance of consignments of plant products	Andrew Robinson
170602	Increasing confidence in pre-border risk management	Susie Hester
170604	The Australian Compartmentalisation Program: A new client service model for the agricultural export trade in animals and animal products	Tom Kompas
170606	Developing models for the spread and management of national priority plant pests	Tom Kompas
170607	Developing pragmatic maps of establishment likelihood for plant pests	Andrew Robinson and James Camac
170608	CBIS/CSP sensitivity analysis: Incorporating pre-border information analysis	Susie Hester
170615 NZ	Assessing ant pathways to better inform site selection for ant surveillance	Andrew Robinson
170618 NZ	Improving New Zealand's marine biosecurity surveillance programme	Andrew Robinson
170621	Proportional value of interventions across pathways and layers of the biosecurity system	Andrew Robinson
1606A NZ	Sample size calculations for phytosanitary testing of small lots of seed	Stephen Lane
1606B	Identifying unexpected biosecurity risks	Andrew Robinson
1606C	Risk-mapping import pathways for risk-return opportunities	Andrew Robinson
1606D	Estimating probabilities of pest absence across geographic space	James Camac
1606E NZ	Scoping the value and performance of interventions across the NZ biosecurity system	Andrew Robinson
Theme: Surveillance, diagnostics and screening		
20121001	Using edmaps and Zonation to inform multi-pest early-detection surveillance designs	James Camac
20121501	Modelling the spread and control of African swine fever in domestic and feral pigs	Richard Bradhurst

CEBRA publications with InCites impact factor and number of citations

Table B: CEBRA publications with InCites impact factor and citations as at 21/07/2021

Key CEBRA project-specific publications

	InCites impact factor 2020	No. of citations as at 21/07/21
IN PRESS/EARLY VIEW		
Bradhurst, R, Garner, G, East, I, Death, C, Dodd, A & Kompas, T (in press) <i>Modeling post-outbreak strategies to support proof of freedom from foot-and-mouth disease</i> . BioRxiv 2021/441714 doi.org/10.1101/2021.04.27.441714	n/a	1
Nguyen, HTM, Van Ha, P & Kompas, T (2021) <i>Optimal surveillance against bioinvasions: The sample average approximation method applied to an agent-based spread model</i> . Ecological Applications	4.657	0
Chu, L, Nguyen, HTM, Kompas, T, Dang, K & Bui, T (2021) <i>Rice land protection in a transitional economy: The case of Vietnam</i> . Heliyon	0.46	0
2021		
Baker, CM & Bode, M (2021) <i>Recent advances of quantitative modelling to support invasive species eradication on islands</i> . Conservations Science and Practice 3 (2) doi.org/10.1111/csp2.246	n/a	3
Bloomfield, NJ, Wei, S, Woodham, B, Wilkinson, P & Robinson, AP (2021) <i>Automating the assessment of biofouling in images using expert agreement as a gold standard</i> . Scientific Reports 11:2739s doi.org/10.1038/s41598-021-81011-2	4.379	0
Bradhurst, R, Spring, D, Stanaway, M, Milner, J & Kompas, T (2021) <i>A generalised and scalable framework for modelling incursions, surveillance and control of plant and environmental pests</i> . Environmental Modelling and Software 139, 105004, 1–16 doi.org/10.1016/j.envsoft.2021.105004	5.288	1
Bradhurst, R, Garner, G, Hovari, M, de la Puente, M, Mintiens, K, Yadav, S, Federici, T, Kopacka, I, Stockreiter, S, Kuzmanova, I, Paunov, S, Cacinovic, V, Rubin, M, Szilágyi, J, Szepesiné Kókány, Z, Santi, A, Sordilli, M, Sighinas, L, Spiridon, M, Potocnik, M & Sumption, K (2021) <i>Development of a transboundary model of livestock disease in Europe</i> . Transboundary and Emerging Diseases 1–20 doi.org/10.1111/tbed.14201	5.005	2
Camac, JS, Umbers, KDL, Morgan, JW, Geange, SR, Hanea, A, Slatyer, RA, McDougall, KL, Venn, SE, Vesik, PA, Hoffmann, AA & Nicotra, AB (2021) <i>Predicting species and community responses to global change using structured expert judgement: An Australian mountain ecosystems case study</i> . Global Change Biology 27 (18) pp 4420–4434 doi.org/10.1111/gcb.15750	10.863	1
Costanza, R, Kubiszewski, I, Kompas, T & Sutton, PC (2021) <i>A global metauniversity to lead by design to a sustainable well-being future</i> . Frontiers in Sustainability doi.org/10.3389/frsus.2021.653721 (online)	n/a	0

Costanza, R, Kubiszewski, I, Stoeckl, N & Kompas, T (2021) <i>Pluralistic discounting recognising different capital contributions: An example estimating the net present value of global ecosystem services</i> . Ecological Economics 183, 106961	5.389	0
Dharmarathne, G, Hanea, A & Robinson, AP (2021) <i>Improving the computation of Brier scores for evaluating expert-elicited judgements</i> . Frontiers in Applied Mathematics and Statistics 7:669546 doi.org/10.3389/fams.2021.669546	n/a	0
Grafton, Q, Parslow, J, Kompas, T, Glass, K & Banks, E (2021) <i>Epidemiological modelling of the health and economic effects of COVID-19 control in Australia's second wave</i> . Journal of Public Health (online)	2.341	0
Kapitza, S, Van Ha, P, Kompas, T, Golding, N, Cadenhead, N, Bal, P & Wintle, B (2021) <i>Assessing biophysical and social-economic impacts of climate change on regional avian biodiversity</i> . Scientific Reports 11, 1-10	4.379	0
Knights, K, McCarthy, MA, Camac, J & Guillera-Arroita, G (2021) <i>Efficient effort allocation in line-transect distance sampling of high-density species: When to walk further, measure less-often and gain precision</i> . Methods in Ecology and Evolution 12 pp 962–970	7.781	0
Kompas T, Grafton RQ, Che TN, Chu L & Camac J (2021) <i>Health and economic costs of early and delayed suppression and the unmitigated spread of COVID-19: The case of Australia</i> . PLOS ONE 16 (6): e0252400 doi.org/10.1371/journal.pone.0252400	3.24	0
Peterson, K, Barnes, MD, Jaynes-Smith, C, Cowen, S, Gibson, L, Sims, C, Baker, C & Bode, M (2021) <i>Reconstructing lost ecosystems: a risk analysis framework for planning multispecies reintroductions under severe uncertainty</i> . Journal of Applied Ecology doi.org/10.1111/1365-2664.13965	6.528	0
Piontek, F, Drouet, L, Emmerling, J, Kompas, T, Mejean, A, Otto, C, Rising, J, Soergel, B, Taconet, N & Tavoni, M (2021) <i>From biophysical to economic impacts of climate change: An integrated perspective</i> . Nature Climate Change 11 pp 563–572	25.29	0
Trouvé, R, Osborne, L & Baker, PJ (2021) <i>The effect of species, size, and fire intensity on tree mortality within a catastrophic bushfire complex</i> . Ecological Applications	4.657	0
Trouvé, R & Robinson, AP (2021) <i>Estimating consignment-level infestation rates from the proportion of consignment that failed border inspection: Possibilities and limitations in the presence of overdispersed data</i> . Risk Analysis 41 (6)	4	0
Welsh, M, Turner, J, Epanchin-Niell, R, Monge, J, Soliman, T, Robinson, AP, Kean, J, Phillips, C, Stringer, L, Vereijssen, J, Liebhold, A, Kompas, T, Ormsby, M & Brockerhoff, E (2021) <i>Approaches for estimating benefits and costs of interventions in plant biosecurity across invasion phases</i> . Ecological Applications 31 (5) e02319 doi.org/10.1002/eap.2319	4.657	1
Whyte, J (2021) 'Model structures and structural identifiability: What? Why? How?' in Wood, DR, de Gier, J, Praeger CE, & Tao, T (eds) <i>2019–20 MATRIX annals</i> . Springer, Cham MATRIX book series 4 pp 185–213	n/a	1
Whyte, JM (2021) 'Branching out into structural identifiability analysis with maple: Interactive exploration of uncontrolled linear time-invariant structures' in Corless, R Gerhard, J & Kotsireas I (eds) <i>Maple in mathematics education and research</i> . Springer, Cham Communications in Computer and Information Science	n/a	0
Zaloumis, S, Whyte, JM et al. (2021) <i>An in silico decision-tool to guide optimisation of intravenous artesunate dosing regimens for severe falciparum malaria patients</i> . Antimicrobial Agents and Chemotherapy doi.org/10.1128/AAC.02346-20	5.191	0

2020		
Ahmed, S, LeMay, V, Yanchuk, A, Robinson, A, Marshall, P & Bull, G (2020) <i>Meta-modelling to quantify yields of white spruce and hybrid spruce provenances in the Canadian boreal forest</i> . Forests 11 pp 609 doi.org/10.3390/f11060609	2.633	0
Alahmadi, A, Belet, S, Black, A, Cromer, D, Flegg, JA, House, T, Jayasundara, P, Keith, JM, McCaw, JM, Moss, R, Ross, JV, Shearer, FM, Tun, STT, Walker, J, White, L, Whyte, JM, Yan, AWC & Zarebski, AE (2020) <i>Influencing public health policy with data-informed mathematical models of infectious diseases: Recent developments and new challenges</i> . Epidemics 32 doi.org/10.1016/j.epidem.2020.100393	4.396	9
Arndt, E, Burgman, M, Schneider, K & Robinson, A (2020) 'Working with government – innovative approaches to evidence-based policy-making' in Sutherland, WJ, Brotherton, Peter, NM, Davies, ZG, Ockendon, N, Pettorelli, N & Vickery, JA (eds) <i>Conservation research, policy and practice</i> . Cambridge University Press pp 2016–2229	n/a	0
Bai, M, Flesch, T, Trouvé, R, Coates, T, Butterly, C, Bhatta, B, Hill, J & Chen, D (2020) <i>Gas emissions during cattle manure composting and stockpiling</i> . Journal of Environmental Quality 49 (1)	2.751	8
Bai, M, Impraim, R, Coates, T, Flesch, T, Trouvé, R, vanGrinsven, H, Cao, Y, Hill, J & Chen, D (2020) <i>Lignite effects on NH₃, N₂O, CO₂ and CH₄ emissions during composting of manure</i> . Journal of Environmental Management 271	6.789	12
Firestone, SM, Hayama, Y, Lau, MSY, Yamamoto, T, Nishi, T, Bradhurst, R, Demirhan, H, Stevenson, M & Tsutsui, T (2020) <i>Transmission network reconstruction for foot-and-mouth disease outbreaks incorporating farm-level covariates</i> . PLOS ONE 15 (7) e0235660 doi.org/10.1371/journal.pone.0235660	3.24	5
French, S, Hanea, AM, Bedford, T & Nane, GF (2020) 'Introduction and overview of structured expert judgement' in Hanea, AM, Nane, GF, Bedford, T & French, S (eds) <i>Expert judgement in risk and decision analysis</i> . Springer	n/a	0
Hanea, AM, Nane, GF, Bedford, T & French, T (2020) <i>Expert judgement in risk and decision analysis</i> . Springer	n/a	5
Hanea, AM & Nane, GF (2020) 'An in-depth perspective on the classical model' in Hanea, AM, Nane, GF, Bedford, T & French, S (eds) <i>Expert judgement in risk and decision analysis</i> . Springer	n/a	3
Hemming, V, Hanea, AM, Walshe, T & Burgman, M (2020) <i>Weighting and aggregating expert ecological judgements</i> . Ecological Applications 20 (4)	4.657	10
Marcot, B & Hanea, AM (2020) <i>What is an optimal value of k in k-fold cross-validation in discrete Bayesian network analysis?</i> Computational Statistics	1	17
Marshall, AM, Link, TE, Robinson, AP & Abatzoglou, JT (2020) <i>Higher snowfall intensity is associated with reduced impacts of warming upon winter snow ablation</i> . Geophysical Research Letters 47 (4) doi.org/10.1029/2019GL086409	4.72	2
Nane, GF & Hanea, AM (2020) 'Building on foundations: The SEJ interview with Roger Cooke' in Hanea, AM, Nane, GF, Bedford, T & French, S (eds) <i>Expert judgement in risk and decision analysis</i> . Springer	n/a	0

Nitschke, C, Trouvé, R, Lumsden, LF, Bennett, LT, Fedrigo, M, Robinson, AP & Baker, PJ (2020) <i>Spatial and temporal dynamics of habitat availability and stability for a critically endangered arboreal marsupial: Implications for conservation planning in a fire-prone landscape</i> . Landscape Ecology 35	3.848	2
Pritzkow, C, Williamson, V, Szota, C, Trouvé, R & Arndt, SK (2020) <i>Phenotypic plasticity and genetic adaptation of functional traits influences intra-specific variation in hydraulic efficiency and safety</i> . Tree Physiology 40 (2)	4.196	14
Roscoe, K, Hanea, AM, Jongejan, R & Vroonwelder, T (2020) <i>Levee system reliability modelling: The length effect and Bayesian updating</i> . Safety	0.52	2
Schmitt, A, Trouvé, R, Seynave, I & Lebourgeois, F (2020) <i>Decreasing stand density favors resistance, resilience, and recovery of Quercus petraea trees to a severe drought, particularly on dry sites</i> . Annals of Forest Science	2.583	1
Trouvé, R, Bunyavejchewin, S & Baker, PJ (2020) <i>Disentangling fire intensity and species' susceptibility to fire in a species-rich seasonal tropical forest</i> . Journal of Ecology 108 (4)	6.256	0
Whyte, JM (2020) 'On Using "emerging interest" in scientific literature to inform chemical risk prioritisation' in <i>Proceedings of the 10th International Environmental Modelling and Software Society Congress</i> .	n/a	0
Wu, CH, Dodd, AJ, Hauser, CE & McCarthy, MA (2020) <i>Reallocating budgets among ongoing and emerging conservation projects</i> . Conservation Biology 35 (3) pp 955–966	6.56	1
2019		
Bradhurst, R, Garner, G, East, I, Death, C, Dodd, A & Kompas, T (2019) <i>Management strategies for vaccinated animals after an outbreak of foot-and-mouth disease and the impact on return to trade</i> . PLOS ONE 14 (10), e0223518 doi.org/10.1371/journal.pone.0223518	3.24	4
Briscoe, NJ, Elith, J, Salguero-Gómez, R, Lahoz Monfort, JJ, Camac, JS, J, Giljohann, KM, Holden, M, Hradsky, BA, Kearney, MR, McMahon, S, Phillips, BL, Regan, TJ, Rhodes, JR, Veski, PA, Wintle BA, Yen, JDL & Guillerá-Arroita, G (2019) <i>Forecasting species range dynamics with process-explicit models: Matching methods to applications</i> . Ecology Letters 22 (11) doi.org/10.1111/ele.13348	9.492	52
Fedrigo, M, Stewart, SB, Kasel, S, Levchenko, V, Trouvé, R & Nitschke CR (2019) <i>Radiocarbon dating informs tree fern population dynamics and disturbance history of temperate forests in southeast Australia</i> . Radiocarbon 6 (2)	1.504	12
Firestone, SM, Hayama, Y, Bradhurst, R, Yamamoto, T, Tsutsui, T & Stevenson, MA (2019) <i>Reconstructing foot-and-mouth disease outbreaks: A methods comparison of transmission network models</i> . Nature Scientific Reports 9, 4809. doi.org/10.1038/s41598-019-41103-6	n/a	25
Grafton, R, Doyen, L, Bene, C, Borgomeo, E, Brooks, K, Chu, L, Cumming, G, Dixon, J, Dovers, S, Garrick, D, Helfgott, A, Jiang, Q, Katic, P, Kompas, T, Little, R, Matthews, N, Ringler, C, Squires, D, Steinshamn, S, Villasante, S, Wheeler, S, Williams, J & Wyrwoll, P (2019) <i>Realizing resilience for decision-making</i> . Nature Sustainability 2 pp 917–913	19.346	41
Hanea, AM & Nane, GF 2019 <i>Calibrating experts' probabilistic assessments for improved probabilistic predictions</i> . Safety Science 118 pp 763–771	4.877	7
Hemming, V, Armstrong, N, Burgman, M & Hanea, AM (2019) <i>Improving expert forecasts in reliability: Application and evidence for structured elicitation protocols</i> . Quality and Reliability Engineering International 36 (2) pp 632–641	2.885	11

Hoffmann, AA, Rymer, PD, Bryne, M, Ruthrof, KX, Whinam, J, McGeoch, M, Bergstrom, DM, Guerin, GR, Sparrow, B, Joseph, L, Hill, SJ, Andrew, NR, Camac, JS, Bell, N, Riegler, M, Gardner, JL & Williams, SE (2019) <i>Impacts of recent climate change on terrestrial flora and fauna: Some emerging Australian examples</i> . Austral Ecology 44 (1) pp 3–27 doi.org/10.1111/aec.12674	2.082	55
Hood, Y, Sadler, J, Poldy, J, Starkey, CS, & Robinson, AP (2019) <i>Biosecurity system reforms and the development of a risk-based surveillance and pathway analysis system for ornamental fish imported into Australia</i> . Preventive Veterinary Medicine 167 pp 159–168 doi.org/10.1016/j.prevetmed.2018.11.006	2.67	6
Johnson, S, Hick, P, Robinson, AP, Rimmer, A, Tweedie, A & Becker, J (2019) <i>The impact of pooling samples on surveillance sensitivity for the megalocytivirus infectious spleen and kidney necrosis virus</i> . Transboundary and Emerging Diseases 66 (6) pp 2318–2328 doi.org/10.1111/tbed.13288	5.005	7
Kattge, J, Bönisch, G, Díaz, S et al. (2019) <i>TRY plant trait database – enhanced coverage and open access</i> . Global Change Biology 26 pp 119–188 doi.org/10.1111/gcb.14904	10.863	265
Keith, JM, Spring, D & Kompas, T (2019) <i>Delimiting a species' geographic range using posterior sampling and computational geometry</i> . Scientific Reports 9 (1) no. 8938	4.379	2
Kim, JH & Robinson, AP (2019) <i>Interval-based hypothesis testing and its applications to economics and finance</i> . Econometrics 7 (2) pp 1–21 doi.org/10.3390/econometrics7020021	4.571	5
Kompas, T, Chu, L, Van Ha, P & Spring, D (2019) <i>Budgeting and portfolio allocation for biosecurity measures</i> . The Australian Journal of Agricultural and Resource Economics 63 (3) doi.org/10.1111/1467-8489.12305	2.863	9
Kompas, T & Van Ha, P (2019) <i>The 'curse of dimensionality resolved': The effects of climate change and trade barriers in large dimensional modelling</i> . Economic Modelling 80 pp 103–110	3.127	10
Lane, SE, Cannon, RM, Arthur, AD & Robinson, AP (2019) <i>Sample size for inspection intended to manage risk within mixed consignments</i> . Neobiota 42 pp 59–69 doi.org/10.3897/neobiota.42.29757	3.684	0
Robinson, AP (2019) 'Testing Simulation Models Using Frequentist Statistics' in Beisbart, C & Saam, NJ (eds) <i>Computer simulation validation – Fundamental concepts, methodological frameworks and philosophical perspectives</i> . Springer pp 465–496	n/a	1
Trouvé, R, Bontemps, J-D, Collet, C, Seynave, I & Lebourgeois, F (2019) <i>When do dendrometric rules fail? Insights from 20 years of experimental thinnings on sessile oak in the GIS coop network</i> . Forest Ecology and Management 433	3.558	5
Trouvé, R, Nitschke, CR, Andrieux, L, Willersdorf, T, Robinson, AP & Baker, PJ (2019) <i>Competition drives the decline of a midstorey tree species: Habitat implications for an endangered marsupial</i> . Forest Ecology and Management 447 pp 26–34	3.558	8

Barons, MJ, Hanea, AM, Wright, SK, Baldock, KCR, Wilfert, L, Chandler, D, Dattah, S, Fannon, J, Hartfield, C, Lucas, A, Ollerton, J, Potts, SG & Carreck, NL (2018) <i>Assessment of the response of pollinator abundance to environmental pressures using structured expert elicitation</i> . Journal of Apicultural Research 57 (5) pp 593–604	2.584	9
Bonneau, M, Hauser, CE, Williams, NSG & Cousens, RD (2018) <i>Optimal schedule for monitoring a plant incursion when detection and treatment success vary over time</i> . Biological Invasions 20 pp 741–756	3.133	2
Camac, JS, Condit, R, FitzJohn, RG, McCalman, L, Steinberg, D, Westoby, M, Wright, SJ & Falster, D (2018) Partitioning mortality into growth-dependent and growth-independent hazards across 203 tropical tree species' in <i>Proceedings of the National Academy of Sciences</i> . 115 (49) pp 12459–12464 doi.org/10.1073/pnas.1721040115	11.205	10
Christophersen, A, Deligne, NI, Hanea, A et al (2018) <i>Bayesian network modelling and expert elicitation for probabilistic eruption forecasting: pilot study for Whakaari/White Island, New Zealand</i> . Frontiers in Earth Science doi.org/10.3389/feart.2018.00211	2.031	16
Clarke-Errey, S, Stenekes, N, Kancans, R, Woodland, C, & Robinson, AP (2018) <i>Undelivered risk: a counter-factual analysis of the biosecurity risk avoided by inspecting international mail articles</i> . NeoBiota 40 pp 73–86. doi.org/10.3897/neobiota.40.28840	3.684	1
Decrouez, G & Robinson, AP (2018) <i>Bias-corrected estimation in continuous sampling plans</i> . Risk Analysis 38(1) pp 177–193 doi.org/10.1111/risa.12811	4	4
Esperón-Rodríguez, M, Curran, TJ, Camac JS, Hofmann, RW, Correa-Metrio, A, Barradas, VL (2018) <i>Correlation of drought traits and the predictability of osmotic potential at full leaf turgor in vegetation from New Zealand</i> . Austral Ecology 43 (4) pp 387–408 doi.org/10.1111/aec.12577	2.082	9
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Glossary

- AADIS:** Australian animal disease model
- AARES:** Australasian Agricultural and Resource Economics Society
- ABM:** actionable biosecurity material
- ABS:** Australian Bureau of Statistics
- ABARES:** Australian Bureau of Agricultural and Resource Economics and Sciences
- ABNMS:** Australasian Bayesian Network Modelling Society
- AC BEE:** Australian Centre for Biosecurity and Environmental Economics
- ACERA:** Australian Centre of Excellence for Risk Analysis (precursor of CEBRA)
- AIMS:** agriculture import management system (department cargo intervention database)
- ANAO:** Australian National Audit Office
- ANU:** The Australian National University
- ANZIAM:** Australian and New Zealand Industrial and Applied Mathematics (division of the Australian Mathematical Society)
- APPDIS:** Australian plant pest and disease model
- ARC:** Australian Research Council
- ASF:** African swine fever
- A&I:** Analysis and Intelligence (group within the department)
- BCA:** benefit-cost analysis
- BMSB:** brown marmorated stink bug
- BMT:** bulk-milk testing
- BT:** blue tongue (a disease of ruminants)
- BWRA:** ballast water risk assessment
- BWRT:** ballast water risk tables
- CA:** competent authority
- CAB:** CEBRA Advisory Board
- CASE:** Contention, argument, source, evidence (argument mapping method)
- CBIS:** compliance-based intervention scheme (formerly, compliance-based inspection scheme)
- CC:** citrus canker
- CEBRA:** Centre of Excellence for Biosecurity Risk Analysis
- CEED:** (ARC) Centre of Excellence for Environmental Decisions
- CEER:** Centre for Environmental and Economic Research
- CMD:** Centre for Market Design
- COST:** European Co-operation in Science and Technology Network
- CREATE:** crowdsourcing evidence, argumentation, thinking and evaluation program
- CRC:** cooperative research centre
- CSIRO:** Commonwealth Scientific and Industrial Research Organisation

CSP: continuous sampling plan

DAWE: Department of Agriculture, Water and the Environment

DAWR: Department of Agriculture and Water Resources (precursor of DAWE)

Department: Where not specified, the 'department' refers to DAWE and/or its precursors

DIBP: Department of Immigration and Border Protection (now Home Affairs)

DPIRD: (Western Australia's) Department of Primary Industries and Regional Development

DOC: (New Zealand's) Department of Conservation

EAD: emergency animal disease

EPA: Environmental Protection Agency

EuFMD: The European Commission for the control of foot-and-mouth disease

EuFMDis: European foot-and-mouth disease model

FAO UN: Food and Agriculture Organization of the United Nations

FMD: foot-and-mouth disease

IBIS: international biosecurity intelligence system

IFOA: integrated forestry operations approval

IPRRG: International Pest Risk Research Group

MPI: (New Zealand's) Ministry for Primary Industries

MHRSS: (New Zealand's) Marine High-Risk Site Surveillance Programme

NAPPO: North American Plant Protection Organization

NIAS: National Invasive Ant Surveillance Programme

NIS: non-indigenous marine species

NMV: non-market valuation

NSW: New South Wales

NZ: New Zealand

PIRSA: (South Australia's) Department of Primary Industries and Regions

PFF: papaya fruit fly

PNG: Papua New Guinea

RRRA: Risk-return resource allocation model

SA: South Australia (state)

SAC: Scientific Advisory Committee

SAC: self assessed clearance (in reference to cargo)

SARDI: South Australian Research and Development Institute

SDM: spatial distribution model

SOC: species of concern

SRA-ANZ: Society for Risk Analysis – Australia and New Zealand

TSI: Torres Strait Islands

UNSW: University of New South Wales

WA: Western Australia (state)



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