Australia's Biosecurity Future

Unlocking the next decade of resilience (2020–2030)

animalhealth AUSTRALIA

Plant Health AUSTRALIA

CENTRE FOR INVASIVE SPECIES SOLUTIONS

CSIRO Futures

At CSIRO Futures we bring together science, technology and economics to help governments and businesses develop transformative strategies that tackle their biggest challenges. As the strategic advisory arm of Australia's national science agency, we are uniquely positioned to transform complexity into clarity, uncertainty into opportunity, and insights into action.

CSIRO Health and Biosecurity

CSIRO Health and Biosecurity works together with government, industry and the community to provide leadership and contribute to measurable improvement in Australia's One Health system; enhancing health, social, environmental and economic wellbeing in the face of increased healthcare pressures and global biosecurity threats. Our science and technology innovations aim to address these challenges to ultimately enhance the nation's health system, ease the burden of disease and create new models of healthcare delivery across Australia.

Animal Health Australia

Animal Health Australia (AHA) is the trusted and independent national animal health body in Australia, bringing together government and industry to deliver animal health and biosecurity. With our members we scan the horizon for threats and opportunities, advocate for and drive solutions and take a whole-of-sector approach to ensure the long-term success of Australia's animal health and biosecurity system.

Plant Health Australia

Plant Health Australia (PHA) is recognised nationally and internationally as the independent and trusted coordinator of a robust, shared and integrated Australian plant biosecurity system. PHA achieves this by coordinating strong industry and government partnerships minimising plant pest impacts to our economy, environment and the community while boosting industry productivity and profitability and enhancing market access.

Centre for Invasive Species Solutions

The Centre for Invasive Species Solutions (CISS) is a national collaborative research, development and extension organisation, formed to tackle the ongoing threat from invasive species. We bring government, industry and research partners together to create solutions-focused collaborative RD&E programs and innovation pipelines.

Accessibility

CSIRO is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document, please contact: csiro.au/contact.

Acknowledgement

CSIRO acknowledges the Traditional Owners of the land, sea and waters, of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture, and we pay our respects to their Elders past and present.

The project team is grateful to the many stakeholders who generously gave their time to provide advice and feedback on this report.

Foreword

The world is currently experiencing the impact of a severe biosecurity event. Early in 2020, Australia, along with the rest of the world was hit with a virulent COVID-19 pandemic. The virus, believed to be transmitted from animals to humans, has dramatically affected individuals, communities, industry and economies. Thousands have died and thousands more have been ill. People have had to significantly change how they live and work; many businesses have disappeared, shut down or changed their operating models; and national and global economic growth has experienced a severe contraction. Full recovery is likely to take some years and until a vaccine is produced, it will be uneven and tied to the severity and frequency of new waves of infection. Australia has coped relatively well with this outbreak, but will we be sufficiently prepared to cope with the next incursions?

Australian Governments have long acknowledged the need for a coordinated approach to biosecurity that builds on the natural protection that comes from being an island nation. However, despite significant efforts by governments, industry, not for profit organisations and various players in the community, this paper highlights the alarming fact that annual interceptions of materials that present a biosecurity risk to Australia have increased by almost 50% in the five years to 2017 to just over 37,000. If that is not sufficiently concerning, the paper highlights that the cumulative burden of yet to be eradicated or ineradicable species has also risen considerably in the last decade.

Australia is a small but open nation which relies heavily on trade for its prosperity; it is not surprising that the number of biosecurity incursions has increased along with increases in our trade and travel. Given that these are likely to continue increasing, business as usual will ensure that the burden of biosecurity threats will only continue to escalate.

Business as usual will ensure that the burden of biosecurity threats will only continue to escalate.

Partnering with Animal Health Australia, Plant Health Australia and the Centre for Invasive Species Solutions, CSIRO Futures and CSIRO Health and Biosecurity have produced a succinct and plausible case for the pressing need to transform, rather than just scale up, our biosecurity system.

Given the cost of COVID-19 to Australia, this paper is extraordinarily timely. It merits significant attention and further investigation by all those who have an interest in seeing Australia retain and improve our biosecurity status and our way of life. It is an important reminder and wakeup call that we need to set ourselves up to be able to adequately respond to the biosecurity challenges that an increasingly interconnected world is going to present to us.

It is an important reminder and wakeup call that we need to set ourselves up to be able to adequately respond to the biosecurity challenges that an increasingly interconnected world is going to present to us.

Wendy Craik AM

Panel Chair Priorities for Australia's Biosecurity System 2017. An independent review of the capacity of the national biosecurity system and its underpinning intergovernmental agreement.

Executive summary

About this report

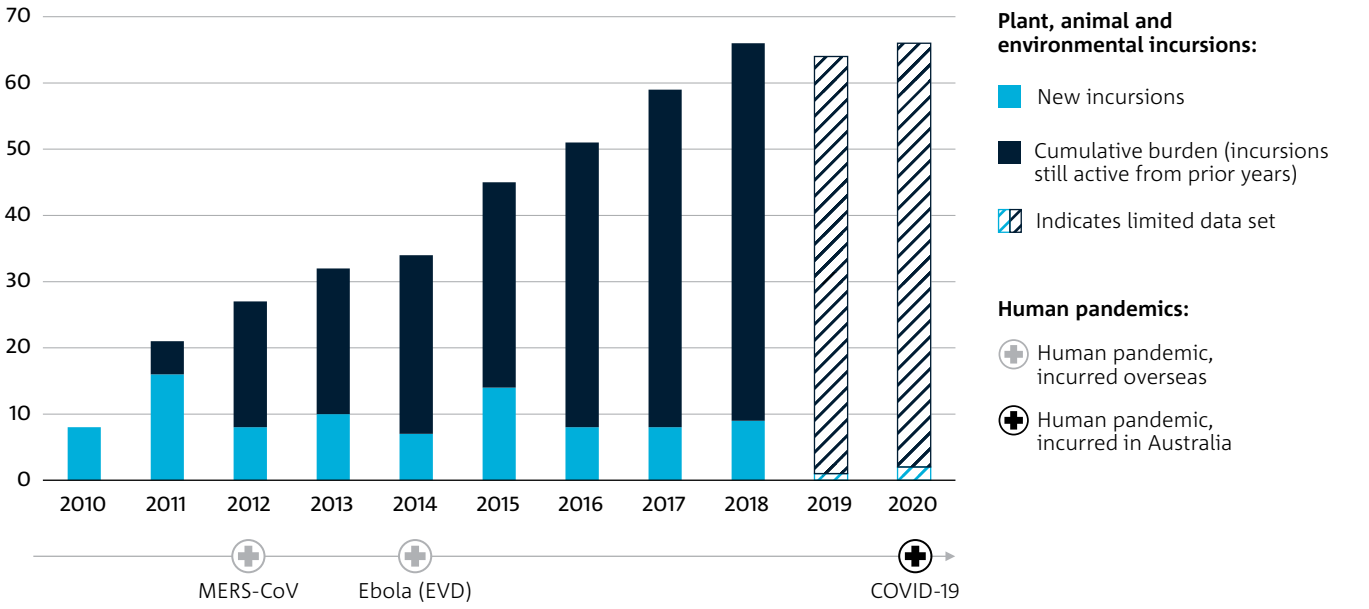
In 2014, CSIRO published *'Australia's Biosecurity Future: Preparing for future biological challenges'*, which identified major biosecurity trends facing Australia's biosecurity landscape, with a focus on an agricultural, environmental and marine biosecurity sector audience. Focusing on the same primary audience, this report seeks to build on the 2014 publication by describing an ideal 2030 future state and identifying actions that can be taken to get there. The report also aims to encourage discussions across government and industry around the importance of cross-disciplinary management of biosecurity risks. The report was developed collaboratively through interviews and workshops with Commonwealth and state governments, research, industry and non-government organisations (NGOs), totalling 57 individuals representing 26 organisations (see Appendix A).

Outbreaks across biosecurity sectors are continuing to rise in volume and complexity

Biosecurity is critical to supporting the health of Australians, their environment and the competitiveness of key industries through biosecure trade networks. While Australia has one of the strongest biosecurity systems globally, outbreaks across human, agriculture, environment and marine health are continuing to rise in volume and complexity. This is due to a range of factors including growing levels of trade and travel, urbanisation, climate change and biodiversity loss.

Between 2012 and 2017, the annual number of interceptions of biosecurity risk materials at Australian borders rose by almost 50%, to 37,014.[1] Figure 1 provides an indication of the number of new incursions in Australia since 2010 as well as the growing cumulative burden created by species which have established and are yet to be eradicated or have been deemed ineradicable.

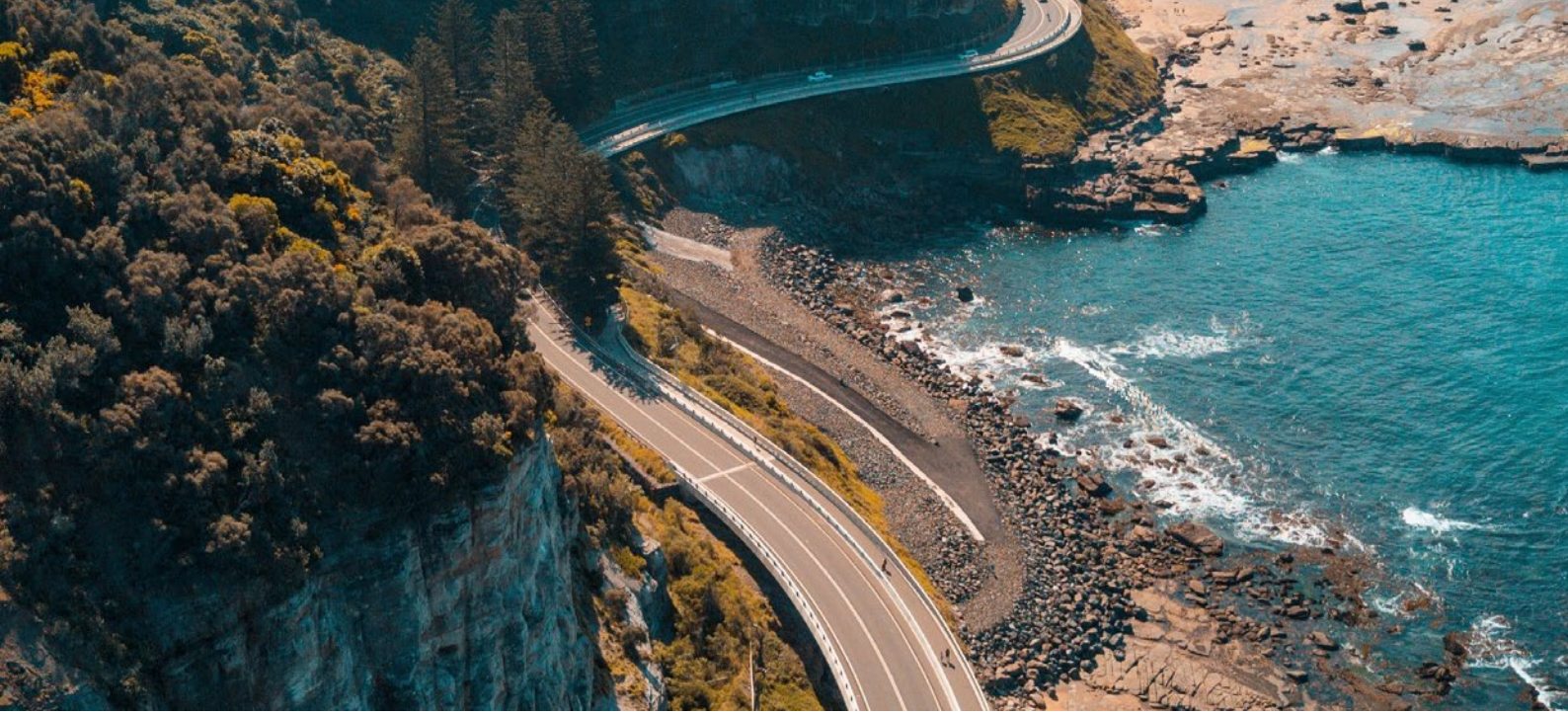
Figure 1: Indicative biosecurity incursions and cumulative burden in Australia[2]



Notes: (1) Incursion and cumulative burden data for years 2019-2020 is limited due to limited data availability (see footnote for sources); expected incursions higher. (2) Animal disease incursion data not included for 2018 due to missing data). (3) Individual incursions differ widely in importance, severity of the issue, and burden of costs and resources. (4) Cumulative burden does not include incursions that initially occurred prior to 2010. (5) Eradicated incursions are not tracked across their active timeframes; cumulative burden is only shown for incursions still active today. (6) 'Transient' marine pest species not listed due to uncertainty of establishment.

1 Inspector-General of Biosecurity (2019) Pest and disease interceptions and incursions in Australia. Department of Agriculture and Water Resources, Canberra.

2 Data sources and timeframes: 2010–2018 data sourced from IGB (2019) Pest and disease interceptions and incursions in Australia, for plant pests and diseases, terrestrial animal diseases, environmental pests, marine pests and aquatic animal diseases. 2019-2020 data sourced from: Commonwealth of Australia (2020) Ehrlichiosis in dogs. Viewed 25 July 2020, <https://www.outbreak.gov.au/current-responses-to-outbreaks/ehrlichiosis-dogs>; Queensland Government DAFF (2019) Varroa mites. Viewed 25 July 2020, <https://www.daf.qld.gov.au/business-priorities/biosecurity/animal-biosecurity-welfare/animal-health-pests-diseases/beekeeping-in-queensland/diseases-and-pests/asian-honey-bees/varroa-mites>; Grains RDC (2020) Fall armyworm. Viewed 25 July 2020, <https://grdc.com.au/resources-and-publications/resources/fall-armyworm>.



Scaling current approaches will not be enough to mitigate these growing risks

While the relatively consistent level of new incursions in Figure 1 is due to Australia's strong biosecurity system, the costly ongoing management of established species coupled with the increasing risk of new incursions is placing growing strain on the system which is already experiencing resourcing challenges. While investments are being made towards some of these challenges, continuing along the 'business as usual' (BAU) trajectory of slow and incremental change could expose Australia to significant triple bottom line risks over the next 10 years.

Scaling the current system through additional funding allocation will not be enough. Modelling shows that even almost tripling investment in interventions out to 2025 will still result in increased residual biosecurity risk compared to 2014–2015 levels.[3] This suggests that the system requires more transformational change in approaches and responsibilities to generate greater efficiencies and effectiveness.

Now is the time for a system re-think

The COVID-19 pandemic has increased community and public awareness of the importance of biosecurity and has enhanced familiarity with broad biosecurity concepts. This presents a unique opportunity to make transformational changes to Australia's biosecurity system while engagement levels are comparatively high.

Preparing Australia for biosecurity resilience in 2030 will require setting nationally coordinated goals across the One Health spectrum (human, agricultural, environmental and marine health sectors). To assist with these discussions, this report describes potential 2030 scenarios for a 'business as usual' and 'transformational' trajectory (Figure 2).

Pursuing the transformational trajectory will require stronger collaboration across governments, industry, research and the community. This report provides 20 recommendations (Figure 3) which aim to highlight priority areas for system improvement. While suggested lead stakeholder groups are provided for each recommendation, all require deeper cross-disciplinary discussions and planning. Recommendations fall under three themes:

- **System connectivity** – Digitising processes, enhancing partnerships and greater data sharing across supply chains and the One Health sectors to facilitate market access and ensure the system is capable of understanding and managing emerging risks and established pests and diseases.
- **Shared responsibility** – Harnessing the collective knowledge and capability of citizens, communities and industries to ensure national biosecurity efforts are optimised; and that all Australians are aware of, and value, their role in managing biosecurity risks.
- **Innovation in science and technology (S&T)** – Creating national innovation platforms for developing and commercialising next-generation technologies and services that target priority biosecurity risks and can be sold globally.

Many of these transformational shifts will take 10 years to plan and successfully implement, meaning collaborative, national action needs to be taken today.

3 Craik W, Palmer D and Sheldrake R (2017) Priorities for Australia's biosecurity system, An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement. Canberra.

Figure 2: Business as usual and Transformation trajectory summary

Business as usual trajectory

Australia's biosecurity system continues to face significant resourcing challenges which are compounded by more frequent pest incursions alongside human, plant and animal disease outbreaks. This harms Australia's reputation as a biosecure trading partner and safe travel destination, which negatively impacts established industries, the environment and the economy. Australia is largely reactionary; with stakeholders sharing intelligence and investing in the system during times of crisis but less so during more stable periods.

Transformational trajectory

Australia is considered the most biosecure trade partner globally. This has been enabled by enhanced data sharing networks, national coordination of biosecurity activities, and investments in new technology applications; all of which have eased resourcing pressures and resulted in a system that more efficiently identifies and manages emerging risks. Engaged communities contribute to surveillance activities, reducing the risks of new incursions or spreading of existing established pests and diseases. Businesses play a greater role in the provision of biosecurity services, enabled by co-developed arrangements with government that ensure criteria around national interests are met.

Declining and stretched	Expertise and infrastructure capability	Up-to-date and adaptive
Response and recovery	System focus	Prevention and detection
Low and slow	Data sharing	High and fast
Under-engaged, one-way	Community and stakeholder engagement	Collaborative, highly informed and engaged
Vulnerable to non-tariff trade barriers	International market access	Increasing export market access
Unaligned and fragmented	Technology development	Strategic
Slow and incremental	Rate of change	Fast and transformational

Figure 3: Enabling themes and recommendations for pursuing the transformational trajectory

Transformational 2030 trajectory

System connectivity

Digitised processes and data sharing

1. Develop procedures and systems for timely biosecurity information exchange
2. Modernise export compliance processes
3. Optimise export protocols through regular assessment of supply chain risk reduction activities

Domestic and international partnerships

4. Develop stronger partnerships within the national system to bolster shared responsibility
5. Strengthen relationships with international counterparts and partners
6. Improve pre-border clearance of imports

Shared responsibility

Community and public engagement

7. Develop and promote a single source of biosecurity information to the public
8. Create robust and verifiable citizen science programs to help engage and empower the public
9. Develop biosecurity education and communication programs to build public and community awareness

Indigenous engagement

10. Make biosecurity engagement with Indigenous communities a more systemic process of the system
11. Empower Indigenous involvement in biosecurity through co-development of fit-for-purpose technology solutions and creation of economic opportunities
12. Increase Indigenous representation at senior decision-making levels

Industry engagement

13. Identify the non-negotiable government conditions and industry incentives associated with privatisation of biosecurity services and activities
14. Invest in social science research to better understand non-compliance behaviours
15. Investigate improvements to incentivise accurate and timely biosecurity detection reporting

Innovation in S&T

Supporting innovation

16. Set national biosecurity innovation priorities
17. Drive development, investment, commercialisation and manufacture of innovative technologies for biosecurity
18. Better integrate social, cultural and ethical considerations into the development, policy and regulation setting of new technologies

Science and technology capability

19. Invest in pathways for the career development and training of biosecurity-relevant specialists and researchers
20. Bolster Australia's vaccine development capability and pipeline

Contents

1 Introduction

Biosecurity enables key trade opportunities and supports the health and wellbeing of all Australians and their environment

Australia's world leading biosecurity system is built on prevention, detection, response and recovery mechanisms to prevent and reduce the impact of pests, weeds and diseases. This includes species not yet in Australia, and those that are already established. Strong biosecurity supports the health and wellbeing of Australian people, resilient communities, healthy ecosystems, and sustainable food systems.

Biosecurity also supports the sustainability, profitability and competitiveness of numerous Australian industries like agriculture, fisheries, forestry, and tourism. Maintaining Australia's strong reputation in the management of many globally important pest and disease risks drives strong economic outcomes by underpinning access to trade partners, supporting the charging of premium prices on exports, and securing domestic supply chains.[4] With the agricultural industry playing an important role in Australia's food security, a robust, resilient and cohesive national biosecurity system is pivotal to enabling the Australian agricultural industry's bold vision of exceeding $100 billion in farm gate output by 2030.[5]

The economic impacts of biosecurity

- Following Australia's first case of COVID-19 in late January, the Australian economy contracted **$1.5 billion** in the March quarter[6] and effective unemployment rose to a peak of 15% in April.[7]
- The environmental biosecurity system protects Australia's environmental assets valued at over **$6.5 trillion**.[8]
- Over **$2.8 billion** – potential costs to the grape vine industries if Xylella – a bacteria known to affect iconic Australian species – established.
- **$5 billion** – potential economic impact of a large multi-state Foot and Mouth Disease (FMD) outbreak each year until it is eradicated.[9]
- Weeds cost Australia around **$5 billion** annually in control measures and lost production.[10] Approximately 20 new weed species establish in Australia every year.[11]

4 Dodd A, et al. (2017) Year one report: Valuing Australia's biosecurity system. CEBRA.

5 National Farmers Federations (2019). 2030 Roadmap: Australian Agriculture's Plan for a $100 Billion Industry.

6 Australian Bureau of Statistics (2020) 5206.0 - Australian National Accounts: National income, expenditure and product, Mar 2020. Canberra. Viewed 28 August 2020, <https://www.abs.gov.au/ausstats/abs@.nsf/mf/5206.0>.

7 Department of the Treasury (2020) Opening statement - July 2020 Senate Select Committee on COVID-19. Viewed 28 August 2020, <https://treasury.gov.au/speech/opening-statement-july-2020-senate-select-committee-covid-19>.

8 Australian Bureau of Statistics (2019) 4655.0 – Australian Environmental-Economic Accounts, Jul 2020. Canberra. Viewed 28 August 2020, <https://www.abs.gov.au/ausstats/abs@.nsf/mf/4655.0>.

9 Buetre B, et al. (2013) Potential socio-economic impacts of an outbreak of foot-and mouth-disease in Australia. ABARES, Canberra.

10 McLeod R (2018) Annual costs of weeds in Australia. Centre for Invasive Species Solutions, Canberra.

11 Dodd AJ, et al. (2015) The changing patterns of plant naturalization in Australia. Diversity and Distributions, 21, 1038-1050. DOI: 10.1111/ddi.12351.

Human, animal and environmental health are all connected – a weakness in one is a vulnerability for all

Pests and diseases can be transferred across organisms and jurisdictions due to the interconnectedness and interdependency of human, agricultural, environmental and marine health sectors (often termed 'One Health'). While management and response approaches often differ across these sectors, stronger relationships and data sharing between sectors can help in the early detection and understanding of risks as they evolve and threaten to impact other sectors. The elevation of environmental biosecurity to equal importance with human and agricultural health in national discussions can also support improved decision-making for the whole biosecurity system. For example, environmental biosecurity in the context of One Health should involve understanding the increasing risks and likelihoods of infectious zoonotic diseases due to environmental destruction, urbanisation, encroachment on natural habitats, increased global trade and travel, and the increased resistance of pathogens to new antimicrobial drugs.[12]

At least 75% of emerging human infectious diseases, such as the SARS, MERS, H1N1 (swine flu – influenza A) and COVID-19 pandemics, originate from animals.[13]

While the wide-reaching impacts of the COVID-19 pandemic have necessarily placed Australia's biosecurity management of human infectious disease under the spotlight, it is critical that this focus does not detract from the required and intrinsically related improvements in agricultural, environmental and marine biosecurity.

Outbreaks across biosecurity sectors are continuing to rise in volume and complexity. The resulting increase in public awareness presents a unique opportunity to transform the system while engagement levels are high.

A resilient and responsive national biosecurity system has never been more important. Between 2012 and 2017, the annual number of interceptions of biosecurity risk materials at Australian borders rose by almost 50%, to 37,014.[14] Figure 4 provides an indication of the number of new incursions in Australia since 2010, as well as the growing cumulative burden created by species which have established and are yet to be eradicated or have been deemed ineradicable. While the relatively consistent level of new incursions in Figure 4 is due to Australia's strong biosecurity system, the costly ongoing management of established species coupled with the increasing risk of new incursions is placing growing strain on the system which is already experiencing resourcing challenges.

While Australia boasts a comparatively strong biosecurity system, scaling the current system through additional funding allocation will not be enough to negate the growing risk from the increased movement of people, animals and goods, and a range of other emerging challenges over the next 10 years (Section 2.2). Modelling shows that even almost tripling investment in interventions out to 2025 will still result in increased residual biosecurity risk compared to 2014–2015 levels.[15] This suggests that the system requires more transformational change in approaches and responsibilities to generate greater efficiencies and effectiveness.

12 United Nations Environment Programme and International Livestock Research Institute (2020) Preventing the next pandemic: Zoonotic diseases and how to break the chain of transmission. Kenya.

13 Johnson I, Hansen A and Bi P (2018) The challenges of implementing an integrated One Health surveillance system in Australia. Zoonoses and public health, 65(1), e229–e236. DOI: 10.1111/zph.12433.

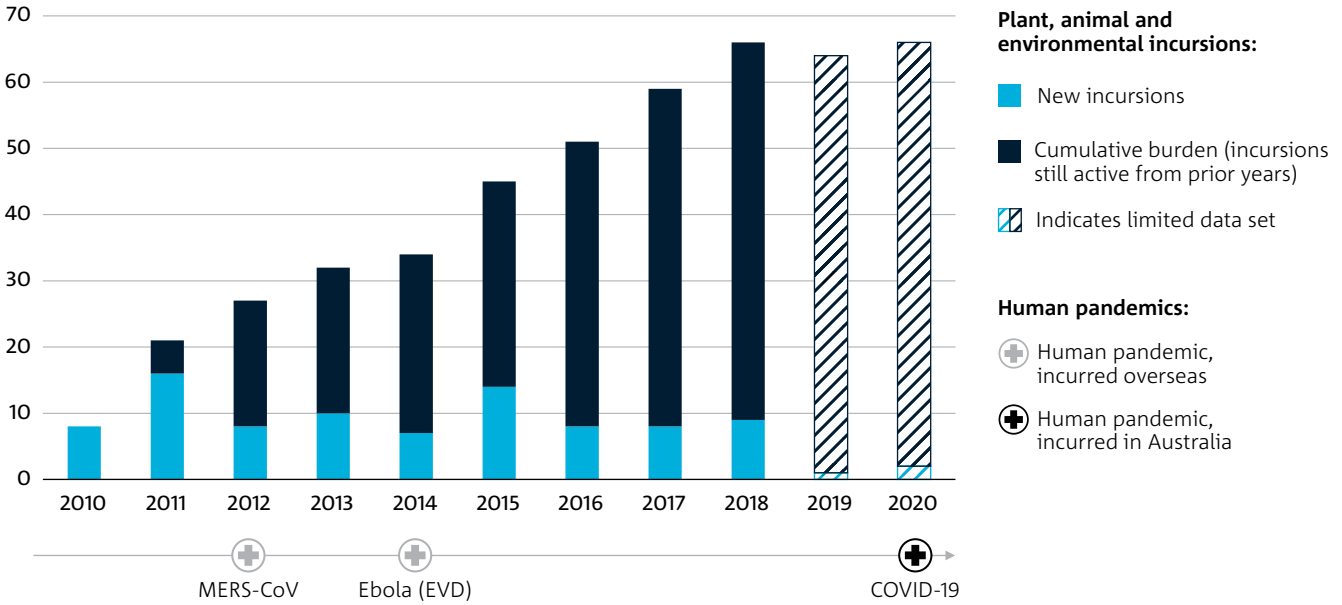
14 Inspector-General of Biosecurity (2019) Pest and disease interceptions and incursions in Australia. Department of Agriculture and Water Resources, Canberra.

15 Craik W, Palmer D and Sheldrake R (2017) Priorities for Australia's biosecurity system: An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement. Canberra.

The COVID-19 pandemic has significantly increased public awareness of general biosecurity concepts and the relationship biosecurity has with the health of individuals and the economy. This, coupled with existing consumer expectation trends (e.g. animal welfare and reduced pesticide usage), presents a critical opportunity to achieve national buy-in for necessary transformational changes.

With each sector within the biosecurity system facing growing risks and increasing resourcing challenges, investments must consider the entirety of the biosecurity system to assist the nation in being better prepared for future incursions of pests and diseases.

Figure 4: Indicative biosecurity incursions and cumulative burden in Australia[16]



Notes: (1) Incursion and cumulative burden data for years 2019-2020 is limited due to limited data availability (see footnote for sources); expected incursions higher. (2) Animal disease incursion data not included for 2018 due to missing data). (3) Individual incursions differ widely in importance, severity of the issue, and burden of costs and resources. (4) Cumulative burden does not include incursions that initially occurred prior to 2010. (5) Eradicated incursions are not tracked across their active timeframes; cumulative burden is only shown for incursions still active today. (6) 'Transient' marine pest species not listed due to uncertainty of establishment.

16 Data sources and timeframes: 2010-2018 data sourced from Inspector-General of Biosecurity (2019) Pest and disease interceptions and incursions in Australia. Department of Agriculture and Water Resources, Canberra. 2019-2020 data sourced from: Commonwealth of Australia (2020) Ehrlichiosis in dogs. Viewed 25 July 2020, <https://www.outbreak.gov.au/current-responses-to-outbreaks/ehrlichiosis-dogs>; Queensland Government DAFF (2019) Varroa mites. Viewed 25 July 2020, <https://www.daf.qld.gov.au/business-priorities/biosecurity/animal-biosecurity-welfare/animal-health-pests-diseases/beekeeping-in-queensland/diseases-and-pests/asian-honey-bees/varroa-mites>; Grains RDC (2020) Fall armyworm: a crop invader on the march. Viewed 25 July 2020, <https://grdc.com.au/resources-and-publications/resources/fall-armyworm>.

2 Australia's biosecurity system

2.1 System overview

Australia has an enviable biosecurity status globally, with key strengths including the nation's natural advantage of being an island continent, robust border control, strong regulations and world-class animal health laboratories with innovative research and development (R&D) capability.[17]

Australia's national biosecurity system has many moving parts with responsibilities often shared (intentionally or otherwise) across levels of government, industry, research, community and biosecurity sectors (i.e. human, agricultural, environmental and marine health) (Figure 5). While these complex governance structures are necessary to a degree and arguably a strength of the system, consulted stakeholders noted that streamlining of responsibilities and organisations could improve ease of system navigation. In addition, involving industry and community at earlier stages of decision-making could better align incentives and efforts across the system while building greater trust and buy-in.

The human health biosecurity sector (e.g. human infectious diseases) often operates separately from the agricultural, environmental and marine biosecurity sectors. This is largely due to the differences in management and response activities for human disease outbreaks when compared to animal, plant and environmental threats. However, this report aims to encourage more integrated discussions and planning across these sectors due to their interconnectedness (e.g. zoonotic diseases).

Figure 5: Australian Biosecurity System: key stakeholder groups

	Agriculture, environmental and marine biosecurity	Human health biosecurity
Government / public sector	DAWE	DoH
	Other federal departments (e.g. DoHA, DFAT)	
	State governments	
	Local governments	
		Public health system
Industry and peak bodies	Transport sector (e.g. airlines, airports, freight)	
	Agriculture industry	Private health system
	Land holders (e.g. primary producers, conservation managers)	
	Trade sector	
	Port operators	
	Peak bodies (AHA, PHA, WHA)	
Other	Research institutions (e.g. CISS, CSIRO, RDCs, PFRAs, universities)	
	Education institutions	
	Indigenous communities*	
	International counterparts and committees	
	General public	

*Note: We acknowledge that many Indigenous individuals and communities consider their status as fundamentally different from other stakeholders in this visual and that this simplified depiction of the system does not reflect the unique connection to Country or biosecurity role that Aboriginal and Torres Strait Islander peoples have.

Acronyms: DAWE – Federal Department of Agriculture, Water and the Environment; DoH – Federal Department of Health; DoHA – Federal Department of Home Affairs; DFAT – Federal Department of Foreign Affairs and Trade; AHA – Animal Health Australia; PHA – Plant Health Australia; WHA – Wildlife health Australia; CISS – Centre for Invasive Species Solutions; RDCs – Rural Research and Development Corporations; PFRA – Publicly Funded Research Agencies.

17 Schneider H, et al. (2015) PVS Evaluable Report Australia. OIE.

2.2 Emerging challenges for Australia's biosecurity system

Despite being one of the strongest biosecurity systems internationally, a range of existing, emerging and growing challenges must be addressed in order to maintain and strengthen this status by 2030. This section provides a summary of key challenge areas identified by consulted stakeholders.

Urbanisation: Increasingly dense urban areas can act as disease incubators and increase disease outbreak risks. In 2018, 55% of the global population (4.2 billion people) lived in urban areas, with that proportion estimated to increase to 68% by 2050.[18] Further, the ongoing expansion of cities is changing interactions between people, wildlife, agriculture and disease vectors; potentially increasing risk of spreading pests and diseases across these boundaries.[19] Fast growing peri-urban regions are also a source of new pest and disease risk as they are often under stewardship of inexperienced or under-engaged owners.

Growing trade and travel: Greater levels and speed of global trade, travel and interstate freight are creating new opportunities for pests and diseases to enter and spread across Australia, as seen with the COVID-19 pandemic. Between 2016 and 2030 international and domestic passenger movements through Australia's capital cities is expected to double.[20] In addition, the volume of freight flown into and out of Australia is projected to increase by 120 per cent from 2014 to 2030.[21] The growth of ecommerce also presents greater opportunity for pest and disease introduction through illegal flora and fauna trade.

Antimicrobial resistance (AMR): AMR presents an ever-growing threat. In 2014 it was estimated that AMR was responsible for 700,000 human deaths globally; and that by 2050 it will be responsible for 10 million deaths annually, with $US100 trillion cumulative cost to the world economy.[22] Currently, Australia's policy and guidelines to monitor or test for AMR in food imports and exports are at an early stage.

Biodiversity loss: Biodiversity loss, largely caused by human activity (e.g. land clearing, invasive species), decreases the resilience of natural environments to pests and diseases and has placed many species on the brink of extinction.[23] Invasive plants, animals and diseases account for 15 of the 21 identified key threatening processes to Australia's native species.[24] In agriculture, the loss of crop diversity can create food security risks in the case of a pest or disease outbreak.

Climate change: Climate change facilitates the movement of pests and disease vectors into new areas and increases the susceptibility of native species to invasive species. For example, climate change may make alpine areas more vulnerable to species such as *Phytophthora*, which are adapted to warmer conditions.[25]

Agricultural intensification: To meet growing food demand, there will be greater agricultural intensification, vertical integration, and expansion into new areas. These changes can impact the resilience of ecosystems and render them more vulnerable to damage from both species not yet in Australia and those that are already established. New crops introduced as the climate changes and Australia attempts to meet the niche food demands of overseas markets may also introduce new pests and diseases. Since 1940, agricultural drivers have been associated with more than 25% of all (and more than 50% of zoonotic) infectious diseases that have emerged in humans.[26]

18 United Nations, Department of Economic and Social Affairs, Population Division (2019). World urbanization prospects: The 2018 revision. United Nations, New York.

19 Cresswell ID and Murphy H (2016) Biodiversity: Key findings. In: Australia state of the environment 2016. Australian Government Department of the Environment and Energy, Canberra.

20 Pre-COVID-19 estimate based on Bureau of Infrastructure, Transport and Regional Economics data, analysis and projections. Bureau of Infrastructure, Transport and Regional Economics (BITRE) (2016) Trends: Transport and Australia's development to 2040 and beyond. Australian Government, Canberra.

21 Pre-COVID-19 estimate based on Bureau of Infrastructure, Transport and Regional Economics data, analysis and projections. Bureau of Infrastructure, Transport and Regional Economics (BITRE) (2014) Trends: Infrastructure and transport. Australian Government, Canberra.

22 O'Neill J (2014) Antimicrobial resistance: Tackling a crisis for the health and wealth of nations. Review on Antimicrobial Resistance, London.

23 Cresswell ID and Murphy H (2016) Biodiversity: Key findings. In: Australia state of the environment 2016. Australian Government Department of the Environment and Energy, Canberra.

24 Department of Agriculture, Water and the Environment (n.d.) Species profile and threats database: listed key threatening processes. Viewed 30 September 2020 <http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl>

25 Burgess T, et al. (2018) Predictors of Phytophthora diversity and community composition in natural areas across diverse Australian ecoregions. https://doi.org/10.1111/ecog.03904

26 Rohr JR, et al. (2019) Emerging human infectious diseases and the links to global food production. Nature Sustainability, 2(6), 445-456. DOI: 10.1038/s41893-019-0293-3.

Data sharing and system connectivity: Data and intelligence sharing between jurisdictions, biosecurity sectors (e.g. human health, agricultural, environmental and marine biosecurity) and industry (e.g. tourism, farming, freight) is limited. This reduces Australia's ability to understand and manage inter-species disease transfers and broader One Health impacts. Within supply chains, consulted stakeholders also mentioned the need for greater transparency around upstream country of origin for both raw and processed products, and faster and more digitised compliance processes to ensure international standards are not used as non-tariff trade barriers.

Resourcing: The biosecurity system is challenged by eroding budgets and declining and uneven biosecurity capability, coordination and expertise across jurisdictions.[27] Examples of declining capabilities include taxonomists, plant pathologists and entomologists.[28] A lack of biosecurity specialists and investment could limit Australia's ability to prevent and respond to shocks.

Commercialisation of new solutions: Biosecurity technology development and commercialisation has historically been hindered by a lack of investment interest, particularly from the private sector, due to small market sizes. Further, biosecurity technology deployment can be limited by a lack of underlying capabilities and skills required to implement and use these innovations.

Social license of emerging technologies: While designed to provide improved biosecurity management, each new technology application will come with its own challenges to manage. Some technologies and policies may have welfare, equity or genetic implications; addressing associated social, cultural and ethical concerns will be critical for ensuring public support. Greater data sharing and system digitisation will require improved cyber security management, and genetics-based technologies will need to ensure near-zero risks around unintentional impacts on the ecosystem (e.g. spread of genetic control mechanisms outside of target species) and bioterrorism (e.g. the genetic engineering of pathogens).

27 Craik W, Palmer D and Sheldrake R (2017) Priorities for Australia's biosecurity system, An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement. Canberra.

28 Srinivasan S and Simpson M (2014) Australia's Biosecurity Future. CSIRO.

3 Australian biosecurity trajectories to 2030

How Australia responds to the existing and emerging biosecurity challenges of today will significantly impact the next 10 years. This section presents an overview of two potential but plausible future scenarios for Australia's biosecurity system in 2030, developed based on consultation with stakeholders from across the system. While Australia's current system performs strongly against international standards, stakeholders believed that this would not be the case by 2030 without transformational change.

Business as usual trajectory

Australia's biosecurity system continues to face significant resourcing challenges which are compounded by more frequent pest incursions alongside human, plant and animal disease outbreaks. This harms Australia's reputation as a biosecure trading partner and safe travel destination, which negatively impacts established industries, the environment and the economy. Australia is largely reactionary; with stakeholders sharing intelligence and investing in the system during times of crisis but less so during more stable periods.

Transformational trajectory

Australia is considered the most biosecure trade partner globally. This has been enabled by enhanced data sharing networks, national coordination of biosecurity activities, and investments in new technology applications; all of which have eased resourcing pressures and resulted in a system that more efficiently identifies and manages emerging risks. Engaged communities contribute to surveillance activities, reducing the risks of new incursions or spreading of existing established pests and diseases. Businesses play a greater role in the provision of biosecurity services, enabled by co-developed arrangements with government that ensure criteria around national interests are met.

Declining and stretched	Expertise and infrastructure capability	Up-to-date and adaptive
Response and recovery	System focus	Prevention and detection
Low and slow	Data sharing	High and fast
Under-engaged, one-way	Community and stakeholder engagement	Collaborative, highly informed and engaged
Vulnerable to non-tariff trade barriers	International market access	Increasing export market access
Unaligned and fragmented	Technology development	Strategic
Slow and incremental	Rate of change	Fast and transformational

3.1 Business as usual trajectory

A disconnected and overly reactive system

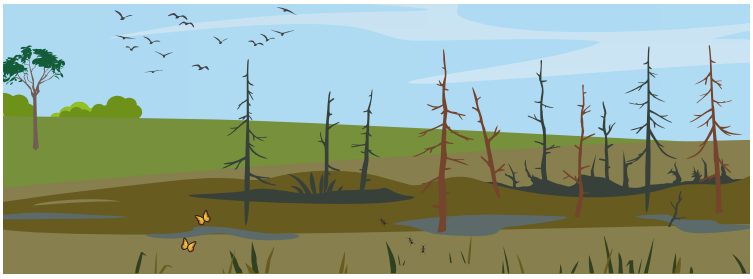
- Inconsistent and uncoordinated prevention and response activities between jurisdictions lead to reduced effectiveness of the system; delaying timely responses to new threats and causing duplication of efforts.
- Shared responsibility continues to be a principle of the biosecurity system; however, it remains poorly defined, understood, accepted and implemented. There is also uncertain responsibility over environmental biosecurity resourcing and efforts.
- Human health remains detached from other biosecurity information flows making it difficult to understand the highest likelihood risks of emerging zoonotic diseases abroad.
- Response and recovery activities from mounting incursions and the spread of damaging impacts of established pests and diseases (zoonotic, animal and plant) require increasing investment and divert resources from vital prevention activities.

An under-engaged community

- Community engagement and public communications by institutions has been limited, one-way and uncoordinated. This has left many unheard and excluded as critical actors in effective surveillance and management of pests, weeds and diseases.
- The social licence to prevent and control pests and diseases is slowly withdrawn and the work defunded as the community fails to understand its impact as incursions continue to mount. The use of pesticides, herbicides and insecticides, even where used cautiously and deemed appropriate by environmental authorities, is severely limited.

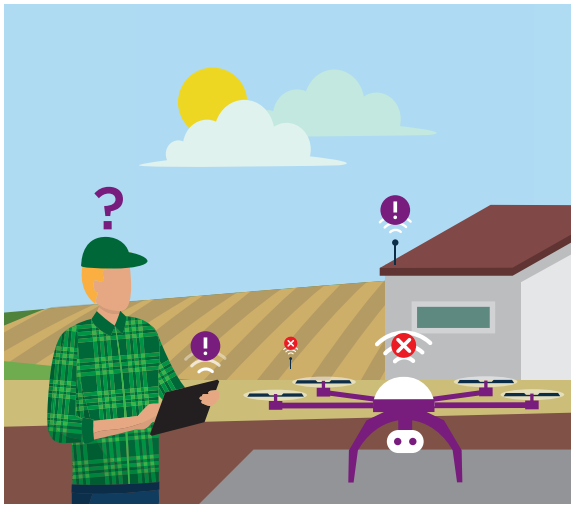
Decline in biodiversity

- Major plant groups such as eucalyptus and acacia suffer mass die-offs from exotic pathogens. Small mammals, birds, frogs and lizards become extinct due to invasive species, and island biodiversity and endemism is progressively lost.



Growing trade barriers

- Australia's reputation as an exporter of high-quality safe food products is jeopardised by a heightened risk of high-impact diseases such as Foot and Mouth Disease, African Swine Fever (ASF) and Xylella; a growing number (and spread) of established pests within Australian borders; and an inability to show proof of pest and disease freedom in a timely manner. This results in reduced demand for Australian exports and many shipments being rejected at destination ports.
- Incursions and a lack of robust compliance systems to prove export integrity have rendered the country more vulnerable to experiencing non-tariff trade barriers related to biosecurity; and place it in a weaker position to deny high-risk imports from overseas.

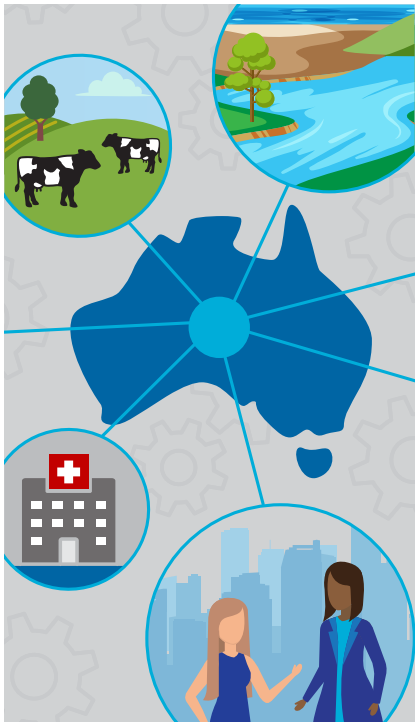


Fragmented technology development

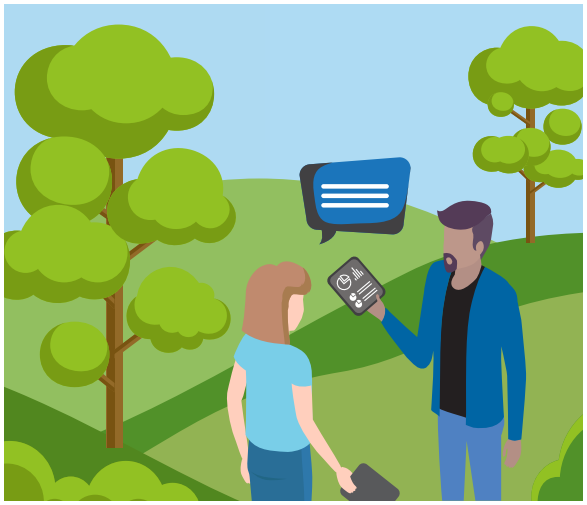
- Biosecurity innovation continues to be challenged by small market sizes failing to attract investors and limited national coordination and collaboration. Investment in research continues to be focused on sectors of commercial return while public interest biosecurity research remains focused on widely known established pest and weeds.
- Australia fails to invest to support vital information and communications technology infrastructure (e.g. an agreed national biosecurity data sharing, tracing and foresighting system).
- Insubstantial training and acceptance by on-the-ground users limits on-farm technology uptake and the effectiveness of citizen science initiatives.

3.2 Transformational trajectory

A nationally coordinated system with a greater prevention focus



- Coordination across governments, industry, and communities has improved; with conservation groups, non-government organisations, Indigenous communities and key biosecurity beneficiaries deeply integrated into system operations and senior decision making. Critically, this has been enabled by the development of agreed shared responsibility principles and practices that meet the values and imperatives of all stakeholders.
- Sharing of critical information, resources and expertise between jurisdictions, departments and biosecurity sectors enables coordinated prevention activities, targeted research initiatives, readiness training and rapid response to incursions which now occur less often. Sharing of response and recovery learnings across sectors facilitates improved preparedness regarding emerging threats.
- Businesses play a greater role in the delivery of biosecurity services, including surveillance, risk assessments and the development of biosecurity management plans for industry. These are delivered under co-developed arrangements with government that ensure criteria around national interests are met.
- Managing the risks associated with a rapidly changing climate is a strategic focus of the system's prevention and detection activities, while also improving the management of established pests and diseases.



Engaged and mobilised communities

- Consistent public messaging and tailored two-way engagement with communities has facilitated greater understanding of biosecurity issues and consequences, which in turn creates support for cross-sectoral national biosecurity investments.
- Informed and engaged communities prioritise buying products from supply chains and regions that can guarantee low biosecurity risk inputs and processes.
- Communities are mobilised through a series of community engagement initiatives, including the co-development of surveillance priorities with local Indigenous communities and scalable app-based citizen science programs that allow individuals to actively contribute to biosecurity surveillance of their local environment.

Improved environmental health

- The enhanced representation of environmental interests within key policy decisions drives better biosecurity and biodiversity outcomes for the environment; improving ecosystem health and providing greater resilience to the growing impacts of global warming.
- Australia becomes a world-leader of pest and weed eradication for high conservation value regions; a capability that can be sold globally.

Open and biosecure trade pathways

- Australia is considered the most biosecure trade partner globally, with the nation's automated biosecurity surveillance and compliance systems providing rapid and clear evidence of the pest- and disease-free status of produce. This facilitates strong export resilience and greater national coordination, leading to clearer frameworks for negotiating low-risk international trade agreements that enhance both environmental and economic outcomes.
- Australia has fostered effective relationships with international partners allowing sharing of best-practice knowledge and critical emerging risk information, and influence over international standards.
- Improved understanding and uptake of biosecurity measures by farmers, tourism operators, utility providers, and national parks and gardens supports stronger risk management across critical supply chains.

Accelerated technology development and applications that can be sold to the world

- As governments increase their focus on Australia's biosecurity resilience and communities place more pressure on industry to implement stronger biosecurity practices, investors see biosecurity technology and associated services as an attractive opportunity to service growing global demand.
- Strategic allocation of government and private funding is used to boost science and technology development to meet needs for greater efficiency, improved detection and surveillance, and better systems for autonomous biosecurity monitoring and compliance. Uptake is optimised by effective deployment campaigns and nationwide access to low cost broadband internet, which allows significantly improved rural and remote biosecurity surveillance and response.
- New disruptive technologies are delivered through innovative private enterprises with service-based business models. These technologies and services are also exported, providing revenue to Australian companies and contributing to global biosecurity efforts.

Conversation starters

The following questions are designed to encourage further exploration of the differences between Australia's current trajectory and the positive outcomes that could be reached through transformational system changes.

- How would major outbreaks of FMD, ASF or Xylella be managed under each trajectory if they occurred alongside a human health pandemic that had resulted in physical distancing protocols across the nation?
- What adjacent sectors and their associated data streams could biosecurity sectors benefit from creating linkages with under the transformational trajectory?
- How could the transformational trajectory help facilitate market access during times of geopolitical instability and greater protectionist policies?

4 Recommendations: Unlocking Australia's transformational biosecurity trajectory

Decisive action must be taken if Australia's biosecurity system is to achieve the transformational 2030 trajectory; remaining world-class and curbing the trend of an increasing cumulative burden of incursions and established pests, weeds and diseases.

This chapter presents a range of recommendations informed by consulted stakeholders that aim to address system challenges and pursue a more efficient and effective approach to managing Australia's biosecurity. Many of the recommendations are designed to promote or enable additional prevention and preparedness activities. While each biosecurity threat is different, in general, prevention and early detection has greater economic returns than eradication and management activities,[29] with savings increasing over time as the value of avoided impacts accumulates.

Recommendations are presented under three themes; system connectivity, shared responsibility and innovation in science and technology. In some cases, the recommendations describe concepts relating to existing efforts that could be further replicated, scaled or applied to other areas of the biosecurity system. In other cases, the recommendations describe new initiatives. Suggested leads and support stakeholder groups are provided as guidance for each action to help outline potential champions of change; however, implementation of all actions would benefit from an inclusive engagement process that covers the One Health spectrum.

Figure 6: Recommendation themes

29 Craik W, Palmer D and Sheldrake R (2017) Priorities for Australia's biosecurity system: An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement. Canberra.

4.1 System connectivity

Digitised processes and data sharing

Domestic and international partnerships

The transformational 2030 trajectory describes a future where the interconnectivity and interdependence between human, agricultural, environmental and marine health are reflected in the coordination of policies, regulations and information sharing between jurisdictions, biosecurity sectors and industry. Timely information sharing across these groups is critical for earlier detection and response to emerging risks, avoiding duplication of efforts, more efficient use of resources, and prioritising investment in innovation projects that can address incoming risks before an incursion overwhelms a region or sector.

Digitised processes and data sharing

Facilitating the shift towards the transformational trajectory will involve system digitisation and interoperability, improved data collection from current levels,[30] greater analytics to support biosecurity claims, and demonstrating the successful application of secure and valuable intelligence sharing platforms that negate industry concerns over data privacy and intellectual property. The AUSPestCheck system, for example, allows the real-time sharing of pest and weed reports from users across the country based on set data sharing rules, and provides updates on significant pest developments.[31] Surveillance and data sharing systems that span across various stakeholder groups - including managers of Indigenous protected areas, national parks, and botanic gardens – could increase geographic coverage and improve system coordination.

Ensuring connectivity and intelligence sharing extends to international trade partners will also be important for supporting market access of key commodities. Faster and more accurate compliance data can help reduce the risk that biosecurity acts as a non-tariff barrier; and will support national industry goals such as exceeding $100 billion in farm gate output by 2030.[32]

Case Study 1: One Health Wildlife Health Information System

Australia's wildlife health information system[33] captures, analyses and disseminates information on six categories of diseases across health, environment and biosecurity. Over 50 agencies and organisations, both government and non-government, are involved from all jurisdictions including the Australian Antarctic Territory.

A management committee provides leadership and a small number of dedicated staff steward, facilitate and coordinate the trust-based relationships and collaborations needed to help manage the adverse effects of wildlife diseases on Australia's environment, biodiversity, animal and human health, trade and tourism. This is achieved by generating norms and standards for monitoring, surveillance, and on-ground action. The initiative also develops tools and resources for use in research, surveillance, preparedness and response, communications, outreach, and education.

30 Inspector-General of Biosecurity (2019) Pest and disease interceptions and incursions in Australia. Department of Agriculture and Water Resources, Canberra.

31 Plant Health Australia (n.d.) AUSPestCheck. Viewed 25 August 2020, <https://www.planthealthaustralia.com.au/resources/auspestcheck/>

32 National Farmers Federations (2019) 2030 Roadmap - Australian agriculture's plan for a $100 billion industry.

33 Wildlife Health Australia (2020) WHA coordinators (general surveillance). Viewed 28 August 2020, <https://www.wildlifehealthaustralia.com.au/ProgramsProjects/WHACoordinators(GeneralSurveillance).aspx>

Image: Dr. Rohan Kimber (SARDI) demonstrating the prototype smart surveillance unit, Sentinel 1.

Table 1: Recommendations for digitising processes and data sharing

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
1	**Develop procedures and systems for timely biosecurity information exchange**		
	Bringing together disparate datasets from across the human, agricultural, environmental and marine health sectors, as well as government, industry and research, could assist in providing contextually relevant information to facilitate better prioritisation of efforts across the system. Shared data could include geospatial data on high-risk detections, pre-border risk notifications, trade volumes from partner countries and climate data. Such systems will need to be underpinned by interoperable and integrated information sharing networks with agreed data standards and sharing protocols that address concerns associated with privacy, commercial sensitivity and trade implications. Identifying appropriate national pilot programs focussed on discrete risks to explore legislative, privacy, ownership and technological constraints on secure data sharing would be an appropriate first step before scaling. In future, information sharing systems could also incorporate citizen science contributions and be used to provide information to the public (see recommendations 7 and 8).	Governments, research institutions, peak bodies	Industry, community
2	**Modernise export compliance processes**		
	While Australia's biosecurity system is world class, the current paper-based system of handling export compliance (registrations, sign-offs, audits, certification) is costly, too complex, and will not easily scale to meet industry growth aspirations. The digitisation of compliance documentation and automation of the data packages needed for export certification will streamline regulatory process for both producers and government, and build the ongoing trust needed to grow market access. Similar systems to simplify and automate certification processes can be applied for interstate trade.	Industry, research institutions	Commonwealth government
3	**Optimise export protocols through regular assessment of supply chain risk reduction activities**		
	Better understanding the risk reduction activities applied at each point of a supply chain can help develop optimised export protocols. Regular assessment of these activities is required to ensure the impacts of new technologies and practices on risk profiles are considered as they arise. Furthermore, risk management systems could integrate the management of multiple risks (e.g. biosecurity, food safety). This will allow data to be used more efficiently, allow greater flexibility in how risk is controlled, and help maintain Australia's competitiveness in the premium market. New digital platforms for compliance will enable the data integration needed to implement these new approaches.	Industry, research institutions	Commonwealth government

Science and technology: Intelligent surveillance platforms

Interoperable systems and platforms that can combine and translate multiple data types from across the country into useful evidence-based insights would be highly beneficial for biosecurity decision-making. Systems in this class will likely make use of big data technology to collate diverse data feeds, alongside artificial intelligence (AI) and machine learning systems to automate data analysis and support decision-making. In the case of systems that incorporate citizen science, AI-driven verification of data reported by users could yield significant accuracy improvements with minimal additional resource strain.

The Technology Readiness Level (TRL) of this technology (see Appendix B) varies widely depending on the level of system capability in question. R&D priorities for AI and Machine Learning to enhance decision-making include auditing applicable datasets to build data interrogation strategies; developing systems to synthesise intelligence from unstructured datasets; designing and creating algorithms for sampling in specific targets contexts (e.g. in airborne/satellite imaging); and developing core technology sensitivity to discern between meaningful and negligible information.

Science and technology: Traceability systems

While Australia's agricultural industry is an early user and developer of traceability systems to demonstrate food safety, there is still significant room to develop technologies that provide greater coverage and transparency of Australian product value chains. Technology has the potential to provide improved export-orientated market access and growth for the industry by building global trust in Australian regulatory processes.[34]

There are many noteworthy Australian examples of supply chain provenance-based technologies and systems, including the National Livestock Identification System (NLIS). This system uses NLIS approved devices to allow identification and tracking of cattle, sheep and goats, with movement recorded centrally on the NLIS database.[35]

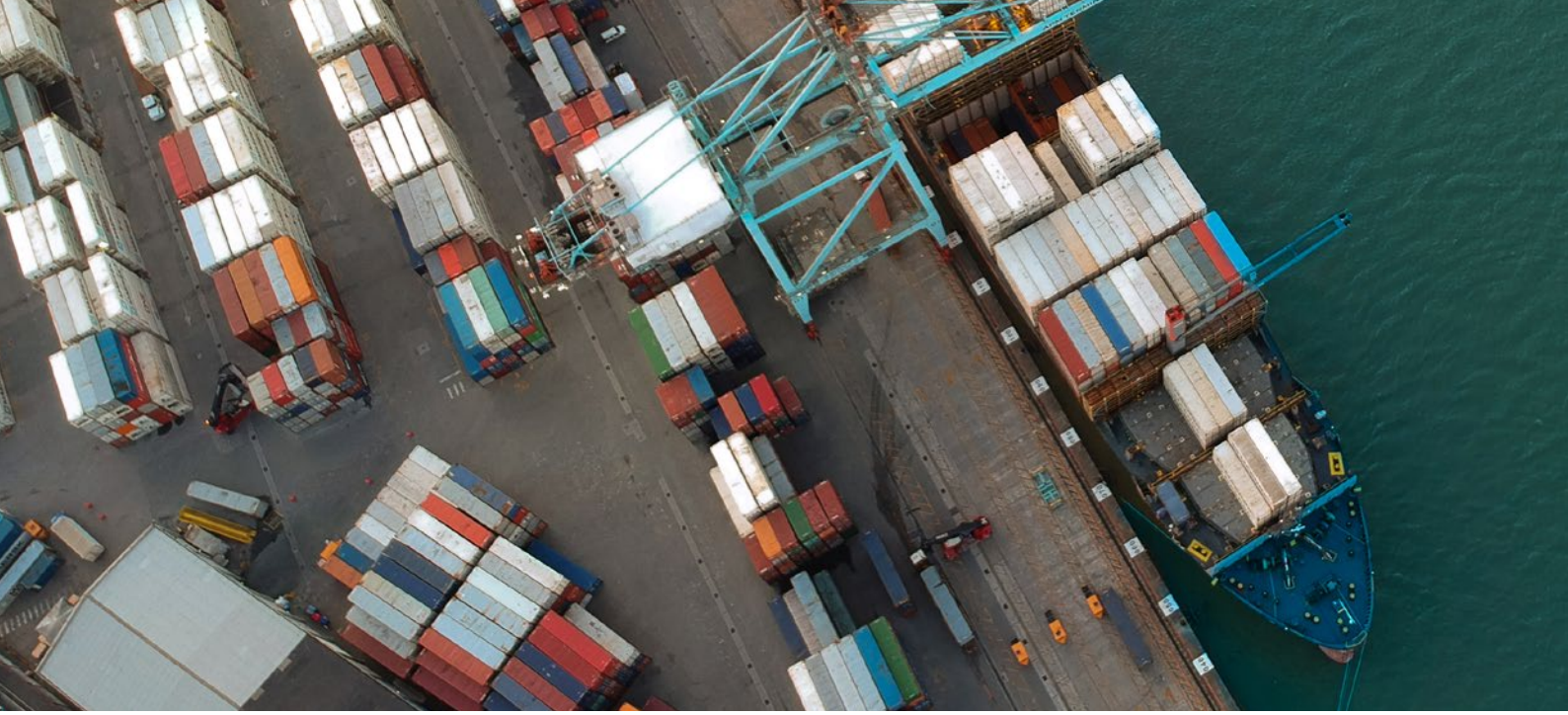
The Victorian Government's Growing Food and Fibre Markets (GFFM) is another example, which aims to support market access and supply chain traceability through uptake of new diagnostic, verification and sensor technologies to assure export product integrity and meet future expectations of trading partners.[36] Benefits of enhancing Australia's traceability systems include improving marketability, market development and access, and strengthening the ability to respond to biosecurity incidents.[37] Traceability of Australia's imports and exports can provide confidence in the biosecurity status of the country of origin, thereby reducing biosecurity risk and making supply chains more transparent.

34 Australian Trade and Investment Commission (2020) Safe, transparent food supply chains. Viewed 21 July 2020, <https://www.austrade.gov.au/agriculture40/news/safe-transparent-food-supply-chains>.

35 Integrity Systems (2019) National Livestock Identification System (NLIS). Viewed 21 July 2020, <https://www.integritysystems.com.au/identification--traceability/national-livestock-identification-system/>.

36 Agriculture Victoria (2020) Growing food and fibre markets. Viewed 13 July 2020, <https://agriculture.vic.gov.au/farm-management/accessing-international-markets/growing-food-and-fibre-markets#h2-1>.

37 The Traceability Working Group (2019) National Traceability Framework: Enhancing Australia's world-class agricultural traceability systems. Canberra. <https://www.agriculture.gov.au/sites/default/files/documents/national-traceability-framework_0.pdf>.



Domestic and international partnerships

Mutually beneficial partnerships and co-developed strategies and activities will be key to strong national biosecurity decision making and rapid, nationally coordinated responses to emerging risks. For example, negotiating consistent domestic trade policies and processes around biosecurity outbreaks could help unify Australia's standards and provide a stronger foundation for engaging in international policy discussions.

International relationships will be equally important; assisting with pre-border intelligence gathering, knowledge sharing, and enabling safe and open trade flows.

Australia's strong dependence on international supply chains and the lack of transparency within them can challenge biosecurity preparedness efforts and impede Australia's ability to accurately understand the risks imposed by a given incoming product. Additionally, trade is often favoured over strong biosecurity, and imported foods and goods can present significant and growing biosecurity risk. For example, in the case of uncooked prawn imports and the outbreak of white spot disease in 2016, the event highlighted longstanding issues with import conditions and serious non-compliance by some major importers.[38]

Case Study 2: Co-design of biosecurity strategies

The Queensland Biosecurity Strategy 2018–2023[39] was co-developed by the Queensland Government, industry, community and other partners across the biosecurity system. Partners from across the system created the strategy from the ground up, creating buy-in and fostering shared responsibility. The strategy was developed through iteration with over 30 organisations and a joint government-industry writing group, creating strategic themes and providing guidance for future action plans.

38 Inspector-General of Biosecurity (2017) Uncooked prawn imports: effectiveness of biosecurity controls. Department of Agriculture and Water Resources, Canberra. <https://www.igb.gov.au/sites/default/files/documents/summary-uncooked-prawn-imports.docx>.

39 Agriculture and Fisheries, Queensland Government (2018) Queensland biosecurity strategy 2018-2023.

Table 2: Recommendations for improving domestic and international partnerships

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
4	**Develop stronger partnerships within the national system to bolster shared responsibility**		
	This could include more co-design and co-ownership of biosecurity strategies and priorities, emergency response plans, and cost sharing arrangements between government, industry and local community champions (see Case Study 2). This would help ensure that these tools meet the imperatives of all stakeholders. In particular, biosecurity risk creators (stakeholders who increase risks of a pest or disease incurring or amplify its impact) such as cargo owners/ importers, incoming vessels etc., could be better engaged in the system to drive shared responsibility. Alongside increasing engagement with these groups, continued review, assessment and introduction of appropriate fee structures for risk creators across the supply chain could help create a sustainable funding source for the required level of biosecurity activities. This could include further consideration of the biosecurity imports levy structure to ensure buy-in and value from industry stakeholders.	All	
5	**Strengthen relationships with international counterparts and partners**		
	International relationships can be used to bolster Australia's biosecurity capability and preparedness. Pre-border intelligence on emerging exotic species and diseases in nearby and key trading countries allows Australia to better direct surveillance and detection investment. Two-way information sharing, potentially enabled by diplomatic postings, could help Australia to better understand risk profiles of other countries and movements between countries of people and products. Improved supply chain traceability and transparency with trading countries allows better line of sight about the true country of origin of imports (enabling more accurate risk assessment). Stronger international relationships could also provide greater awareness of technology and policy development being implemented by other leading countries. Australia could work with international committees to co-design biosecurity strategies and trade standards, helping to align domestic and international protocols to support market access (e.g. the Plant Health Quadrilaterals Group, a cooperative venue for policy discussion).[40] Finally, international experience programs (also relevant to Recommendation 19) can help build Australian expertise for specific response pathways, species prioritisation and management while strengthening the nation's international networks. Better relationships with Australia's Pacific neighbours could support biosecurity capability development, providing mutual benefit through reduced risk of pest or disease spread. For example, ACIAR'S 'Improving plant biosecurity in the Pacific Islands' project aims to increase the level of agricultural biosecurity in Pacific region partner countries.[41]	Commonwealth government	Research, industry
6	**Improve pre-border clearance of imports**		
	Prevention of incursions is ideally achieved in the pre-border phase before reaching Australia. Improving pre-border biosecurity clearance of imports and people, and better offshore biosecurity processing will reduce the risk of exotic species and diseases reaching Australia. This could involve a stronger Australian presence at international ports; pre-border biosecurity agreements with trading countries and companies; and stronger legislative requirements, reporting standards and compliance systems for good biosecurity practices. All activities would need to be based on stronger, mutually beneficial intergovernmental relationships. Pre-border biosecurity measures can also be incentivised through benefit schemes. The Australian Trusted Trader scheme, for example, provides accreditation to Australian businesses that can guarantee a secure international supply chain; successful applicants are granted benefits such as simplified customs processes.[42]	Commonwealth government	Research institutions, industry, peak bodies

40 United States Department of Agriculture (2020) Plant Health Quadrilaterals Group. Viewed 31 August 2020, <https://www.aphis.usda.gov/aphis/ourfocus/planthealth/international/sa_phytostandards/ct_quadrilateral_group>

41 Australian Centre for International Agricultural Research (2020) Improving plant biosecurity in the Pacific Islands. Viewed 10 August 2020, <https://aciar.gov.au/project/gp-2018-109>.

42 Australian Border Force (2020) Australian Trusted Trader. Viewed 20 August 2020, <https://www.abf.gov.au/about-us/what-we-do/trustedtrader>.

4.2 Shared responsibility

Community and public engagement

Indigenous engagement

Industry engagement

Everyone has a role to play in upholding Australia's biosecurity status; this is a key aspect of the shared responsibility principle of the Australian biosecurity system. Despite this, consultations highlighted that this is still a major challenge, with many Australians – individuals, communities and businesses – not understanding One Health relationships, their biosecurity responsibilities or the benefits associated with good biosecurity practice.

Supporting the transformational 2030 trajectory will be deeper biosecurity engagement and participation by industry, communities and the public through arrangements and initiatives that motivate shared responsibility and have clear value propositions for all involved.

We all share the risks. We all share the benefits. We must all share the responsibility of protecting our unique natural environment – Australia's National Biosecurity Statement.[43]

43 Department of Agriculture, Water and the Environment (2019) National Biosecurity Statement. Viewed 21 July 2020, <https://www.agriculture.gov.au/biosecurity/partnerships/national-biosecurity-statement>

Community and public engagement

Communities (e.g. local citizens, agriculture producers, and leisure groups) and the general public can impact biosecurity through their direct interactions with their environment, by contributing to public sentiment and social license, and by providing support for monitoring and surveillance activities. Engagement is critical to understanding community values and generating buy-in to biosecurity initiatives. One approach to deeper community engagement is through citizen science platforms; which can generate local-level buy-in for biosecurity efforts and, with appropriate data validation and analytics support, can supplement surveillance data collected through more scientifically robust approaches.

In the case of the national red imported fire ant (RIFA) eradication program, the return on investment was $60 for every $1 invested in community engagement, measured as the savings in active surveillance from passive citizen surveillance (reports from the public of encounters with pests and diseases).[44]

Case Study 3: Citizen Science

Between 2013–2015, approximately 550 community members joined the Queensland Weed Spotters program. More than 3,000 specimens were submitted for formal identification, and of these, 383 incursions of 88 priority weed species were notified to Biosecurity Queensland, local government and other organisations. Furthermore, 45% of the submissions were incorporated into collections and databases such as Australia's Virtual Herbarium and the Atlas of Living Australia, making data widely available for use.[45]

To build on this success, technology can be mobilised to make community weed identification and reporting easier and more efficient. For example, CISS is currently leading a consortium to develop a national weed identification app that uses AI to automatically identify priority weeds.[46]

44 Cacho O, et al. (2012) Valuing community engagement in biosecurity surveillance. Viewed 22 July 2020, <https://cebra.unimelb.edu.au/__data/assets/pdf_file/0005/2068736/1004B_OID7_Report.pdf>

45 Laidlaw MJ, Holland A and Guymer G (2016) Many eyes on the prize: the role of citizen scientists in active weed surveillance. Paper presented at the 20th Australasian Weeds Conference, Perth, Australia.

46 Centre for Invasive Species Solutions (2019) Ministerial media release – artificial intelligence to help weed out pests. Viewed 17 August 2020, <https://invasives.com.au/news-events/ministerial-media-release-artificial-intelligence-help-weed-pests/>.

Table 3: Recommendations for improved community and public engagement

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
7	**Develop and promote a single source of biosecurity information to the public**		
	Numerous websites for biosecurity information exist, however few are strongly promoted, offer public-friendly interfaces, or provide comprehensive coverage across all biosecurity risks (human, agricultural, environmental and marine). A single promoted national website could assist in providing the public with relevant information about current incursions, emerging risks, best practices for the general public, links to other high quality or government approved information sources, and information about available citizen science platforms. An associated app could facilitate greater engagement with the public through the two-way exchange of actionable information, including tools for identifying and reporting backyard pests, citizen science platforms, and partaking in virtual discussions around the biosecurity of goods relevant to individuals (e.g. risks associated with imported foods).	Commonwealth government	State governments, industry, community representative groups, peak bodies
8	**Create robust and verifiable citizen science programs to help engage and empower the public**		
	Strong examples exist already (see Case Study 3), however citizen science programs are yet to reach their full potential in biosecurity. The concept faces challenges around analysing and drawing useful inferences from collected structured and unstructured data,[47] and how to ensure insights are verifiable and trusted without significant extra cost. Citizen science is not a replacement for empirical scientific research and surveillance; however, it is a valuable supplementary tool that allows those at the centre of the problem to obtain some power and buy-in to the solution. Improved programs will involve better data verification and integration with intelligence systems, sharing outcomes with the public, and stronger engagement techniques such as virtual and augmented reality platforms and gamification.	Governments, research institutions, industry	Community, peak bodies
9	**Develop biosecurity education and communication programs to build public and community awareness**		
	This might include education programs for school-aged children, where strengthening biosecurity engagement can help educate the next generation, with added benefits of children passing along messages to family members. These programs could involve active participation of children through site visits, use of citizen science platforms, and engaging their assistance to tackle local problems. A national community-based biosecurity prevention and surveillance education program could also be developed, potentially targeting those visiting natural ecosystems. Standardised messaging across all state jurisdictions could help promote the idea of shared responsibility and extend the obligations beyond those traditionally involved in biosecurity activities such as agricultural industries. Target audiences could include domestic travellers, fishers, walkers, boaters and campers.	Education, governments	Industry, community, outdoor leisure and tourism organisations and related industries

47 Welvaert M and Caley P (2016) Citizen surveillance for environmental monitoring: combining the efforts of citizen science and crowdsourcing in a quantitative data framework. SpringerPlus, 5(1), 1890. DOI: 10.1186/s40064-016-3583-5.

Indigenous engagement

Aboriginal and Torres Strait Islander people have continuously and actively managed their lands and waters for over 65,000 years.[48] As Australia's largest land custodians, their rights and interests in land are formally recognised for over 40% of Australia's land mass.[49] With such strong historical and present-day connections with the land, Indigenous communities are critical partners in Australia's biosecurity ecosystem. Weaving Indigenous and western science, knowledge and values into biosecurity strategies, from national through to local, will ensure all biosecurity activities leverage the nation's pooled knowledge to benefit all Australians.

Currently, Aboriginal and Torres Strait Islander peoples are engaged through a range of mechanisms including formal government-supported natural resource management projects, Indigenous and co-managed protected areas, and endangered species initiatives.[50] However, consulted stakeholders noted that much of the Indigenous engagement relating to biosecurity is currently ad hoc and far from resembling the systemic relationships and processes that need to be present. While organisations are increasingly developing Indigenous engagement guidelines and establishing Indigenous advisory committees, the transformational 2030 trajectory also involves a larger number of Indigenous individuals and groups having greater decision-making powers in addition to consultative roles.

To reach the transformational trajectory, relationships need to be established that acknowledge the different values placed on a healthy natural environment by different groups and focus on building trust and exchanging knowledge for the benefit of all Australians. In some instances, Indigenous communities might lead the way, drawing on their established networks and traditional knowledge. In others, modern science and technology could be used to support Indigenous decision-making. This was demonstrated in a 2019 project involving Kakadu rangers, Microsoft and CSIRO working in partnership to bring together science, Indigenous knowledge and technology to help solve complex environmental management problems (see Case Study 4).

48 Clarkson C, et al. (2017). Human occupation of northern Australia by 65,000 years ago. Nature 547, 306–310. DOI: 10.1038/nature22968.

49 National Indigenous Australians Agency (n.d.). Land and housing. Viewed 21 July 2020, <https://www.niaa.gov.au/indigenous-affairs/land-and-housing>.

50 Pert PL, et al. (2020). Is investment in Indigenous land and sea management going to the right places to provide multiple co-benefits?. Australasian Journal of Environmental Management, 1-26. DOI: 10.1080/14486563.2020.1786861.

Table 4: Recommendations for improved Indigenous engagement

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
10	**Make biosecurity engagement with Indigenous communities a more systemic process of the system**		
	Currently, engagement with Indigenous communities around matters of biosecurity is not uniform and often relates to a specific incursion or event. To ensure the system better manages the social, cultural, environmental and economic impacts of biosecurity threats, key decision-making stakeholders from within the biosecurity system could actively increase the levels of co-development of biosecurity procedures and strategies with Indigenous peoples and organisations. Engagement approaches need to be respectful and aim to support self-determination principles that recognise the rights of Aboriginal and Torres Strait Islander people in identifying local solutions that can respond to biosecurity threats. Though not biosecurity specific, the Our Knowledge Our Way in Caring for Country guidelines showcases best practices for working with Indigenous knowledge in land and sea management.[51]	Governments, Indigenous communities	Industry, peak bodies
11	**Empower Indigenous involvement in biosecurity through co-development of fit-for-purpose technology solutions and creation of economic opportunities**		
	Integrating Indigenous knowledge, practices and values with modern science and technology, such as state-of-the-art surveillance, monitoring and data analysis can create fit-for-purpose solutions for complex biosecurity management issues. For example, protecting northern Australia from biosecurity threats as agricultural intensification occurs. This type of innovation in biosecurity has the potential to create significant and impactful economic opportunities for Indigenous communities across Australia. Other opportunities to empower Indigenous communities could include positioning Indigenous corporations to lead biosecurity activities, further expanding the Indigenous Rangers network and developing new service models underpinned by capability building initiatives.	Governments, research institutions, Indigenous communities	Peak bodies
12	**Increase Indigenous representation at senior decision-making levels**		
	There is a significant imbalance in the representation of Indigenous values in Australia's biosecurity governance and decision-making. Indigenous communities, representing significant holders of Australian lands, have considerable biosecurity responsibility and knowledge, and are extensively impacted by biosecurity incursions and threats. Governments and large businesses responsible for decisions that have national and state level biosecurity impacts could address this imbalance by ensuring strong Indigenous representation in leadership teams, senior advisory committees and boards.	Governments, industry, Indigenous communities	Peak bodies

Case Study 4: Kakadu rangers and Microsoft meld science, Indigenous knowledge and technology to help solve complex environmental management problems[52]

Microsoft has partnered with Kakadu National Park rangers and CSIRO to develop responsible AI and modern science with traditional knowledge to solve complex environmental management problems, and care for animal species and habitats. Under the direction of Indigenous rangers, drones capture video footage in Kakadu, with data labelled and interpreted using a combination of Indigenous knowledge and AI. The results and analysis are made available to rangers through a dashboard designed in partnership with the Traditional Owners based on cultural values. Rangers access this on a mobile device to support their on-the-ground decision making and environmental management.

51 CSIRO (2020) Our knowledge, our way. Viewed 12 August 2020, <https://www.csiro.au/en/Research/LWF/Areas/Pathways/Sustainable-Indigenous/Our-Knowledge-Our-Way>

52 Microsoft (2020) AI transforms Kakadu management. Viewed 21 July 2020, <https://news.microsoft.com/en-au/features/ai-transforms-kakadu-management/>.

Industry engagement

Despite the Australian agriculture and aquaculture industry's heavy reliance on the outputs of the national biosecurity system for market access and continued productivity, there is uneven uptake of good biosecurity practices[53] and training across industries and their supply chains. Some stakeholders, such as some newly emerging peri-urban and amateur producers, may not be following best practices due to a lack of awareness. For those with higher levels of awareness, some lack incentive to report detections where this may have a detrimental impact on their livelihood.

Developing models for two-way information flows could help to better engage industry operators to encourage uptake of good biosecurity practices and involvement in surveillance initiatives.[54] These communication channels will also be essential in exploring and developing mutually beneficial arrangements for industry to take on delivery of certain biosecurity services where appropriate.

Table 5: Recommendations for improved industry engagement

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
13	**Identify the non-negotiable government conditions and industry incentives associated with privatisation of biosecurity services and activities**		
	Currently government exercises responsibility over a wide range of biosecurity services. In the shift toward greater private sector biosecurity responsibility, consideration could be made into the non-negotiable standards that Government would set to ensure national and public interests are met; including rules around data collection, intellectual property (IP) and artificial intelligence. Additionally, incentives that would encourage industry to take on greater biosecurity responsibilities could be identified. The Approved Arrangements scheme, for example, involves agreements to facilitate industry responsibility over some biosecurity activities in accordance with requirements set by the Department of Agriculture, Water and the Environment (DAWE).[55]	Commonwealth government, peak bodies	Industry
14	**Invest in social science research to better understand non-compliance behaviours**		
	From large industry through to smallholders and hobby farmers, there are portions of these groups who are not complying with biosecurity standards. Understanding the differences across these groups, and their values and perceptions of biosecurity, will help develop more targeted and impactful engagement approaches, guidelines and penalties. Such research would also help ensure information flows are simplified and delivered through appropriate channels.	Research institutions, governments	Peak bodies, industry, community
15	**Investigate improvements to incentivise accurate and timely biosecurity detection reporting**		
	The challenge of sufficient reporting incentives is particularly acute where reimbursements for response activities and associated productivity impacts are not guaranteed, or reporting may have a detrimental impact on livelihoods. Investigating compensation schemes and incentives for agricultural producers and transport providers operating in-line with best biosecurity practices could assist with this challenge. Legislative instruments to incentivise reporting through compensation programs could also be explored. Best practice for various producers and transport providers could be defined by government and industry peak bodies.	Governments, industry, peak bodies	Land holders and primary producers

53 Maclean K, Farbotko C and Robinson CJ (2019) Who do growers trust? Engaging biosecurity knowledges to negotiate risk management in the north Queensland banana industry, Australia. Journal of Rural Studies, 67, 101-110. DOI: 10.1016/j.jrurstud.2019.02.026.

54 McAllister RRJ, et al. (Under revision) Multilevel stakeholder networks for Australian marine biosecurity: well-structured for top-down information provision, requires better two-way communication. Ecology and Society.

55 Department of Agriculture, Water and the Environment (2020). Approved arrangements. Viewed 20 August 2020, <https://www.agriculture.gov.au/import/arrival/arrangements>.

Case Study 5: BioSecure *HACCP*[56]

Biosecure *HACCP* is an industry-developed on-farm biosecurity program designed to assist Australian nursery producers in assessing and managing biosecurity risks. The program helps to identify threats to a business' biosecurity integrity from pests, weeds and diseases; and guides the implementation of management strategies to improve processes and preparedness. The risk management system allows businesses to record quarantine procedures and track actions taken at critical points to provide quality assurance; validating best management practices under the Nursery Industry Accreditation Scheme Australia. The program provides businesses with recognition of good practice and opportunity for greater trading flexibility, whilst increasing traceability and sharing of biosecurity responsibility. The peak industry body Greenlife Industry Australia (GIA) administers and provides accreditation for the program.[57] Biosecure *HACCP* is an example of an industry-administered program supported by government legislation, having been approved under the Queensland Biosecurity Act 2014.[58]

Case Study 6: Simulations[59]

In 2019, the National Biosecurity Response Team conducted a simulation exercise with representatives from the honey-bee industry, Commonwealth and state governments to increase Australia's biosecurity emergency response capability. The exercise simulated two scenarios: a varroa mite detection in Jervis Bay Territory, and a red imported fire ant detection at Canberra International Airport; and involved determining and conducting the appropriate response operations under each scenario.

Objectives included identifying complexities, testing the ability to implement the *Commonwealth Biosecurity Act 2015* and increasing knowledge of relevant legislation and arrangements for incursions. Participants and observers indicated the exercise had significantly contributed to their response capabilities, with collaboration providing cross-jurisdiction sharing of knowledge and experience. Improvements around legislative and policy arrangements were identified, as were issues such as difficulty interpreting legislation and use of IT infrastructure.

56 Greenlife Industry Australia (n.d.) Biosecure HACCP. Viewed 24 August 2020, <https://www.greenlifeindustry.com.au/Category?Action=View&Category_id=127>.

57 Australian Plant Production Standard (n.d.) About us. Viewed 24 August 2020, <https://nurseryproductionfms.com.au/about-us/>.

58 Australian Interstate Quarantine (n.d.) BioSecure HACCP gets tick of approval. Viewed 24 August 2020, <https://www.interstatequarantine.org.au/biosecure-haccp-gets-tick-of-approval/>.

59 Animal Health Australia (2019) National Biosecurity Response Team update. Viewed 21 July 2020, <https://www.animalhealthaustralia.com.au/news/nbrt-update-april/>.

4.3 Innovation in science and technology

Supporting innovation

Science and technology capability

In the 2030 transformational trajectory, coordinated investment in science and technology facilitates a more effective and efficient biosecurity system. Existing technologies can be better applied or redesigned to allow stronger system coordination and preparedness through data sharing and novel surveillance and response capabilities. At the same time, emerging science and technologies have the potential to create step-changes in the effectiveness of biosecurity management such as environmental DNA (eDNA) sampling and genetic technologies to control pest populations.

Developments in science and technology can underpin new biosecurity service offerings both for use in Australian industry and as an export opportunity. Strategic investment in technology innovation and the skills required to develop and use these tools will help ensure Australia's position at the forefront of biosecurity best practice is maintained.

Science and technology: Genetic technologies for diagnosis and surveillance

Genetic technologies present the opportunity for faster and more cost-effective detection of pests and diseases than current methods.

CRISPR-diagnostic platforms

CRISPR technology, while primarily being developed for genetic modification, can also be used for disease diagnosis. Specific high-sensitivity enzymatic reporter unlocking (known as SHERLOCK), is one such CRISPR-based diagnostic platform under development at TRL 2-3. The technology could provide rapid, point-of-care diagnosis without expertise, ancillary equipment or power; allowing for earlier disease detection, in turn allowing faster action to prepare for and manage incursions.

R&D next steps for this technology including laboratory and clinical evaluation of the performance of CRISPR-based diagnostics in a range of settings, for example in multiplex point-of-care testing (where various analyses can be conducted from a single sample).

Environmental DNA

Another genetics-based approach, eDNA, allows the accurate identification of a species from environmental samples as small as faeces, footprints, soil or water. The sampling can be conducted rapidly and efficiently over wide areas; and exceeds sensitivities of conventional observational monitoring for terrestrial and aquatic environments. For example, an eDNA device could be used at airports to test for pest fish and diseases in an imported bag of fish using only a sample of water, providing results within as little as 20 minutes.[60] It can also assist with detection and rapid responses to new incursions of aquatic pests. The University of Canberra through CISS is currently undertaking research to develop new eDNA tools to test for two high-risk invasive species: the red-eared slider turtle and the Asian black spined toad.[61,62] eDNA could be paired with robotic devices for autonomous surveillance and is currently at TRL 4-9.

R&D next steps for eDNA include development of new gene targets to improve taxonomic resolution; improving quality and breadth of reference databases, development of eDNA biosecurity surveillance networks; increasing the range of environmental samples tested to detect a broader spectrum of organisms; development of the required polymerase chain reaction for targeted or high-throughput sequencing; and development of a standardised sampling strategy.

60 Department of Agriculture, Water and the Environment (2019). eDNA innovations for biosecurity identification. Viewed 21 July 2020, <https://haveyoursay.agriculture.gov.au/biosecurity-innovation/news_feed/edna-innovations-for-biosecurity-identification>.

61 Centre for Invasive Species Solutions (2020) Real time eDNA tools to improve early detection and response approaches for high risk pest animals. Viewed 17 August 2020, <https://invasives.com.au/research/real-time-edna-tools/>

62 EcoDNA (2019) Real-time detection of red-eared slider turtles. Viewed 17 August 2020, <https://www.ecodna.org.au/case-study/real-time-detection-red-eared-slider-turtles/>.

Science and technology: Genetic technologies for biocontrol and increased resilience

Traditional biocontrol methods involve the introduction of organisms or diseases to curb target populations. Genetic technologies, however, can protect or enhance species and ecosystem resilience to threats without the need to introduce new organisms or diseases.[63]

Genetic biocontrol is an emerging technology that is particularly attractive for established pests for which there are currently no effective eradication measures. It involves application of advances in precision gene editing technologies to introduce controlling biological traits into invasive plants and animals in a controllable manner,[64] to mitigate their environmental impacts or even collapse the reproductive capacity of the species. While still in early stages of development for complex organisms such as vertebrates, the technology offers the advantages of species specificity, large geographic coverage and minimal residual environmental impact. Possible application areas for genetic biocontrol over the next decade include control of pest animal populations (e.g. cane toads, carp, rabbits or feral cats); removing the ability of insect vectors to spread diseases; and creating buffer zones of genetically incompatible animals or insects that prevent the proliferation of an invasive species.

Plant and animal species can also be genetically engineered to increase their disease resistance. For example, some plant species can be genetically modified to produce Plant-Incorporated-Protectants (PIPs), pesticidal substances which destroy or deter pest and disease species.[65]

The future development and employment of genetic technologies will need to consider environmental, ethical, and social factors. This will require close liaison with regulatory authorities, Aboriginal and Torres Strait Islander people, and the general public. R&D next steps for genetic biocontrol include identifying near term candidates for controlled development and pilot studies; and defining the potentially adverse ecological outcomes and unanticipated traits associated with the release of gene-drive modified organisms.

63 CSIRO (2020) Synthetic biology Future Science Platform - Environment and biocontrol, Viewed 21 July 2020, <https://research.csiro.au/synthetic-biology-fsp/research/application-domains/environment-biocontrol/>.

64 Hayes KR, et al. (2018) Identifying and detecting potentially adverse ecological outcomes associated with the release of gene-drive modified organisms. Journal of Responsible Innovation, 5:sup1, S139-S158. DOI: 10.1080/23299460.2017.1415585.

65 United States Environmental Protection Agency (2016). What are biopesticides. Viewed 22 July 2020, <https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides>.

Supporting innovation

To date, the development of biosecurity technologies has been limited primarily by its smaller market size when compared to other technology areas; and consequent difficulty in attracting private and government investment. As a result, technology is developed largely through research institutions and universities, leaving a commercialisation gap to take technologies from early development to TRL 7 and above (see Appendix B). Coordinated efforts to support biosecurity innovation could accelerate development and application of technologies which could play a major role in supporting the 2030 transformational trajectory.

Table 6: Recommendations to accelerate development of biosecurity innovations

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
16	**Set national biosecurity innovation priorities**		
	Nationally coordinating and communicating biosecurity innovation priorities (both major risks and R&D areas) across human, agricultural, environmental and marine health sectors will help the range of government departments, NGOs and research organisations involved in technology development direct their efforts towards Australia's highest priority biosecurity risks in an efficient manner. These priorities could be developed by an S&T innovation committee with representatives from government, industry and research that aim for agreement across all jurisdictions.	Governments	Industry, peak bodies, research institutions
17	**Drive development, investment, commercialisation and manufacture of innovative technologies for biosecurity**		
	An interdisciplinary innovation hub that focusses on national biosecurity priorities could help facilitate and coordinate biosecurity commercialisation and the development of Australian SMEs. A key aim of the hub would be to enhance industry's involvement in driving the development of biosecurity innovations through pooled investment and resources. Research programs should consider end-use applications within and outside of the biosecurity sector to maximise market opportunities. Governance structures involving strong industry leadership should be considered, be they industry-consortiums or public-private partnerships; however the hub is likely to benefit from strong collaboration across industry, government and research.	Industry, research institutions, governments	Peak bodies
18	**Better integrate social, cultural and ethical considerations into the development, policy and regulation setting of new technologies**		
	This is particularly important for technologies and policies that may have welfare, equity or genetic implications. Importantly, better integrating these considerations into technology development may not equate to higher barriers to development. Improved understanding of the beliefs of different communities could aid in shifting towards a risk-benefit policy framework compared to current risk-based frameworks.	Research institutions	Governments, peak bodies, community

Science and technology capability

While Australia is home to world-class researchers and facilities, the biosecurity system is increasingly challenged by a longstanding trend of declining and uneven biosecurity capability, coordination and expertise across jurisdictions,[66] alongside limited sovereign manufacturing capability. Further, the historical development of the biosecurity system has centred largely on responding to animal and plant industry risks. This has meant environmental biosecurity systems are not as mature or well resourced.

Consultations for this project indicated that Australia has a noticeable gap in veterinarians and plant scientists with experience detecting and managing exotic diseases, which may limit the nation's ability for early detection and rapid response. The gradual erosion of resourcing for the biosecurity system[67] has resulted in fewer training opportunities for a biosecurity workforce and fewer biosecurity-related professional positions around the country. Training biosecurity specialists and optimising the networking of expertise across the system could significantly bolster prevention, preparedness and response capabilities across the system.

Table 7: Recommendations for improved science and technology capability development

	RECOMMENDATIONS	SUGGESTED LEAD(S)	SUPPORTERS
19	**Invest in pathways for the career development and training of biosecurity-relevant specialists and researchers**		
	This could include mentoring programs, active succession planning through graduate programs, and facilitation of international experience programs. Noted specialist capability development areas include pathogen biology, disease therapeutics and prophylactics, genetic/genomics literacy, plant pathology, marine pest response, entomology, taxonomy, exotic diseases, geospatial analytics, digital integration, environmental benefit quantification, and social and economic sciences. Biosecurity professional education could also incorporate stronger transdisciplinary systems concepts to support closer links between human, agricultural, environmental and marine health sectors.	Education, research institutions	Industry, governments, peak bodies
20	**Bolster Australia's vaccine development capability and pipeline**		
	Australia's key capability currently lies in vaccine candidate validation, a critical segment of the vaccine development pipeline, along with pilot-scale manufacturing capability. Australia could expand its capability across other stages of vaccine development such as vaccine design, pre-clinical and clinical trials, or manufacturing technologies to enhance sovereign capability and expand its role in international supply chains. Consulted stakeholders also noted value in auditing the nation's vaccine manufacturing capability (human and animal vaccines) and developing a library of vaccine technologies to draw upon for application to newly emerging infectious and emergency human and animal disease threats. Accompanying this could be a review of regulatory barriers to importing materials required for timely vaccine manufacturing and testing.	Research institutions, commonwealth government	Industry

66 Craik W, Palmer D and Sheldrake R (2017) Priorities for Australia's biosecurity system: An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement, Canberra.

67 Craik W, Palmer D and Sheldrake R (2017). Priorities for Australia's biosecurity system: An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement, Canberra.

5 Conclusion

With growing biological risks and increasing pressure on resourcing, Australia's biosecurity system is facing a challenging decade ahead. Continuing or scaling the current system is unlikely to reverse the trends of increasing incursions, declining environmental health and trade disruptions.

However, with national biosecurity understanding and appreciation at an all-time high, there is significant opportunity to investigate and act on the country's greatest system needs to secure the health of Australia's people, environment and economy, and pursue a national goal of becoming the most biosecure trade partner globally. This report has outlined a selection of these needs, including system digitisation and data sharing; effective partnerships; enhanced engagement and contributions from the public, communities and industry; and the development and application of next-generation technologies.

While this report aims to provide broad sector direction and recommendations for where key stakeholders may prioritise activities and investments, further collaborative problem-solving and deeper analysis is required to reach system-wide agreement on answers to the following questions:

- What forms of trans-governmental approaches or resource sharing across the system could facilitate more efficient prevention, management and response activities?
- What commercial opportunities or funding arrangements could help facilitate greater private sector responsibility in managing Australia's biosecurity while still maintaining national interest and public good benefits?
- What is the optimal balance in investment between early detection/rapid response and management phases of biosecurity responses for Australia's highest priority threats?
- How can the environmental benefits of biosecurity be better quantified, assessed and integrated into policy (biosecurity and more broadly) development processes?
- How can these quantified environmental benefits assist in incentivising improved biosecurity practices by businesses (e.g. pairing with existing carbon credit markets)?
- What are the best forms of partnership agreement to formalise the necessary relationships between government, industry and the community?

Appendix A – Consulted stakeholder groups

The following organisations contributed to this report through interviews or document reviews.

- CSIRO
- Agriculture Victoria
- Animal Health Australia
- Australian Banana Growers Council
- BioProperties
- Biosecurity Tasmania
- Bush Heritage Australia
- Centre for Invasive Species Solutions
- Chevron
- Department of Agriculture, Water and the Environment
- Department of Home Affairs
- Fisheries Research & Development Corporation
- Freight and Trade Alliance
- Grains Research & Development Corporation
- Invasive Species Council
- Island Conservation
- Monash University
- MTP Connect
- Murdoch University
- National Farmers Federation
- Plant Health Australia
- Queensland Department of Agriculture and Fisheries
- Royal Botanic Garden Sydney
- Scolexia
- Wildlife Health Australia
- Zoetis

Appendix B – Technology readiness level definitions

The technology readiness level index is a widely accepted tool for tracking progress of a technology through the stages of its research and development, from fundamental early-stage research (TRL 1) to actual operation over the full range of expected conditions (TRL 9).[68] Where mentioned in the report, TRL values refer to stages in the TRL index (Table 8).

Table 8: Technology readiness levels

Concept validation Prototyping and incubation of emerging technology ideas and developing knowledge to support industry development				**Development and demonstration** De-risking and demonstrating promising technologies opportunities and understanding scale-up requirements			**Commercial deployment** Delivering continuous improvement in mature technologies and supporting deployment and trouble shooting	
Basic principles observed	Formulation of concept or application	Proof of concept	Validation in lab environment	Validation in relevant environment	Pilot scale validated in relevant environment	Full scale demo. in relevant environment	System complete and qualified and hypothetical commercial proposition	Actual system operated full range conditions (commercial trial, small scale)
TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9

68 Australian Renewable Energy Agency (2014) Technology readiness levels for renewable energy sectors. Australian Government, Canberra.

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us
1300 363 400
csiro.au/contact
csiro.au

For further information
Health and Biosecurity
Andy Sheppard
+61 2 6246 4198
andy.sheppard@csiro.au
csiro.au/Research/BF

CSIRO Futures
Greg Williams
+61 3 9545 2138
greg.williams@csiro.au
csiro.au/futures

B&M | 20-00277