Australian Government
Department of Agriculture and Water Resources

cebra
Centre of Excellence for Biosecurity Risk Analysis

Ministry for Primary Industries
Manatū Ahu Matua

CEBRA Report Cover Page				
Title, ID, & Output #	Evaluating the Health of Australia's Biosecurity System, Project 1607B – Milestone 6			
Project Type	*Standard*	**CEBRA Project Leader**	*Karen Schneider*	
Sponsoring Org.	*Australian Government Department of Agriculture and Water Resources (DAWR)*	**DAWR Project Sponsor**	*Matthew Koval*	
DAWR Project Leader	*Paul Pheloung*	**Collaborators**	*Jay Gomboso* *Zoltan Lucas*	
Project Objectives	*The primary objective of the project is to develop a framework and methodology to measure and report on the health, or performance, of Australia's national biosecurity system that can be repeated at regular intervals. This should capture all elements of the biosecurity system and all participants in the system; articulate relevant attributes of system performance; and establish qualitative and quantitative measures of performance and associated performance indicators.*			
Outputs	*Key outputs for phase 1 of the project include:* - *a comprehensive review of the performance evaluation literature of relevance to the biosecurity system, including performance evaluation of complex systems in the public sector in Australia and internationally;* - *a detailed description of Australia's biosecurity system, using a program logic approach;* - *a framework for evaluating the health of the biosecurity system based on ten principles;* - *a list and definition of the attributes of biosecurity system health against which the performance of the biosecurity system can be evaluated;* - *a case study that demonstrated the application of indicators to measuring attributes of health on the international air passenger pathway and discussed some of the opportunities and challenges associated with collecting and analysing the data that are needed for such exercises.*			
CEBRA Workplan Budget	**Year 2016-17**			
	$100,000			
Project Changes	*Nil*			
Research Outcomes	*N/A*			
Recommendations	*N/A*			
Related Documents	*Project Business Case*			
Report Complete	*Yes*			

Evaluating the Health of Australia's Biosecurity System

Final report: CEBRA Project 1607B – Milestone 6

Karen Schneider, Hannah Fraser, Aaron Dodd, Andrew Robinson, Edith Arndt
The University of Melbourne

March 2018

Centre of Excellence for Biosecurity Risk Analysis

Acknowledgements

This report is a product of the Centre of Excellence for Biosecurity Risk Analysis (CEBRA). In preparing this report, the authors acknowledge financial and other support provided by the Australian Department of Agriculture and Water Resources, the New Zealand Ministry for Primary Industries and the University of Melbourne.

Table of Contents

Table of Tables

Table of Figures

Executive Summary

This is the final report of the first phase of CEBRA project 1607B *Evaluating the health of Australia's biosecurity system*. The report represents the outcomes of the first phase of a multi-year project designed to develop a rigorous method that can be used repeatedly to evaluate the health of the national biosecurity system against agreed performance criteria using appropriate performance indicators. The report was prepared for the Department of Agriculture and Water Resources (the department) but has relevance to all participants in the national biosecurity system.

The department currently relies largely on qualitative pathway-specific risk analyses and reviews to assess and address potentially unacceptable exposures to biosecurity risk. These analyses and reviews focus mainly on elements of the biosecurity system for which the Australian government has responsibility. However, the department does not currently have a means of estimating the health of the national biosecurity system as a whole against appropriate performance criteria This is a significant business gap that limits the capacity of the department to evaluate the effectiveness of its investments across the biosecurity system. Other participants, such as state and territory governments, are equally constrained in assessing the role they play in meeting the objectives of the overarching biosecurity system.

The report summarises progress to date on the project. It uses a program logic model to describe the key elements of the national biosecurity system, including the activities undertaken in the system by different participants, the resources to support them, the outputs that are produced by these activities and the outcomes they generate. The report also identifies the broad attributes of health against which the biosecurity system will be evaluated. These recognise that the national biosecurity system should be capable of meeting its objectives in an effective, efficient, robust, resilient and sustainable manner.

A case study is used in the report to measure aspects of biosecurity health against the framework. The case study is focused on some activities in the biosecurity system that are designed to prevent biosecurity risk material from entering the country on the air passenger pathway. The case study provides insights into the challenges and opportunities that will arise from the measurement of national biosecurity system health. It also explores the accessibility of data necessary to underpin effective performance evaluation and identifies gaps in current data availability.

The capacity to articulate the health of the national biosecurity system in clear terms against appropriate criteria provides a sound basis on which all participants can identify where system improvements can be made, either individually or on a collective, system-wide basis.

1 Introduction

The overarching objective of Australia's national biosecurity system is to minimise the harmful impacts of exotic pests and diseases on Australia's economy, environment and community. In doing so, it underpins access to international markets for agricultural commodities, protects native flora and fauna, and helps preserve the amenity of the community's natural and social assets. The combined value of the economic, environmental and social benefits of the system are considerable, although as yet unmeasured in an aggregate sense.

The national biosecurity system is complex, comprising multiple actions undertaken by a range of participants at different points along the biosecurity continuum – off-shore or pre-border, at the border, and on-shore or post-border. These actions are designed to achieve three broad objectives: (i) to reduce the likelihood of exotic pests and diseases that have the potential to harm the economy, environment and community entering, establishing and spreading in Australia; (ii) to prepare for and respond to incursions of harmful exotic pests and diseases; and (iii) to ensure that significant pests and diseases already in Australia are appropriately managed.

Key players in the national biosecurity system are the Australian, state, territory and local governments, industry, landholders and producers, and the general community. Each of these has different roles and responsibilities, although the concepts of partnership and shared responsibility have underpinned the system for some time.

A fundamental principle of the biosecurity system is that activity is based on sound science and underpinned by a risk management approach. Risk management is designed to ensure that resources invested in the system are allocated to the areas of highest risk where the returns on investment are likely to be maximised. It recognises that achieving zero risk is unattainable but aims to reduce risk to a very low level – defined as Australia's appropriate level of protection (ALOP). This definition of ALOP is consistent with Australia's obligations under the World Trade Organisation and the associated Agreement on the Application of Sanitary and Phytosanitary Measures, which sets the international rules for managing biosecurity risk.

The biosecurity risks facing Australia are not static. Over time the scale of biosecurity risks will increase with growing volumes of trade and passenger movements. Pressures on the biosecurity system will also change as the origin and destination of trade and passenger movements shift; the global distribution of pests and diseases changes in response to factors such as climate; and supply chains become more complex. At the same time, innovation and technological advances are providing opportunities to manage biosecurity risks in new ways. The long-term sustainability of the national biosecurity system will be influenced by these pressures and responses to them by the multiple players in the system, including through the provision of sustainable funding mechanisms.

The national biosecurity system represents a significant investment by all participants, with expenditure totalling almost $1 billion in 2015-16. The Australian government currently spends approximately $624 million a year on its biosecurity responsibilities. State, territory and local governments collectively spend in the order of $375 million a year. Of these amounts, industry participants contribute levies on production and fee for service payments of approximately $575 million. Industry, landholders and community groups also make substantial in-kind contributions (Craik et al., 2017).

Given the important objectives of the national biosecurity system and the significant investment involved it is imperative to evaluate the overall performance of the system. The Australian and state and territory governments have a strong focus on performance evaluation and require that performance frameworks are in place to assess the effectiveness and efficiency of their activities, including biosecurity. Performance evaluation supports the accountability of agencies and can be used to identify risks in the system and areas of potential improvement, as well as supporting investment decision making.

Evaluation of components of the national biosecurity system occurs on a regular basis. The Australian and state and territory governments, for example, articulate performance measures in corporate plans, strategy documents and annual reports, although their coverage and sophistication vary widely (Craik et al., 2017). Jurisdictional auditors-general undertake reviews of aspects of the biosecurity system from time to time and have been influential in driving system reform in some jurisdictions.

Several independent reports have provided 'one-off' overviews of the biosecurity system. These include the Nairn review (Nairn et al., 1996), which established the principle of shared responsibility and the Beale review (Beale et al., 2008), which built on this principle, moved from consideration of quarantine to the broader concept of biosecurity, and underscored the importance of a risk based management approach. In 2011, the Matthews review assessed Australia's preparedness for the threat of foot-and-mouth disease, including the capacity to prevent and respond to an outbreak (Matthews, 2011).

There has not, however, been a consistent, rigorous approach to evaluating the performance, or the health, of the biosecurity system at the national level. This gap has been identified by the review into the Intergovernmental Agreement on Biosecurity, which notes that it is not possible to 'roll up' individual jurisdictional performance measures to capture the national system and assess national performance (Craik et al., 2017). The review recommends the development of a performance framework and performance measures for the national biosecurity system.

This report into the health of Australia's biosecurity system responds to that recommendation by proposing a performance evaluation framework and candidate measures that can be used to assess performance of Australia's biosecurity system at the national level. Regular, objective and evidence based reporting of the health of the biosecurity system would benefit all participants in the system by providing a sound basis on which to assess the impacts of investments in different elements of the biosecurity system and in the system as a whole.

2 Defining the biosecurity system

The Australian biosecurity system is complex, comprising multiple actions undertaken by a range of participants at different points along the biosecurity continuum – off-shore or pre-border, at the border, and on-shore or post-border. The broad goal of the system is articulated in the Intergovernmental Agreement on Biosecurity (IGAB), an agreement between the Commonwealth, state and territory governments, with the exception of Tasmania. The goal is defined as being to '*minimise the impacts of pests and diseases on Australia's economy, environment and the community, with resources targeted at managing risk effectively across the continuum, while facilitating trade and the movement of animals, plants, people, goods, vectors and vessels to, from and within Australia*' (COAG, 2012).

Beneath this overarching goal the objectives of the national biosecurity system are identified in the IGAB as being to provide arrangements, structures and frameworks that:

- reduce the likelihood of exotic pests and diseases, which have the potential to cause significant harm to the economy, the environment and the community, from entering, establishing or spreading in Australia;
- prepare and allow for effective responses to, and management of, exotic and emerging pests and diseases that enter, establish or spread in Australia; and
- ensure that, where appropriate, significant pests and diseases already in Australia are contained, suppressed or otherwise managed (COAG, 2012).

Through meeting these objectives, the biosecurity system helps to deliver some important outcomes for Australia's economy, environment and people. By reducing the impacts of pests and diseases, an effective biosecurity system supports the sustainability, profitability and competitiveness of Australia's agriculture, fisheries and forestry industries, which, in turn, helps drive a stronger Australian economy. The reduction in pest and disease impacts also contributes to the health of the environment through better functioning ecosystems. It supports a healthier population by reducing the incidence of mortality and morbidity arising from pests and diseases, and underpins resilient communities through its protection of social assets in natural and built environments and the amenity value they create.

2.1 The external context

The Australian biosecurity system does not operate in isolation – global and domestic factors define the context within which biosecurity activities take place. Changes in these factors change the biosecurity risks facing Australia. For example, over time, the scale of biosecurity risks will increase with growing volumes of trade and passenger movements. Containerised imports to Australia are forecast to grow by 50 per cent between 2013 and 2025 and non-containerised imports by 27 per cent (DIRD, 2014). Passenger arrivals by air are expected to increase by more than 90 per cent by 2030, and there is a significant increase forecast in the movement of passengers by sea, including on cruise vessels to remote locations (DIRD, 2014).

Pressures on the biosecurity system will also change as the origin and destination of trade and passenger movements shift, leading to increasingly diverse and potentially higher risk import pathways (Hulme, 2009; Dodd et al., 2015). Similarly, international supply chains are expected to become more complex over time with final goods made up of components from multiple origins that may involve different risk profiles, while the growing use of online shopping requires new approaches to risk management. Other global trends with implications for biosecurity risk are the intensification of agricultural industries and the expansion of monocultures that can concentrate the impacts of pests and diseases, and urbanisation that brings biosecurity risks closer to agriculturally sensitive areas (Craik et al., 2017). The global distribution of pests and diseases is also likely to change in response to factors such as climate. At the same time, technological advances are bringing new opportunities to manage biosecurity risk in innovative and cost-effective ways.

In the domestic context, there is much to protect. Australia's agriculture, fisheries and forestry industries generate significant value and have a reputation for quality and safety that supports their access to international markets. Australia also has a mega-diverse natural environment with many unique native animals and plants (Mittermeier et al., 1997; Mittermeier et al., 2011). Together these characteristics contribute to a strong economy and high standard of living, including access to a rich natural environment. While the immediate impact of biosecurity management is to regulate imports to protect Australian primary industries from unwanted pests and diseases, it also directly underpins export market access and the quality of the environment.

Consistent with its international obligations under the World Trade Organization, Australia has defined its tolerance to biosecurity risk, or its appropriate level of protection (ALOP), as being very low but not zero. This definition is included in the Biosecurity Act 2015 and has been reached with the agreement of all states and territories. It recognises that a zero-risk stance is impractical because it would mean that Australia would have no tourists, no international travel and no imports. It also ignores the potential for pests and diseases to be introduced through natural processes such as wind. Australia's biosecurity risk management measures established in import risk analyses are designed to achieve the broad objective of ALOP.

2.2 Principles of the national biosecurity system

There are a number of principles that underpin the operation of the national biosecurity system that are outlined in the IGAB. These are that:

- biosecurity is a shared responsibility between all participants in the system, including governments; industry; natural resource managers, custodians or users; and the community;
- the attainment of zero biosecurity risk is impossible in practical terms;
- the biosecurity continuum is managed to minimise the likelihood of biosecurity incidents and to minimise their impacts;

- the biosecurity continuum is managed through a nationally integrated system that recognises and defines the roles and responsibilities of all sectors and sets out cooperative activities;
- activity in the system is undertaken and investment is allocated on a cost-effective, science based and risk management approach that prioritises the allocation of resources to the areas of greatest return;
- relevant parties contribute to the cost of biosecurity activities, with governments contributing in proportion to the public good accruing from those activities;
- governments, industry and other relevant parties are involved in decision-making according to their roles, responsibilities and contributions; and
- Australia's national biosecurity arrangements comply with its international rights and obligations.

These principles provide a guiding framework for the operation of the biosecurity system and strengthen the collaborative approach between the Australian, state and territory governments and other participants.

2.3 Participants in the biosecurity system – a partnership approach

Given the broad ranging objectives of the national biosecurity system, encompassing economic, environmental and social dimensions, there are many participants. These are, principally, the Australian government, state, territory and local governments, industry representative groups, land holders and producers, research providers, relevant non-government organisations (NGOs) and the general community. Each of these has different roles and, in some cases, formal responsibilities. While these can be articulated individually, it is the cooperation and relationships between these participants that underpin the national biosecurity system. The shared responsibility or partnership approach articulated in the IGAB is fundamental to the effective performance of the system.

Governments, as regulators, have prime responsibility for the development, implementation, monitoring and enforcement of the system (Beale et al., 2008). The Australian government is responsible largely for the pre-border and border elements of the biosecurity system. It also conducts some specific post-border activities such as the Northern Australia Quarantine Strategy (NAQS) and shares funding with the states and industry for other pest and disease control and surveillance programs, including those conducted through Animal Health Australia and Plant Health Australia.

State and territory governments are responsible for animal and plant health within their jurisdictions, and participate with the Australian government and industry to coordinate national programs. They share enforcement activities with the Commonwealth. There are formal institutional arrangements under the National Biosecurity Committee (NBC) and its subcommittees that provide a forum for Commonwealth and state and territory collaboration and decision making on priority biosecurity issues (see Box 1).

Box 1: National Biosecurity Committee

The National Biosecurity Committee (NBC) provides advice to the Agriculture Senior Officials' Committee and the Agriculture Ministers' Forum on national biosecurity and on progress on implementing the Intergovernmental Agreement on Biosecurity. The NBC is also responsible for managing a national, strategic approach to biosecurity threats relating to animal and plant diseases and pests, marine pests and aquatics, and the impacts of these on agricultural production, the environment, community well-being and social amenity. A core objective of the committee is to promote cooperation, coordination, consistency and synergies across and between Australian governments. The NBC is supported by four sectoral committees (Animal Health Committee, Plant Health Committee, Marine Pest Sectoral Committee and the Invasive Plants and Animals Committee) that provide policy, technical and scientific advice on matters affecting their sector. The NBC also forms expert groups and short-term task specific groups from time to time to provide advice and deliver key initiatives.

Local governments provide biosecurity-relevant services, including controls on domestic and feral animals, weeds and wildlife, and are essential participants in emergency responses to pest and disease incursions (Beale et al., 2008). In some jurisdictions, local governments may have a regulatory role to direct landholders to control noxious weeds.

Farmers and industry groups manage biosecurity within their areas of operation, including developing biosecurity plans and adopting measures that reduce biosecurity risk. Animal Health Australia and Plant Health Australia are important partnerships between industry and governments that work to achieve biosecurity outcomes through a range of projects and programs (see Box 2).

Box 2: Animal Health Australia and Plant Health Australia

Animal Health Australia and Plant Health Australia are not-for-profit companies that facilitate partnerships between the Commonwealth and state and territory governments and industry. Animal Health Australia facilitates improvements in Australia's animal health policy and practice in partnership with the livestock industries, governments and other stakeholders; builds capacity to enhance emergency animal disease preparedness; ensures that Australia's livestock health systems support productivity, competitive advantages and preferred market access; and contributes to the protection of human health, the environment and recreational activities (AHA, 2017). The purpose of Plant Health Australia is for government and industry to have a strong biosecurity partnership that minimises pest impacts on Australia, enhances market access and contributes to industry and community sustainability (PHA, 2017a).

Other businesses and individuals participate in the biosecurity system. These include those directly engaged in biosecurity activities, such as those involved in importing goods to Australia, including importers, customs brokers, freight forwarders, managers of facilities under approved arrangements, retailers and others along the supply chain, as well as those in ancillary activities such as travel and shipping (Beale et al., 2008). Other community

members and groups, including NGOs, contribute to the biosecurity effort in diverse ways, including through coordinated or individual passive surveillance activities, and general awareness raising efforts.

The research community is another essential element of the biosecurity system and supports Australia's science based approach to biosecurity risk management. Biosecurity relevant research is delivered through a range of funding mechanisms and by multiple providers, including the CSIRO, universities, the Rural Research and Development Corporations (RDCs), Cooperative Research Centres (CRCs) and government agencies. Many organisations that are involved in biosecurity risk management, including AHA, PHA, the Invasive Plants and Animals Committee and Rural RDCs have developed research and development strategies. The National Biosecurity Committee has endorsed overarching national biosecurity Research, Development and Extension priorities that are intended to provide a strategic and unified guide to investment in high priority research activities (DAWR, 2016c; Craik et al., 2017).

The concept of 'shared responsibility' or partnership across the many participants in the national biosecurity system has underpinned the system for some time and is a core principle of the IGAB. However, as the recent review of the IGAB identifies, the roles and responsibilities of participants in the national biosecurity system are not well articulated and have not been agreed formally. This limits the broad understanding and effectiveness of the 'shared responsibility' concept (Craik et al., 2017).

2.4 Resourcing the national biosecurity system

A diverse range of inputs is required to ensure the effective and efficient operation of the national biosecurity system. In financial terms, the system represents a significant investment by participants with expenditure totalling nearly $1 billion in 2015-16. The Australian government currently spends approximately $624 million a year on its biosecurity responsibilities. States and territories collectively spend in the order of $375 million each year. Of these amounts, industry participants contribute levies on production and fee for service payments of approximately $575 million. Industry, landholders and community groups also make substantial in-kind contributions (Craik et al. 2017).

The most important element of resourcing in the biosecurity system is the human resource, encompassing both the number, or capacity, of people who work within the system and their capability. A diverse range of skills is required to ensure the effective operation of the system. These include veterinary and plant sciences, taxonomy, diagnostics, epidemiology, and entomology. Advanced skills in statistics, data analytics and risk analysis are becoming increasingly important inputs to effective biosecurity risk management. The human resources in the biosecurity system also include government officers who perform policy, management and operational functions, in offices and in the field. Also critical are the skills of those participants in the system that provide in-kind support such as producers who manage on-farm biosecurity and community groups that undertake and report on passive

surveillance activities. Skills shortages in some key science-based areas are an emerging concern in the biosecurity system.

There are also extensive physical resources that support the biosecurity system. These include inspection facilities at major points of entry to Australia – airports, sea ports and international mail centres; diagnostic facilities, including laboratories, equipment and taxonomic collections that support activities at the border and post border; post-entry quarantine facilities to screen high risk materials before they are cleared for entry to Australia; and information technology (IT) systems that facilitate the collection, management and analysis of the significant amounts of data generated by the biosecurity system. While many of these resources are managed and operated by the Australian and state and territory governments, industry also contributes physical resources, including approved premises for quarantine purposes and facilities and IT infrastructure operated by customs brokers and freight forwarders.

2.5 Biosecurity is a complex system

A characteristic of the biosecurity system is the complex interactions that occur between different participants at different stages of biosecurity risk management. This reflects the different relationships that exist between participants at different levels of the system and the need for a partnership approach to ensure the effective and efficient operation of the system.

The many components of the biosecurity system are interconnected and interdependent and can interact with each other in unpredictable ways such that outcomes of the system cannot necessarily be forecast on the basis of known components. Some interactions are non-linear in nature so that small changes in inputs, for example surveillance effort, can have large impacts on outcomes, such as detection of invasive species, and vice versa. There are also multiple feedback loops in the system that may not be readily apparent (see Box 3). Consequently, the outcomes of risk management interventions may be highly dependent on the context in which they are implemented – the same action may lead to different outcomes in different sets of circumstances.

Box 3: Feedback loops in the biosecurity system

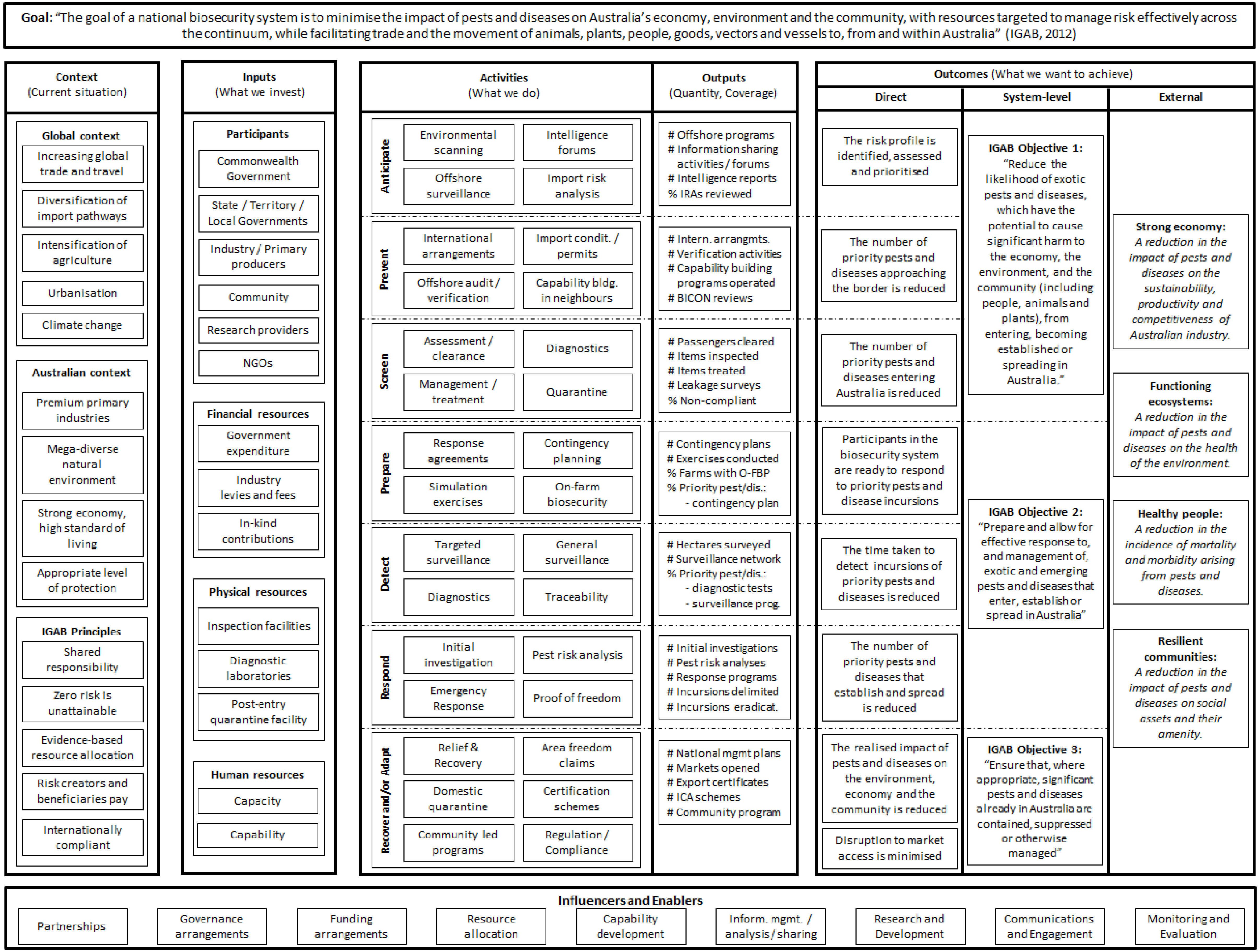
In 2015-16 the Australian government Department of Agriculture and Water Resources reviewed the global risk profile of a range of pests, including the bacterial pathogen *Xylella fastidiosa*. Xylella is an invasive bacterial plant pathogen that causes significant environmental and economic impacts. Xylella is spreading around the world and, although not present in Australia, is of major concern to Australia's plant industries. Following this review, the department implemented emergency quarantine measures to reduce the likelihood of entry of Xylella and strengthened the import requirements for several plant species considered to pose an increased risk of introducing Xylella, principally on olives from the European Union. A previous review undertaken in the early 2000s had identified the risk of Xylella on grapes from the United States. The changing risk profile in terms of both hosts and geographic locations highlights the need for ongoing risk analyses and a flexible approach to risk mitigation measures.

Adding to the complexity of the system is that the external environment is dynamic and evolving rapidly over time. For example, the recent growth in new channels for trade such as e-commerce has been swift and has required the implementation of new rules and practices, including the development of new relationships, to manage the changing pathways of biosecurity risks. A further complicating factor is increasing incidents of deliberately non-compliant behaviour by importers, including those who are beneficiaries of the biosecurity system. Designing systems that incentivise compliant behaviour without imposing undue efficiency costs on system participants is an ongoing challenge.

The existence of complexity and the lack of precision around the roles and responsibilities of participants mean that it is difficult to succinctly and clearly define the overall biosecurity system. However, developing a framework for evaluating the performance or measuring the value of the system requires an appropriate balance between the detail inherent in the system and the practical requirements of implementing a meaningful evaluation, or valuation, framework.

The following draws on the broad outline of the national biosecurity system in the IGAB, as well as the detailed descriptions contained in the Risk Return Resource Allocation model developed by the Department of Agriculture and Water Resources. It uses a program logic model to describe the key inputs to the system, the main activities that are performed and the outcomes that are derived from the operation of Australia's biosecurity system. Such a model allows the many participants in the system to identify where they 'fit' and how and where they contribute to overall system performance. This can be important in encouraging ownership of performance evaluation processes.

Figure 1: Program logic diagram outlining the relationships between inputs, activities/outputs and outcomes within Australia's biosecurity system



2.6 Activities

The Australian biosecurity system consists of a set of activities that are designed to:

- **anticipate** biosecurity risk;
- **prevent** the entry of exotic pests and diseases;
- **screen** goods, conveyances and people at the border to detect non-compliance;
- **prepare** for an outbreak or incursion of exotic pests and diseases;
- **detect** any pest and disease outbreaks or incursions within Australia;
- **respond** to an incursion of an exotic or established pest or disease; and
- **recover** from an incursion and adapt to the new circumstances created by an incursion.

Associated with each of these activities is a range of risk management interventions undertaken by various participants in the biosecurity system. These are outlined below and in Figure 1.

Anticipate biosecurity risk

Understanding the context in which Australia's biosecurity system operates, particularly the offshore environment, is important because it helps us anticipate biosecurity risk. This helps us identify the potential biosecurity risks facing Australia. Enhanced anticipation of these risks increases our capacity to prepare for and manage those risks in a timely and cost effective manner.

A key activity that contributes to this element of the biosecurity system is environmental scanning that systematically examines the external environment and detects early signs of emerging biosecurity risks. Environmental scanning involves understanding trends in global production, trade and travel and the risks arising from these, including changes in risk pathways for high risk species. It also includes tracking of global pest and disease spread and increasing our understanding of the pest and disease status in our near neighbours.

Another activity that enhances our capacity to anticipate biosecurity risk is participation in intelligence forums that contribute information and assessments of emerging risks. The Australian government conducts this type of activity across functional areas to identify changes in the external environment that might lead to changes in risk profiles.

Active surveillance for biosecurity risks in our near neighbours and trading partners is also designed to enhance our capacity to anticipate risk. Understanding the pest and disease status in our neighbouring countries contributes to identifying the potential for biosecurity risks to threaten Australia's animal and plant health. For example, the Australian government undertakes regular surveys of animal and plant health in Indonesia, Papua New Guinea and Timor Leste, in cooperation with the authorities in those countries.

These types of activities – environmental scanning, intelligence forums and offshore surveillance – generate considerable volumes of data and information. Ensuring that this translates to robust intelligence that can be used to manage risk effectively requires the

capacity to analyse, report and provide timely access to the outputs of these activities to all relevant participants in the biosecurity system. Although most of the investment in anticipation activities is undertaken by the Australian government, the intelligence that is generated is highly valued by state and territory governments, industry and other players in the system.

Using its understanding of the biosecurity risk context facing Australia, the Australian government prioritises risks and undertakes biosecurity import risk analyses (BIRAs) or non-regulated risk analyses (see Box 4). These are designed to assist the Australian government to consider the level of biosecurity risk associated with the importation of goods into Australia. If the biosecurity risks exceed the appropriate level of protection, then risk management measures are proposed to reduce the risks to an acceptable level. If the risks cannot be reduced to an acceptable level, the goods will not be imported into Australia until suitable measures are identified (DAWR, 2016a).

Box 4: Biosecurity import risk analyses and non-regulated risk analyses

A BIRA is generally undertaken in response to a new import proposal where risk management measures have not been established or where biosecurity risks could differ significantly from those associated with the import of similar goods. A BIRA is conducted through a regulated process under the *Biosecurity Act 2015* and Biosecurity Regulations. A non-regulated analysis is undertaken where the criteria for a BIRA are not met and can include reviews of existing policies or import conditions or reviews of biosecurity measures in response to new scientific information.

The risk measures proposed in import risk analyses must be compliant with Australia's international trade and biosecurity obligations and apply Australia's ALOP in a consistent manner.

The direct outcomes from the suite of activities that are designed to anticipate the biosecurity risks facing Australia are that the range and magnitude of risks are identified and understood, can be prioritised, and then analysed according to their priority. This increases the capacity to allocate investment across the biosecurity system more efficiently and to manage risk more effectively.

Prevent entry of risk material

Preventing pests and diseases from entering Australia on goods or conveyances is generally considered to be the most cost-effective approach to managing biosecurity risk. Along with anticipation activities, the returns on investment in prevention are believed to be higher than at other points on the biosecurity continuum (Biosecurity Victoria, 2009, 2010). The overarching aim of prevention activities is to manage biosecurity risk off shore in order to prevent threats to Australia's animal and plant health reaching the border.

Among the activities undertaken to prevent biosecurity threats reaching Australia are cooperation in international forums such as the World Organisation for Animal Health (OIE),

the International Plant Protection Convention (IPPC) and Codex Alimentarius to develop science based standards, guidelines and codes of practice for the safe trade of animal, plant and food products. Australia has also ratified the International Convention for the Control and Management of Ships' Ballast Water and Sediments (the Ballast Water Management Convention), which came into effect in September 2017 and establishes global regulations to control the transfer of potentially invasive species. The Biosecurity Act 2015, as amended, establishes national domestic ballast water requirements that are consistent with the Convention to reduce the risk of spreading marine pests that establish in Australian seas. Other international arrangements between governments and importers to agree upon offshore risk mitigation measures can also be effective mechanisms for managing biosecurity threats. The Australian Fumigation Accreditation Scheme (AFAS), the Quarantine Regulators' Meeting (QRM), the International Cargo Cooperative Biosecurity Arrangement (ICCBA) and the Sea Container Hygiene Scheme (SHS) are examples of these mechanisms (Box 5).

Box 5: International risk mitigation arrangements

The Australian Fumigation Accreditation Scheme (AFAS) is a management system run by participating overseas government agencies to ensure compliance of fumigators with Australia's treatment requirements as well as a registration system for fumigation companies. The Quarantine Regulators' Meeting (QRM) is an annual forum that aims to connect government agencies responsible for, or involved in, biosecurity and border management. Its focus is to support a harmonised approach to biosecurity border management relating to cargo. The International Cargo Cooperative Biosecurity Arrangement (ICCBA) is a voluntary non-binding, multilateral arrangement that encourages international cooperation on the harmonisation and verification of international biosecurity activities and processes.

A further approach to preventing biosecurity risks arriving at the Australian border is the development of import protocols that define the conditions under which biosecurity risk material can be imported to Australia. These conditions are generally based on the BIRAs and non-regulated import risk analyses undertaken by the Australian government. They are implemented through the issuing of import permits to individual importers that specify the conditions under which a commodity is permitted to be imported. In 2015-16, 19,000 import permits were issued by the Australian government (DAWR, 2016b).

The Australian government conducts off-shore audit and verification activities to provide assurance that import conditions are met and that risks are mitigated prior to arriving at the border. Periodic audits are undertaken, for example, of pre-export quarantine facilities for horses and ornamental fish and of approved treatment facilities for imported plant material. The Australian government also certifies competent authorities in exporting countries to undertake some pre-export activities. In the case of live animal imports, for example, the government veterinary service in the country of export will certify that the animal complies with the requirements described in the import permit.

An additional measure that reduces the likelihood of risk material arriving at the Australian border is work undertaken in neighbouring countries to build their capacity to manage biosecurity risks. The Australian government supports a number of projects in Indonesia, Papua New Guinea and Timor Leste on issues such as strengthening the capacity of government veterinary services, enhancing poultry biosecurity, and establishing surveillance systems that provide early warning of pests and diseases that could potentially enter Australia. Some state and territory governments and other institutions contribute to this area of activity.

The intended outcome of this suite of activities is that the majority of biosecurity risks are managed offshore, leading to a reduction in the number of priority pests and diseases that arrive at the Australian border.

Screen risk material at the border

Investments by governments and other participants in the biosecurity system to anticipate and prevent risk material arriving at the border will not be completely effective. This is consistent with the setting of Australia’s risk tolerance or ALOP to a very low level but not to zero. As a result, the screening of passengers, cargo, plants, animals and mail at ports and airports and through mail centres to ensure that they meet import conditions is an important risk management intervention. The screening of conveyances – vessels and aircraft – is a further element of the biosecurity system designed to reduce the number of ‘hitchhiker’ pests entering Australia.

The Australian government is largely responsible for activities undertaken at the border. This includes the assessment of passengers, mail, cargo, vessels, live animals and plant material for biosecurity risk. Each year, millions of items are assessed at arrival ports (Table 1). Commercial goods are classified before their arrival according to their tariff code as well as characteristics such as country of origin, supplier and importer. This classification, called profiling, is used as a screening step to determine if further biosecurity management intervention, such as inspection, is necessary.

Many imported goods are not of biosecurity concern. For those that are, clearance without inspection, using declarations and information provided by the importer, is common. Goods may be released from biosecurity control or directed for further assessment. This could include inspection, diagnostic testing, and, where a biosecurity concern is identified, management such as treatment, export or destruction. Some goods that would not typically be directed for inspection will be randomly selected for inspection as part of the Cargo Compliance Verification Scheme.

The Department of Agriculture and Water Resources operates an ‘approved arrangements’ system that permits authorised entities to perform certain activities with goods under biosecurity control without the supervision of biosecurity officers. This involves using their own premises, facilities, equipment and people and is subject to periodic compliance monitoring and auditing.

Where assessment of goods is required, assessment regimes are designed that are based on sound science and statistics and targeted at highest priority risks. Inspections rely on investment in the quality and capacity of inspectorate staff supported by border biosecurity tools and infrastructure such as x-ray machines, detector dogs, and diagnostic capabilities that are capable of dealing with increasing passenger and goods volumes.

Goods may be cleared following inspection if they comply with import conditions. Alternatively, they may be directed for diagnostic testing to identify if biosecurity risk material is present. This relies on the availability and quality of diagnostic facilities, including laboratories, tests and trained staff. Following assessment, if the goods pose an unacceptable biosecurity risk then they may be directed for management, which may involve treatment such as fumigation, export or destruction to manage biosecurity risks.

In the case of imports of live animals, hatching eggs and plant material, import conditions require that they be quarantined in Australia's post arrival quarantine facility, or other approved facilities, for specified periods of time, where they will be observed and tested to ensure that they do not present a biosecurity threat on release.

Management at the border also involves a range of measures designed to target, assess and manage non-commodity risks. These are risks that are not specific to the imported goods but are facilitated through the movement of goods, people and conveyances. The pests and diseases in this category are commonly referred to as 'hitchhikers' and may be attached to a container carrying the goods, the packaging around the goods, or the vessel or aircraft. The types of hitchhikers are varied and can include tramp ants, reptiles, bees, beetles, snails, other animals and dirt. Programs are in place to manage these risks, including targeting at the border, and industry and community communication and reporting programs.

The outcome of these activities at the border is a reduction in the number of priority pests and diseases that enter Australia. Post arrival verification activities such as leakage surveys are undertaken at the border to estimate the success of these intervention strategies.

Table 1: Size of the import task, selected indicators, 2015-16 (DAWR, 2016d).

Indicator	Volume
Passenger clearances	19,000,000
International mail articles	138,000,000
Pratique visits – first ports	18,000
Wharf gate sea container inspections	250,000
Import permits issued	17,000
Live animal imports in Post Entry Quarantine	5,700

Collectively, the activities undertaken to anticipate biosecurity risk, prevent risk material arriving at the Australian border and to screen passengers, cargo, plants, animals and mail at the border to ensure they comply with import conditions contribute to meeting the first objective of the IGAB, that is, to 'reduce the likelihood of exotic pests and diseases, which have the potential to cause harm to the economy, the environment and the community (including people, animal and plants), from entering, becoming established and spreading in Australia'.

Prepare for an incursion

Given Australia's ALOP, it is not expected that pre-border and border activities will successfully intercept all threats to Australia's plant and animal health from exotic pests and diseases – some biosecurity risk material will inevitably cross the border. Across Australia, 18 outbreaks of pests and diseases were being managed in August 2017 (DAWR, 2017). Considerable investment is undertaken by a range of participants in the biosecurity system to ensure that Australia is well prepared to respond to incursions of pests and diseases in order to minimise the likelihood that they establish in Australia and to reduce or contain the harmful impacts on the economy, the environment and the community caused by those that do.

A major set of activities that helps participants in the biosecurity system prepare for an incursion of a potentially harmful exotic pest or disease is the development and maintenance of emergency response deeds and agreements and contingency plans. These define the nationally agreed approach that will be taken in an incursion response so that participants are able to respond quickly and effectively when one occurs.

Animal Health Australia is custodian of the Emergency Animal Disease Response Agreement (EADRA) and the Australian Veterinary Emergency Plan, or AUSVETPLAN. The EADRA is a contractual agreement between the Commonwealth, state and territory governments and livestock industry groups to increase Australia's capacity to prepare for and respond to emergency animal disease incursions. In particular, it defines how to manage the costs and responsibility for an emergency response to an animal disease outbreak. For all EADs listed in EADRA, there is an agreed initial approach to responding to an outbreak set out in AUSVETPLAN. AUSVETPLAN consists of a series of technical manuals and supporting documents that describe the proposed approach to an emergency animal disease incident, including roles, responsibilities and policy guidelines for agencies and organisations involved in the response to a disease outbreak (PIMC, 2008).

The equivalent arrangements for emergency plant pest incidents are the Emergency Plant Pest Response Deed (EPPRD) and PLANTPLAN, both of which are managed by Plant Health Australia (PHA, 2016, 2017b).

EMPPLAN and AQUAVETPLAN set out the preferred approach to diseases that affect marine and aquatic animals, respectively. The Department of Agriculture and Water Resources manages the development and maintenance of both plans.

The National Environmental Biosecurity Response Agreement (NEBRA) sets out emergency response arrangements, including cost sharing arrangements, for responses to biosecurity incidents that primarily affect the environment and/or social amenity and where the response is for the public good. It was delivered under the IGAB.

As well as formal agreements and contingency plans, training activities are used to help participants in the biosecurity system maintain their readiness for a response to an incursion of an emergency pest or disease. This includes emergency response simulation exercises that test the capacity of the biosecurity system to respond. Exercise Odysseus, for example, was a series of more than 40 simulated field activities and discussions in each Australian state and territory held throughout 2014 and 2015. It was designed to focus on the first week of a hypothetical outbreak of foot and mouth disease initially detected in Queensland. Exercise Haryana was conducted in 2015 and 2016 to test the preparedness for, and capacity to respond to a Karnal bunt detection in Australia. Simulation exercises typically involve government and industry representatives.

Other activities to prepare for an emergency animal disease (EAD) incursion include training for government officers, private veterinary practitioners and livestock industry managers in emergency response functions; the development of national scale modelling capability to capture complex disease epidemiology, regional variability in transmission, and different jurisdictional approaches to disease control; and membership in the International Animal Health Emergency reserve, an arrangement between Australia, Canada, Ireland, New Zealand, the United Kingdom and the United States to share personnel and resources in an EAD outbreak (AHA, 2017).

Good on-farm biosecurity practices can be a powerful means of reducing the risk that an exotic pest or disease present in Australia can establish and spread. While good farm biosecurity is the responsibility of land owners and managers, training programs are important for raising awareness and disseminating information about good practices. The Farm Biosecurity Program is a joint initiative of Animal Health Australia and Plant Health Australia that provides information and on-line resources on a range of farm level biosecurity issues.

The intended outcome of activities that increase our preparedness for an emergency pest or disease incursion is that participants in the biosecurity system are ready to respond to new incursions, with the appropriate arrangements, tools and training to maximise the effectiveness of the response action. In this way, the potential harm from newly detected pests and diseases is minimised.

Detect an incursion post border

Early detection of an exotic pest or disease incursion can significantly improve the outcomes of response activities. Targeted, or active, and general surveillance programs to ensure timely detection of pests and diseases are important components of the biosecurity system. Effective surveillance requires cooperative partnerships between the Australian and state and territory governments, industry and the community and is part of the shared

responsibility concept described in the IGAB. The Australian government is responsible for reporting surveillance outcomes to the OIE and the IPPC. State and territory governments run many surveillance programs targeting exotic pests and diseases, as well as extensive general surveillance activities. By underpinning Australia's claims to pest and disease freedom, surveillance activities facilitate access to international markets, as well as supporting the management of established pests and diseases.

In 2016, the Animal Health Committee endorsed the National Animal Health Surveillance and Diagnostics Business Plan 2016-2019 (DAWR, 2016d), developed collaboratively by the Australian, state and territory governments and livestock industries. Under this business plan, Animal Health Australia coordinates several active or targeted surveillance programs, including the National Arbovirus Monitoring Program, the National Sheep Health Monitoring Program, the National Transmissible Spongiform Encephalopathies Surveillance Project and the Screw-worm Fly Freedom Assurance Program. Other programs use targeted and general surveillance activities to provide early detection of diseases, including the National Significant Disease Investigation Program and the National Avian Influenza in Wild Birds Surveillance Program (Box 6).

Surveillance activities are undertaken by jurisdictional veterinary authorities, private practitioners, industries and non-government organisations under a range of partnership agreements. Collectively, state and territory governments invest in more than 100 field veterinarians with district surveillance responsibilities, supported by seven government veterinary laboratories, veterinary pathology staff, abattoir veterinarians and inspectors and stock inspectors (Craik et al., 2017) .

In addition, the Australian Government funds the Northern Australia Quarantine Strategy (NAQS), which undertakes surveillance for targeted animal diseases in coastal areas of northern Australia from Broome to Cairns.

Box 6: National Avian Influenza in Wild Birds Surveillance Program

The National Avian Influenza in Wild Birds Surveillance Program is conducted Australia-wide and comprises two components: targeted surveillance via sampling of apparently healthy and hunter-killed birds, and general surveillance via investigation of significant unexplained morbidity and mortality events in wild birds, including captive and wild birds within zoo grounds. Sources for targeted wild bird surveillance data include state and territory government laboratories, universities and samples collected through the NAQS program. Samples from sick birds are sourced from members of the public, private practitioners, universities, zoos and wildlife sanctuaries. The program is managed by Wildlife Health Australia.

Plant pest surveillance activities are, similarly, undertaken on a collaborative basis between the Australian, state and territory governments, industry and the community. Current surveillance activities are outlined in the National Plant Biosecurity Surveillance Strategy 2013-2020 (PHA, 2013). They include the National Plant Health Surveillance Program

(NPHSP) coordinated by the Australian Department of Agriculture and Water Resources. The objective of the NPHSP is to 'develop and implement a nationally consistent, multi-jurisdictional approach to plant pest surveillance that incorporates pest surveillance activities in the vicinity of ports as well as in urban areas that have a relatively high risk of pest presence based on pathway and host considerations' (PHA, 2013). Its three main components are ports of entry trapping, multiple pest surveillance and surveillance information management. The Australian government also undertakes surveillance for plant pests through the NAQS program.

State and territory governments run a number of surveillance programs targeting a range of exotic and established plant pests. General surveillance is also used, involving the development and dissemination of awareness information relating to pest threats, as well as maintaining systems for public reporting. Agricultural participants also invest in surveillance, either directly or through the purchase of services from private or government providers, primarily to manage established pests on an ongoing basis (PHA, 2013).

Early detection of exotic incursions also relies on having sound diagnostic capability and capacity available to support identification of pests and diseases. Diagnostic services (i) underpin the identification of exotic, emerging and nationally significant endemic pests and diseases; (ii) assist in assessing the magnitude of an incursion, which helps determine whether a pest or disease is eradicable; and (iii) provide evidence to support any claim that a pest or disease has been eradicated. They provide the necessary information to support pest and disease control programs and reporting requirements (Craik et al., 2017).

Australia's animal disease diagnostic capacity is well developed. Facilities include the Australian Animal Health Laboratory, state and territory government veterinary laboratories and university and private veterinary laboratories. Institutional arrangements support the effective operation of the laboratory system. For example, the Laboratories for Emergency Animal Disease Diagnosis and Response (LEADDR) network plays an important role in ensuring quality assurance for targeted emergency animal diseases through standardising or harmonising the relevant testing performance in all member laboratories. All government laboratories and the major private laboratories in Australia are accredited by the National Association of Testing Authorities (NATA) for testing of various emergency animal diseases.

Plant pest diagnostic facilities are distributed across all states and territories, including in major agricultural and horticultural regions. Services are delivered by a range of agencies, including the Australian government, state and territory governments, private laboratories, museums, the CSIRO and universities. Services are provided on an ad hoc, commercial or nationally coordinated basis. Diagnostic operations are often performed as part of collaborative research activities that focus on specific pests of concern (PHA, 2017a).

The Subcommittee on Plant Health Diagnostics was established in 2004 by the Plant Health Committee to improve the quality and reliability of plant diagnostics in Australia. Its role includes to develop diagnostic policies, protocols and standards; to develop strategies to address national capability and capacity issues; to endorse national diagnostic protocols; and to drive the development and uptake of accreditation and quality management systems

for diagnostic laboratories. Unlike the animal system, not all plant diagnostic laboratories are accredited by NATA to the appropriate international standard. The plant pest diagnostic system is underpinned by the National Plant Biosecurity Diagnostic Strategy (PHA, 2012) and a national network of diagnosticians. The latter improves capacity by facilitating communication between experts and sharing of diagnostic resources. Together these initiatives are designed to build an integrated national network that can provide efficient delivery of services, including the provision of surge capacity during incursions (PHA, 2017a).

Not all exotic pest and disease incursions are initially identified at source. A diseased animal, for example, might have been moved from its property before identification occurs at a saleyard or abattoir, or an infected plant might have been sold from an importer to a retail chain before detection occurs. The capacity to trace the source of an incursion is an important part of the detection element of the biosecurity system.

Animal traceability systems in Australia are well developed under the National Livestock Identification System (NLIS). The NLIS was developed to meet the National Livestock Traceability Performance Standards (NLTPS) endorsed in 2004 by the former Primary Industries Ministerial Council (PIMC). The NLTPS outline the requirements and timeframes for livestock to be traced quickly and reliably if needed (ABARES, 2014).

Under the NLIS all cattle, goat, pig and sheep producers must identify their stock and record their movements onto and off properties in the NLIS database. All movements to and from saleyards and abattoirs must also be recorded. When fully implemented for a type of livestock, NLIS is a permanent, whole-of-life system that allows animals to be identified – individually or by mob – and tracked from property of birth to slaughter, for the purposes of food safety, product integrity and market access (AHA, 2017). Box 7 summarises the status of animal traceability systems in Australia.

Box 7: Status of national animal traceability systems

NLIS (Cattle) is an electronic identification system for individual animals. NLIS (Sheep and Goats) is a mob-based system using visually readable ear tags labelled with property identification codes. Victoria is currently transitioning to an individual electronic identification system for sheep and goats. Australian Pork Limited is continuing to develop NLIS (Pigs), or PigPass, and voluntary movement reporting occurs through the PigPass portal. The development of legislation for NLIS (Pigs) is progressing. An NLIS (Alpaca and Llama) tracing system is also under development (AHA, 2017).

State and territory governments are responsible for the legislation governing animal movements, the implementation of NLIS and monitoring of compliance with NLIS requirements throughout the livestock supply chain. NLIS Limited administers the NLIS database on behalf of industry and government stakeholders (AHA, 2017).

Tracing the source of a plant pest incursion is a more ad-hoc process than occurs in the animal system, partly because plant pests move independently of their hosts. Hence there is no feasible equivalent of the NLIS and tracing activities are conducted on a case-by-case

basis. An incursion of Mexican feather grass in Victoria in 2008 is an example of the types of actions undertaken to trace an incursion back to its source (see Box 8). The capacity to implement a successful tracing exercise in these circumstances relies on sound relationships between participants in the biosecurity system, the willingness of all participants to contribute to the tracing effort and effective communication.

Box 8: Tracing of a Mexican feather grass incursion in Victoria, May 2008

Following a detection of Mexican feather grass in a large retail chain, tracing was conducted by the state government back along the supply chain to the seed importer and forward through distribution channels to discover more than 10,000 plants for sale in Victorian retail outlets. Statewide product recalls were initiated, instructing retail chains to recover as many plants as possible. Sales information, including credit card transactions, was used to help assess where plants had been planted. New building-permit information from local governments provided locations for targeted public awareness campaigns. Community weed spotters were alerted to support the surveillance effort. *Source: Biosecurity Victoria (2009)*

The intended outcome of the surveillance activities, the provision of sound diagnostic services and the capacity to trace an incursion to its source is that the time taken to detect incursions of priority pests and diseases is reduced. This contributes to minimising the costs of response activities and maximising the effectiveness of eradication or containment efforts.

Respond to an incursion

Following the detection of an exotic pest or disease, response actions are implemented collaboratively between governments, industry and other stakeholders. Broad response actions are outlined in the response agreements and contingency plans discussed above – EADRA and AUSVETPLAN; EPPRD and PLANTPLAN; and EMPPLAN and AQUAVETPLAN, and NEBRA. These are supported by detailed industry specific or pest/disease specific response plans. The agreements and plans are designed to ensure rapid and effective responses to detections and to provide certainty regarding the management and funding of the response.

Coordination of response activities is enhanced by the use of established management groups and consultative committees. The National Management Group (NMG) is responsible for making the key decisions in a response to an emergency pest or disease incursion. It is formed in response to a detection and comprises representatives from the Australian and state and territory governments, AHA/PHA, and affected industries. The NMG is responsible for approving a response plan, including the budget, if it is agreed that eradication is technically feasible and cost beneficial. The NMG is advised on technical matters by the relevant Consultative Committee (CC). The CC comprises the Australian Chief Plant Protection Officer/Chief Veterinary Officer, their state and territory counterparts, AHA/PHA, and industry representatives. It assesses the grounds for eradication and provides technical advice on which the NMG can base decisions.

Operational responsibility for the response to an emergency incursion lies with the relevant state or territory.

Once a detection has been advised to a government party, the deeds require that the relevant government advises the CC within 24 hours. There follow sequential phases of response activities, as outlined in the relevant deeds. These are:

i) *The incident definition phase* where an initial investigation is undertaken by the relevant government authority. On the basis of a pest risk analysis, the CC advises the NMG if the incident relates to an emergency incursion and is capable of being eradicated or contained. In this case, an emergency response plan (ERP) is agreed by the NMG;

ii) *The emergency response phase* during which the ERP is implemented. The control measures used may evolve as new information about the outbreak becomes available. This phase continues until the NMG, on advice from the CC, determines that the incursion has been contained or eradicated, or cannot be contained or eradicated.

iii) *The proof of freedom phase* following a declaration by the NMG that an outbreak has been contained or eradicated. This period may include research and/or surveillance activities and will end when the NMG determines that the ERP has been successful.

iv) In the case of plant pests, where containment or eradication is not feasible, a *transition to management phase* may be determined by the NMG where it considers that transition to management is achievable within a reasonable timeframe not exceeding 12 months.

In the small number of cases where an exotic pest or disease incursion affects an industry that is not covered by a deed, the state or territory where the outbreak occurs is responsible for the response plan and the negotiation of funding arrangements. Currently, more than 90 per cent of the value of Australia's agricultural production is covered by the relevant deeds.

Having mechanisms in place that support rapid and effective responses to pest and disease incursions, including decisions about eradication and containment, ensures that the number of priority pests and diseases that establish and spread in Australia is reduced.

Collectively, the activities undertaken to prepare for an incursion, detect an incursion post-border and respond to an incursion once detected contribute to meeting the second objective of the IGAB, that is, to 'prepare and allow for effective response to, and management of, exotic and emerging pests and diseases that enter, establish or spread in Australia'.

Recover and/or Adapt to an incursion

A number of activities undertaken as part of the biosecurity system are designed to reduce the ongoing impacts of introduced pests or diseases on the environment, the economy and the community. These can be short term actions that occur immediately after an incursion as part of the recovery strategy or they may become long term activities that help the

system adapt to changed circumstances. These activities are undertaken by a range of participants, including the Australian, state and territory governments, producers and industry and community groups.

Following pest or disease eradication or containment efforts, there is generally a need to provide evidence of success in order to underpin future interstate or international trade. Area freedom claims are based on surveillance activities and surveys that may be undertaken for a specific time or may become ongoing activities. Re-opening of international markets is a particularly important recovery strategy for trade dependent industries and requires certification by the Australian Department of Agriculture and Water Resources to verify that goods for export meet importing country requirements.

Part of the process of recovering from a pest or disease incursion is the provision of information and support to affected parties to facilitate their financial and non-financial recovery. These activities are provided by a range of participants in the biosecurity system and can be subject to agreements already in place, for example under the EADRA and the EPPRD.

Not all pests and diseases that enter Australia will be successfully eradicated. This might occur because the pest or disease was not detected sufficiently early or because it is technically infeasible to eradicate. Containment of pests and diseases to specific areas or regions can be used to minimise their negative impacts. In the case of plants, pests can be contained at a local, regional or state level, depending on their current distribution and the ability to implement cost beneficial measures for containment (PHA, 2017a). Domestic quarantine and movement restrictions on high risk material that are implemented under state and territory legislation are used to limit the spread of pests nationally. Interstate certification systems exist to govern the movement of plant products under the quarantine regulations in each state and territory.

In some cases, long-term management strategies will be implemented that seek to reduce the adverse impacts of the pest or disease. These plans might include changes in regional or local biosecurity practices to reduce the chance of a pest or disease spreading. The (Draft) National Fruit Fly Strategy is an example of a coordinated approach to managing the impacts of endemic fruit fly species on productivity and market access through the strategic use of containment, exclusion and other local management practices (PHA, 2008)

The biosecurity system also comprises a range of long term activities that are designed to ensure that those pests and diseases that have established and spread following incursions that occurred sometime in the past are managed effectively. These include community led programmes that coordinate action targeting established weeds, such as serrated tussock, where collective action has a social benefit (for example, the Serrated Tussock Working Party).

A substantial proportion of the activity that occurs at the state and territory level – up to 60 per cent – is directed at ensuring that relevant participants in the biosecurity system comply with jurisdictional biosecurity regulations. One common example is the targeting of

enforcement activities at landowners who fail to control noxious weeds on their property. These activities are often delivered in conjunction with local community led programs and are another example of 'shared responsibility'.

Part of recovering from and adapting to pest or disease incursions is evaluating outcomes of emergency response activities, including eradication and containment actions. Evaluation processes are used to update response tools, plans and procedures and to encourage the application of best practice across biosecurity sectors nationally.

The cumulative impact of activities in the national biosecurity system to recover from and adapt to incursions is that the realised impact on the economy, environment and community of pests and diseases that establish and spread in Australia is reduced and that disruptions to international market access are minimised. This contributes directly to meeting the third IGAB objective to 'ensure that, where appropriate, significant pests and diseases already in Australia are contained, suppressed or otherwise managed'.

2.7 Influencers and Enablers

In addition to the specific elements of the biosecurity system outlined above, there are activities undertaken as part of the system that are fundamental to its performance and the value it creates. These enablers and influencers underpin some, or all, of the biosecurity system's elements.

A key characteristic of the biosecurity system that underpins its performance at the national level is the shared responsibility or *partnerships approach* that strengthens relationships between its participants. While a somewhat abstract concept, it reflects the fact that the national biosecurity system does not exist as a single physical or legal entity (Craik et al. 2017) but is built on a complex set of relationships and interactions that link multiple participants. It is the effective cooperation and collaboration between these participants that helps ensure that the biosecurity system is more than the sum of its individual elements.

Governance arrangements define how each participant in the system will behave, including the relationships between participants. At the highest level, each jurisdiction has implemented biosecurity legislation that provides the overarching framework for the operation of the system. Key inter-governmental governance arrangements in the national biosecurity system are the IGAB and the National Biosecurity Committee and its sub-committees and working groups. These arrangements support the development of national policy on key biosecurity issues. Other important governance settings are provided in the emergency response deeds managed by Animal Health Australia, Plant Health Australia and the Department of Agriculture and Water Resources.

Because of the significant investment required to operate the biosecurity system, *funding arrangements* are important to the sustainability of each of its elements, as is ensuring the optimal *allocation of resources* across the system. This is particularly the case given the ongoing financial challenges faced by governments at all levels. The IGAB outlines principles

for the funding of biosecurity activities and the prioritisation of resources to the areas of highest return. However, existing financial arrangements are complex and multi-faceted, and in some cases lack transparency (Craik et al., 2017).

An effective biosecurity system requires a high level of skill and experience from its staff across all levels and areas of operation. A sustainable supply of relevant skills requires ongoing *capability development*, delivered through the general education system, specialist training and on-the-job experience.

Also critical to operations across the entire biosecurity system is the capacity for *information management and analysis*. Ready access to comprehensive and reliable data and information is essential for anticipating, responding to and managing national biosecurity risks, substantiating Australia's claims to pest and disease free status, and for decision making, policy development, and performance measurement (Craik et al., 2017). All jurisdictions, industries and relevant NGOs hold data of relevance to the national biosecurity system but these data holdings cannot easily be integrated to derive maximum benefit. Agreed data standards and formats are generally lacking as are interoperable technology platforms. However, recent developments across jurisdictions are addressing these issues. For example, the Victorian government's MAX system, which is designed to collect, manage and report data, is being used by five other jurisdictions for routine and emergency biosecurity activities. Plant Health Australia's AUSPestCheck is capable of providing and receiving national surveillance information on weeds and plant pests from a wide range of stakeholders. And the Australian government is investing significantly in sophisticated data capture, use and analysis through its Biosecurity Integrated Information System Analytics program (BIISA).

Because Australia's biosecurity system is based on sound science, *research and innovation* is a critical element that enables technological solutions to be delivered to biosecurity problems and helps drive down the cost of many biosecurity operations. Biosecurity relevant research and innovation is funded principally by the Australian and state and territory governments, the Rural Research and Development Corporations (RDCs) and Cooperative Research Centres (CRCs). The latter two of these receive funding from both government and industry, although from June 2018 there will be no biosecurity relevant CRCs. Research is delivered by multiple providers, including the CSIRO, universities, state and territory research agencies and private consultants.

The allocation of investment in research and innovation is guided by several strategies that are framed within the national research priorities outlined in the National Science and Research Priorities and the National Rural R&D priorities. These include the Animal Biosecurity RD&E Strategy and the Plant Biosecurity RD&E Strategy that have been developed under the IGAB and the Invasive Plants and Animals Research and Development Strategy. There are also a few industry specific research and innovation strategies. In July 2017, the National Biosecurity Committee endorsed overarching national biosecurity Research, Development and Extension priorities that are intended to provide a strategic and unified guide to investment in high priority research activities (DAWR, 2016c).

Because of the many participants in the biosecurity system, the complex nature of their interactions, and the rapidly evolving nature of the system effective *communications and engagement* are important to achieve outcomes. Communication encompasses general strategies to inform and educate those who play a direct role in the biosecurity system such as producers and other landholders, as well as more peripheral participants such as travellers, traders and port workers. Communication between governments and industry is critical in an emergency response situation and can be central to building community resilience in the period following an outbreak.

There are numerous effective communication mechanisms are in place in the Australian biosecurity system that facilitate communication at different levels. These include the Farm Biosecurity program operated by AHA and PHA to raise awareness of producers about on-farm biosecurity and prevention of animal diseases and plant pests. It uses many channels to communicate its messages about biosecurity, including electronic media, educational materials and direct stakeholder engagement. DAWR coordinates an annual Biosecurity Roundtable that provides biosecurity stakeholders and government agencies with a forum to exchange perspectives on priority biosecurity issues. DAWR also has a dedicated communications section that coordinates communication between governments and industry during biosecurity incidents. The Biosecurity Incident National Communication Network produces nationally consistent public information in response to pest and disease outbreaks. It has members from the Australian and state and territory governments and from Animal Health Australia and Plant Health Australia. DAWR also produces a bi-monthly newsletter, *Biosecurity Matters*, as well as brochures on travel, biosecurity and citizens' awareness.

A further important element of the biosecurity system is the capacity to undertake *monitoring and evaluation* of its performance. This provides a basis on which all participants can identify what improvements in investment allocation can be made, either individually or on a collective, system-wide basis. Evaluation of components of the national biosecurity system occurs on a regular basis. The Australian and state and territory governments, for example, articulate performance measures in corporate plans, strategy documents and annual reports, though their coverage and sophistication vary widely (Craik et al., 2017). Jurisdictional auditors-general undertake reviews of aspects of the biosecurity system from time to time and have been influential in driving system reform in some jurisdictions. However, there is no current framework for monitoring or evaluating the performance of the biosecurity system at the national level. This gap has been identified by the review into the IGAB, which notes that it is not possible to 'roll up' individual jurisdictional performance measures to capture the national system and assess national performance (Craik et al., 2017).

3 How have others evaluated complex systems?

The interim report for this project was delivered in January 2017 and provided a comprehensive overview of the peer-reviewed literature relating to the evaluation of the performance or 'health' of complex systems. The learnings from that review that are of direct relevance to this project are summarised here. (For the interim report and bibliography see CEBRA Project 1607B Deliverable 3). Following the delivery of the interim report, CEBRA contracted ABARES to undertake a further and more detailed review of the experience of Australian and international governments in evaluating complex systems. This included reviews of performance evaluation approaches in the health, education and defence sectors. CEBRA contributed to this review by examining the Department of Finance's guidance for performance evaluation in Commonwealth agencies, as well as performance evaluation frameworks in New Zealand's health, education, defence and primary industries sectors. This review of the 'grey' literature is also summarised below and is attached in full at appendix A.

3.1 Approaches to evaluating the performance of complex systems

The peer reviewed literature on performance evaluation methods and frameworks is extensive and a diverse set of evaluation frameworks is reported. Evaluations can be conducted at different levels of a system (system-wide, sub-system, individual action); in different time frames (annual, decadal); at different geographical scales (regional, national, international). They can be conducted at different stages (ex-ante, interim, ex-post); by various sources of expertise (internal, external, mixed); and for different purposes (to evaluate only, or to evaluate, learn and improve).

Two alternative frameworks for evaluation are those that focus on outcomes or results, known as summative evaluation, and those that focus on the processes of a system, or formative evaluation. Summative evaluations are mainly performed when an action has been completed or when it has matured to the point of impact. The approach focuses on evaluation as the endpoint, with less consideration of what could be learned or how the system could be improved. Formative evaluations are generally ongoing and focus on regularly evaluating the processes of the system. These evaluations often allow for systems to be updated and improved over time.

The complexity of a system has particular implications for the level at which evaluation should be conducted – single action, program, or whole of system – and for the timeframe of the evaluation – short-term or long-term. Glouberman and Zimmerman (2002) distinguish between simple, complicated, and complex systems. A simple system usually comprises a single action; complicated systems typically include multiple actions but respond in predictable ways; and complex systems have multiple components but may respond unpredictably.

While there is no universally accepted definition of complexity, the following have been proposed as characteristics of a complex system (Ladyman et al., 2013):

- contains many components
- exhibits emergent behaviour such that the outcome of a system cannot be readily predicted based on known components
- contains some degree of spontaneous order, or self-organisation, and robustness of order, which allows it to withstand failures and perturbations
- contains non-linearity of interactions, such that small inputs may have large effects and vice versa
- contains interacting components
- contains feedback loops, and mechanisms of self-regulation
- exhibits context dependency, where outcomes of similar components vary from one context to another.

In a simple system, the appropriate scale of evaluation is the individual action. If several measures of health are used, then they can typically be summed together or averaged to evaluate system health (for example Almahmoud et al., 2012; Gupta & Dokania, 2014; Blondeau et al., 2015; Wu et al., 2016). A similar approach can be taken for complicated systems, except that indicators are used to measure performance of multiple actions (for example EC Directorate-General for Regional and Urban Policy, 2013; Agriculture and Agri-Food Canada, 2015; European Commission, 2015a; Canada Border Services Agency, 2016). In both simple and complicated systems, it is often possible to evaluate health over relatively short time frames because the causal relationships between the components are simple and behave consistently over time.

In contrast, it is not sufficient to understand the behaviour of isolated components in complex systems and then aggregate these to measure system health. This is because complex systems often contain interactions between components of the system and exhibit non-linearity and emergent behaviour (Shiell et al., 2008; Walton, 2014), which can result in unexpected outcomes at varying time scales. Therefore, evaluation procedures for complex systems typically require identifying all interactions that may exist within a system, between components within a system, and between the system and its context.

A practical consequence of this is that most evaluation procedures for complex systems are conducted at multiple levels of a system, for example individual actions and whole-of-system; in multiple contexts; and over long time frames to ensure that any possible emergent behaviour is detected.

A key challenge with system wide and/or long-term evaluations of complex systems is the difficulty in establishing causality between the outcome and changes in the system components. As highlighted by Liu et al. (2014), the strength of inferred causal relationships decreases with: (i) the scale of the evaluation (i.e., from action to system); and (ii) the time between implementation and evaluation of an action/system. This is a particular issue for complex systems, which can involve multi-scale evaluations and long evaluation time frames. For example, in trying to measure the effect of increasing the proportion of shipment containers screened on the number of insect pest establishments over a 20-year period it would be important to determine whether decreases in pest establishments were

the outcome of increases in screening or the result of changes in weather conditions, import regulations or the origin of shipments over that period.

There are various tools to aid in evaluating the health of complex systems, including theory-driven approaches such as logic models, and systems thinking. *Theory-driven evaluations* aid the design and implementation of complex system evaluations using a conceptual framework. Specifically, they assist in describing the various objectives, inputs, outputs, outcomes, assumptions and components of the system. There are several types of theory-driven approaches, including logic models and theory-of-change evaluations.

A logic model is a diagrammatic representation of how a system functions and what it achieves. The most basic format of a logic model involves the intervention—output—outcome—impact structure, and includes a description of resources/inputs needed to undertake interventions. The purpose of a logic model is to provide clarity about the components of a system and how these help achieve the system's objectives.

The theory of change focuses on inputs, activities and outcomes, but also specifies the order of activities, and the relevant assumptions and context, which typically are not included in logic models. It requires a deeper understanding and explanation of the system and as a result is often more narrative than diagrammatic, and there is less standardisation in its format. Theories of change often take a system's goal as the starting point, and work backward to articulate how and why the practices will lead to the goal. Producing theories of change is likely to involve more time and effort and a larger set of stakeholders than a logic model.

Theory-driven approaches are generally used in both complex and complicated systems. For example, the majority of evaluations performed by governmental and inter-governmental organisations such as the Canadian border services or the European Union use a theory-driven approach (EC Directorate-General for Regional and Urban Policy, 2013; Agriculture and Agri-Food Canada, 2015).

In the past decade there has been increasing recognition in the evaluation literature that in order to be effective, the evaluation of complex systems must take into account features such as emergent outcomes and non-linearity (Walton, 2016). *Systems thinking* is a recent term that has been used in public health and social sciences for advocating new approaches that explicitly consider complexity properties when evaluating complex systems (Glouberman & Zimmerman, 2002; Forss et al., 2011; Patton, 2011; Westhorp, 2012; Lamont et al., 2016).

Systems thinking is defined as 'an approach to problem solving that views problems as part of a wider dynamic system. Systems thinking involves more than a reaction to present outcomes or events. It demands a deeper understanding of the linkages, relationships, interactions and behaviour among the elements that make up a system.' (World Health Organization, 2009). Many concepts found in the systems thinking literature already existed in the evaluation literature, for example, understanding linkages and relationships, or evaluating a system from multiple scales (Cabrera et al., 2008). Yet, systems thinking is a

paradigm shift in how evaluations are traditionally constructed (World Health Organization, 2009). It frames the problem in terms of patterns of behaviour over time; views causality as an ongoing process not a fixed relationship; and emphasises the need to understand the context of relationships.

Despite its recent popularity within the evaluation literature, systems thinking remains only peripheral in evaluation practice (Walton, 2016). On the basis of interviews with 41 evaluation practitioners, Walton (2016) identified several barriers to the use of systems thinking. These included resource constraints; time and data requirement of the method; the dominance of existing approaches; expectations of evaluation funders and users; limited practitioner knowledge; and limitations in complexity-informed methods. Several participants reported the difficulty of translating complexity thinking into practical tools. For example, despite academic definition it is still difficult to know how to implement the concepts of emergence or boundaries in a practical sense.

The choice among these various evaluation tools depends on the characteristics and complexity of the system. However, all these tools emphasise the importance of developing indicators of performance that reflect different elements of a system, the attributes of performance that are considered relevant and the scales of the evaluation.

3.2 Using indicators to measure performance

Indicators form the basis of any evaluation framework. Indicators are measurable aspects of a system that allow assessment of whether the objectives of an action or system are being met. Indicators can:

- measure an output, outcome or impact of the system or action;
- address an average behaviour, or the outliers (for example the average versus the maximum number of border interceptions); and
- examine changes at the system level or at a specific action level.

Indicators can be quantitative – reported in terms of a number or a percentage – or qualitative – requiring description. Quantitative indicators are typically easier to collect and interpret than qualitative indicators but they may tell only part of the performance story. Qualitative indicators provide complementary and valuable insights into the attitudes, perceptions and beliefs underlying the behaviour of participants in a system (Victorian DEPI, 2014). Using a combination of quantitative and qualitative data can improve performance evaluation by ensuring that the limitations of one type of information are balanced by the strengths of another. This helps to ensure that understanding is improved by engaging different ‘ways of knowing’ (BetterEvaluation, www.betterevaluation.org).

Good performance information – use of quantitative and qualitative measures

Quantitative data refers to observations that are represented numerically, including as a number (count), grade, rank, score or proportion. Examples are standardised test scores, average age, the number of grants made during a period, and the number of clients assisted during a period.

Quantitative inquiry emphasises measurement rather than narrative.

Qualitative data is information that describes something.

Qualitative inquiry emphasises narrative rather than numbers.

Qualitative inquiry involves capturing and interpreting the characteristics of something. This can involve tapping into the experience of stakeholders through observation, interviews, focus groups and the analysis of documents.

Department of Finance (2015)

The distinction between quantitative and qualitative indicators is not always clear-cut. Many quantitative indicators reported in the literature are derived from qualitative indicators (EC Directorate-General for Regional and Urban Policy, 2013; Agriculture and Agri-Food Canada, 2015; European Commission, 2015a; Canada Border Services Agency, 2016). For example, a survey with qualitative statements can be summarised into a quantitative measure, such as '50 per cent of respondents said collaboration was sufficient during the program.' In the literature review, evaluations performed by scientists and economists were largely focused on quantitative indicators. In contrast, both qualitative and quantitative indicators were used in evaluations performed by management consultants, policy analysts and governmental and non-governmental agencies.

The characteristics of good performance indicators vary according to the nature of the activities or system being evaluated, the purpose of the evaluation and the values of the organisation. The management literature frequently cites variants of five SMART criteria – that indicators should be:

- Specific: target a specific area for improvement;
- Measurable: quantify or at least suggest an indicator of progress;
- Assignable: specify who will do it;
- Realistic: state what results can realistically be achieved, given available resources; and
- Timely: specify when the result(s) can be achieved (Doran, 1981).

The EC Directorate-General for Regional and Urban Policy (2013) uses a similar framework but includes relevance – that an indicator should be directly related to the objective being measured; understandable – that the indicator can be readily interpreted; and cost effective – that collection of an indicator should provide a benefit commensurate with its cost.

Reflecting the purpose of its activities, the United States Agency for International Development (USAID) requires that its performance indicators be, among other things, objective – unambiguous about what is being measured and what data are being collected; useful for management – able to provide a meaningful measure of change over time for management decision making; and able to be disaggregated to the appropriate level, for example by age or gender – to manage for sustainable project impact (USAID, 2010).

There are many other examples of organisations defining the types of indicators useful for their specific purposes. Key considerations for all organisations are that the indicator set chosen should, when interpreted together, be capable of providing a more effective picture of the impacts of interventions than any individual indicator. The set of indicators should also reflect different points along the pathway to long term outcomes and impacts to provide an understanding of how results are linked to activities and identify areas that might require further investigation (Peersman, 2017).

Diverse sources of data and other information are required to assess the outcomes of activities. These can include reviews of reports, previous evaluations and audits (Lauras et al., 2010; European Commission, 2015a; Wu et al., 2016); statistical sources such as national and regional statistics; program and system monitoring data sets (Gupta & Dokania, 2014); experiments (Susaeta et al., 2016); case studies (Wu et al., 2016); interviews (Agriculture and Agri-Food Canada, 2015); surveys (European Commission, 2015b) and reviews of the academic literature or media (Agriculture and Agri-Food Canada, 2015). The literature review shows that indicators used by government or intergovernmental agencies were mainly based on data gathered from previous reports as well as from interviews and surveys (EC Directorate-General for Regional and Urban Policy, 2013; Agriculture and Agri-Food Canada, 2015; European Commission, 2015a; Canada Border Services Agency, 2016).

It is worth remembering that good performance reporting is not about the volume of data; it is about using quality data to support better decision making and better assessment of performance (Department of Finance, 2015).

3.3 Benchmarking performance

Good performance in a system is a relative concept. While performance indicators are essential to understanding the links between activities in a system and outcomes, they do not of themselves define whether a system is healthy. An essential step towards evaluating system performance is defining what a 'healthy' system looks like. This can involve defining indicator thresholds, or benchmarks, that are deemed 'healthy'. These targets and benchmarks might be considered minimum levels of performance required for a system to be considered healthy, or levels required to be considered 'best practice'. Most benchmarks in the literature are established on the basis of industry-level agreed standards, for example those developed by the International Organization for Standardization.

3.4 Evaluation of system health by public sector agencies

Governments internationally, including in Australia, have developed a strong focus on performance evaluation and require that performance frameworks are in place to assess the effectiveness and efficiency of their activities. The following summarises the review undertaken by ABARES of emerging trends in public sector performance evaluation in Australia and internationally, supplemented with additional information and interpretation from CEBRA.

Emerging trends in public sector performance evaluation in Australia

In Australia, performance evaluation of Commonwealth agencies is guided by the Department of Finance. In its guide to developing good performance information (Department of Finance, 2015), the Department of Finance articulates that accurate and reliable performance information helps officials, ministers, the parliament and the public form judgments about whether a Commonwealth entity is delivering on its intended results. Such information underpins the accountability of agencies to the parliament and the public. Performance information can also be used for strategic decision making that supports government consideration of how to best allocate limited public resources to achieve its policy objectives, and can be used at an agency level to support tactical and operational decisions.

While the Department of Finance guidance material is intended to support good performance reporting in the corporate plans and annual performance statements of Commonwealth agencies under the *Public Governance, Performance and Accountability Act 2013*, it provides sensible and pragmatic advice for performance reporting and evaluation in a wide range of contexts. The following draws on information relevant to the assessment of biosecurity system health.

The guide takes a flexible approach to performance measurement, noting the following key points:

- if well designed and reported, key performance indicators (KPIs) can be a powerful source of non-financial performance information that can be easily understood and related to the efficiency and effectiveness of an activity;
- KPIs alone may not give a full performance picture – particularly when the effectiveness of activities is hard to measure quantitatively, for example policy advice; when activities are complex; when outcomes are best observed over the medium to long term; and when activities require collaboration across diverse entities, including other jurisdictions;
- Good performance reporting is not about the volume of data – it is about using quality data to support better decision making and better assessment of performance;
- Performance reporting must be cost effective; and
- Performance measures should be informed by the nature of the activities they are trying to assess and the key stakeholders involved in the activity.

The Department of Finance (2015) notes that there is no general rule for what constitutes a good performance measure. It provides principles to assist in determining measures that are fit for purpose:

- focus on a small number of well targeted and defined performance measures rather than a large number of loosely framed performance measures;
- the form and content of the performance measures should provide sufficient evidence to show whether an activity is achieving or adequately progressing towards desired outcomes;
- the performance measures should be carefully worded to ensure that the results being monitored are specific enough to allow a meaningful discussion of performance;
- performance measures should drive behaviours that deliver the desired outcomes of the activity; and
- a comprehensive and balanced set of performance measures should compare actual performance with expected results.

Practical considerations raised by the Department of Finance include that data should be of the appropriate quality to ensure that performance information is meaningful and consistent. Performance measurement must also be cost effective – that is, the effort required to collect and manage the information should be commensurate with the significance of an activity and should not detract from an agency's ability to deliver activities and achieve its purpose. Performance information should also provide the appropriate link between an activity or intervention and an outcome. This can be difficult where activities are delivered in complex environments that are constantly changing and where there is limited control over external factors. There is also recognition that different entities often work together to achieve a common purpose. Although the entities may deliver discrete components of a broader undertaking, the performance information of interest will identify whether the common purpose is being achieved. This observation is of particular relevance to the biosecurity system where there are multiple participants across linked activities that are designed to deliver common objectives.

The Department of Finance also notes that many activities will deliver different results at different times. Long term results can be difficult to measure as they may only be observable once an activity has ended, or has been going for many years. In such cases, it is important to use results observable in the short to medium term to provide confidence that long term results will follow. It is also important to ensure that performance information is based on durable data or data that is stable over time. If the types of information used to evaluate performance vary significantly over time, the ability to make meaningful comparisons between different time periods will be compromised.

The Department of Finance guidance is also clear that meaningful performance reporting will be supported by both quantitative and qualitative information. Quantitative and qualitative information make different contributions to an assessment of performance and when used to complement each other can provide a more complete performance picture.

In addition, the Department of Finance provides guidance on how to use performance information to tell a meaningful performance story that is targeted to the appropriate audience. A small set of relevant and high quality performance measures that generates information that tells a coherent story about the achievements of activities directed at satisfying a particular objective is preferred over larger amounts of poorly focused and messaged performance information. Because it is likely to be a combination of quantitative and qualitative data, performance information will often be presented through a mix of graphics and narrative descriptions.

The ABARES review of literature identified different approaches to system wide performance evaluation used in defence, education, environment, finance, forestry, health, Indigenous and social justice, and science. The assessment focused on the work undertaken by public sector agencies to evaluate and provide measures of the health of their system using performance indicators and other criteria.

The ABARES review identified emerging trends in the way entities approach performance reporting in Australia:

- Some entities are moving away from a reliance on Key Performance Indicators (KPIs) that measure performance solely in terms of inputs (measuring the quantity of resources provided) and outputs (the volume of products or services provided), to include other types of indicators of performance such as:
    - process indicators (measuring what happened during implementation)
    - efficiency indicators (relationship of outputs to inputs)
    - effectiveness indicators (extent to which planned activities are realised and planned results achieved)
    - impact and outcome indicators (that measure short and long term effects, respectively)
    - indirect indicators (used when direct measures are not available or feasible).
- Performance reporting tends to focus on a small set of well targeted, high level (or core) indicators to evaluate performance, rather than an in-depth review of many indicators.
- Although the use of quantitative measures (such as indicators that measure values or counts, expressed as numbers or frequencies) is core to evaluating the performance of a department or system, there has been movement towards using a mix of quantitative and qualitative measures that, together, provide more complete and insightful information about performance at the level of an entity’s purpose.
- There is evidence of reporting information at different time scales, and at a level appropriate to measuring long-term outcomes.
- While indicators comprise the bulk of a review, agencies are now supplementing this type of measure with a range of other tools, including: benchmarking (against relevant best practice); stakeholder surveys (to provide firsthand data on the results of activities on the intended recipients); peer review (to provide assessments against the experience of those with proven records of delivering similar activities); and

comprehensive evaluations (to provide a better understanding of the overall impact of an activity).

- There are clear linkages in reported departmental and system strategic objectives (particularly those identified in corporate plans, and key strategies and action plans) and the core measures selected in performance reporting.
- The need for transparency, honesty and integrity was identified by a number of government departments as being an important attribute of performance reporting.

The ABARES report reviews contemporary examples of performance reporting of three complex systems – national Indigenous health and well being; forestry; and defence. These are reported in Appendix A.

The New Zealand experience

The New Zealand Government State Services Commission and the Treasury (2008) provides advice on performance evaluation that has been adopted across government agencies. The most recent annual reports from New Zealand ministries demonstrate a consistent evaluation framework. This involves describing the agency's key goals and how they are achieved using a program logic structure: resources, outputs, impacts and outcomes. In this context, resources are the staff or finances allocated to activities, outputs are the direct results of particular activities, impacts represent what the activities achieve immediately, and outcomes represent what the activities achieve collectively or over the long term.

In the case of the Ministry of Education, the overall objectives are stated as contributing to 'social and cultural participation and wellbeing' and 'economic prosperity and growth'. Outcomes that contribute to that objective include: 'the education system is relevant and reaches all children and students', and 'every child and student reaches academic success (Ministry of Education, 2016: 9). Certain impacts contribute to these outcomes, for example 'responsive educational services that meet the needs and raise the aspirations of all children and students' are achieved by implementing activities such as 'provide tailored services and support to raise achievement'.

Evaluation of systems using this framework involves identifying changes in impacts and outcomes through time. This usually means quantitative evaluation of the effectiveness or efficiency of impacts and outcomes, plotting them through time and reporting on the difference between the current performance and a benchmark, which is often set according to government priorities. This is accompanied by quantitative indicators of key outputs and financial resources and a qualitative narrative about the activities that are undertaken and why they may or may not have been successful, plans for the future and any other highlights or concerns that are poorly covered by the quantitative metrics.

Although the reports from different Ministries follow a similar format, they differ in how much emphasis they place on the different aspects of their system, the emphasis they place on the effectiveness and efficiency of the system, and how the main indicators are chosen and grouped.

The international context

The ABARES review also considered approaches to evaluation of health and education systems in an international context, with an emphasis on literature from Canada and the OECD (see Appendix A). The review summarises the use of indicators to track change in performance over time and across geographic regions or sectors of the population. In the reports reviewed, the criteria used to select indicators included the importance of what is being measured in terms of impact and policy relevance; the scientific soundness of the measure in terms of its validity, reliability and the explicitness of the evidence base; and the feasibility and cost of obtaining data for the measures (Kelly & Hurst, 2006; UNESCO, 2016). OECD (2015) uses similar criteria of policy relevance, data availability and data interpretability.

All the systems evaluated had clearly defined goals that were aligned to the strategic priorities of system stakeholders, including government, policy makers and the general public. For example, CIHI (2012) lists three 'ultimate goals' of Canada's health system that are largely consistent with other international frameworks:

- to improve the health status of the population;
- be responsive and provide services in a way that meets needs and expectations; and
- to deliver value for money by balancing resource allocation to obtain the best outcomes for the resources used.

Education systems reviewed had similar high-level goals aligned with policy objectives, for example to improve education status, be responsive and deliver value.

The ABARES review identified that evaluation frameworks measure system performance by first defining a number of performance dimensions – or key aspects – under which performance indicators and measures are grouped. For example, common dimensions used when evaluating health system performance include accessibility, effectiveness, efficiency, equity and patient-centeredness, which can be tailored according to need.

The majority of international reports reviewed contained a moderate to large number of mostly quantitative indicators, ranging from 20 to more than 200 and grouped under a variable number of dimensions. Five to seven dimensions was a typical number, although some reports had just four dimensions. Dimensions themselves can be grouped if necessary, as demonstrated by a performance measurement framework for the Canadian health system proposed by the Canadian Institute for Health Information in 2012. That framework included four quadrants composed of a number of performance dimensions linked through expected causal relationships (CIHI, 2012).

Most reports presented performance indicators and measures throughout the body of the report, grouped under the different dimensions, together with an analysis of that dimension's key results. An alternative to this format was to keep the amount of performance data in the body of the report to a minimum and to include most performance information in an appendix.

The approach taken by most reports reviewed was to include a relatively large number of indicators and measures in the body of the report or the appendices, from which conclusions were drawn about a smaller number of performance dimensions. For example, OECD (2015), *Health at a Glance 2015* presented around 200 pages of health indicators from which conclusions were drawn in the executive summary in five selected areas: pharmaceutical spending, life expectancy, number of doctors and nurses per capita, out-of-pocket expenses, and quality of care. The report also presented a series of five dashboards showing relative country rankings on five dimensions of healthcare: health status, risk factors, access to care, quality of care, and healthcare resources—all of which depend strongly on the availability of underpinning data.

Performance targets or benchmarks were a strong feature in some reports. In Canada, waiting times for surgery are considered a major indicator of health system quality by consumers. As a result, six waiting time targets or benchmarks were established by government for specific procedures in four high-priority areas and are reported annually in Canada by each province. An example of a waiting time target or benchmark is 48 hours for surgical repairs of hip fractures (Marchildon, 2013; CIHI, 2017). Similarly, the New Zealand government reports annually against a set of six high-priority health targets, including life expectancy and health expectancy; rates of death from cancer; rates of death from cardiovascular disease; childhood and adult obesity; immunisation rates; and smoking rates (Gericke, 2014).

The ABARES report notes that average or median results for indicators in cross-country comparative reports such as those prepared by the OECD can act as targets against which countries can benchmark their performance. Within a country, targets can be used to identify disparities in performance between different geographic areas, socioeconomic groups or demographic groups.

The reports reviewed by ABARES contained a mix of static or point measures for a single year as well as trend data. Trend data make it possible to identify if areas are improving or declining over time, or if performance targets such as increasing the level of educational attainment in the population, reducing waiting times for surgery, moving closer to the OECD average on selected indicators, or reducing Indigenous disadvantage in the population, are being achieved.

Most reports on the health system reviewed by ABARES describe a number of factors outside the health system that influence system performance (Murray & Frenk, 2000; Arah et al., 2006; CIHI, 2012; Marchildon, 2013; OECD, 2015; Squires & Anderson, 2015). These provide the context in which the system operates, and include the physical environment in which people live, individual lifestyles and behaviours, level of adult obesity and diabetes, drug consumption, socioeconomic status, health insurance status, and rates of accidents and violence. Understanding these contextual factors can be important in interpreting system performance indicators.

The ABARES report also comments on the use of different forms of indicators in the one report to provide a broader picture of system performance. It notes the use in the 2014 US

Commonwealth Fund report (Davis et al., 2014) of different types of data. Survey results from patients and doctors on care experiences and ratings on various dimensions of their countries' healthcare systems were used, as well as three objective health outcome indicators—mortality amenable to medical care, infant mortality, and life expectancy at age 60. Country rankings based on survey results did not necessarily align with country rankings based on the objective health outcome indicators. The authors concluded that the healthcare system is just one of many factors, including social and economic well-being that influence the health of a nation.

Summary performance indicators can also be effective. A 2013 Canadian health system review included an index that was used as a summary measure for the quality of the Canadian health system, based on 8 quality indicators (Marchildon, 2013). Plotting the index over time showed that overall health system quality had improved over a decade.

The ABARES report also notes the importance of ensuring that there is a well-integrated evaluation and assessment framework that is designed as a whole, rather than one based on individual elements of a system that may have been developed independently of each other over time. This is important in a complex system such as biosecurity where there are multiple elements and participants at different levels of the system.

4 Evaluation Framework

The review of literature undertaken for this project by CEBRA and ABARES provides useful guidance on the type of framework that can be used to assess the health, or the performance, of the biosecurity system. This review, summarised in the previous section, draws on both the theoretical literature and the application of performance frameworks in practical, public sector contexts. On the basis of this review, the following principles are proposed for the evaluation of the health of the biosecurity system.

4.1 Use a program logic/theory of change structure as the basis for the evaluation framework.

This structure defines and describes the biosecurity system that we wish to evaluate, including the broad context in which the system operates. It provides clarity about the individual components of the system. It also articulates the links between the resources, or inputs, that are invested in the system, the activities that are undertaken and the outputs that are created, as well as the immediate and longer term outcomes that are generated as a result of these investments. This structure provides a framework for explicitly linking activities to outputs and outcomes that allows us to assess the effectiveness, efficiency and other attributes of investments at different points in the system. Such a model also allows the many participants in the system to identify where they 'fit' and how and where they contribute to overall system performance. This can be important in encouraging ownership of performance evaluation processes.

The structure of the biosecurity system was outlined in diagrammatic and narrative form in section 2 of this report. The key relationships between its elements are summarised in Figure 2.

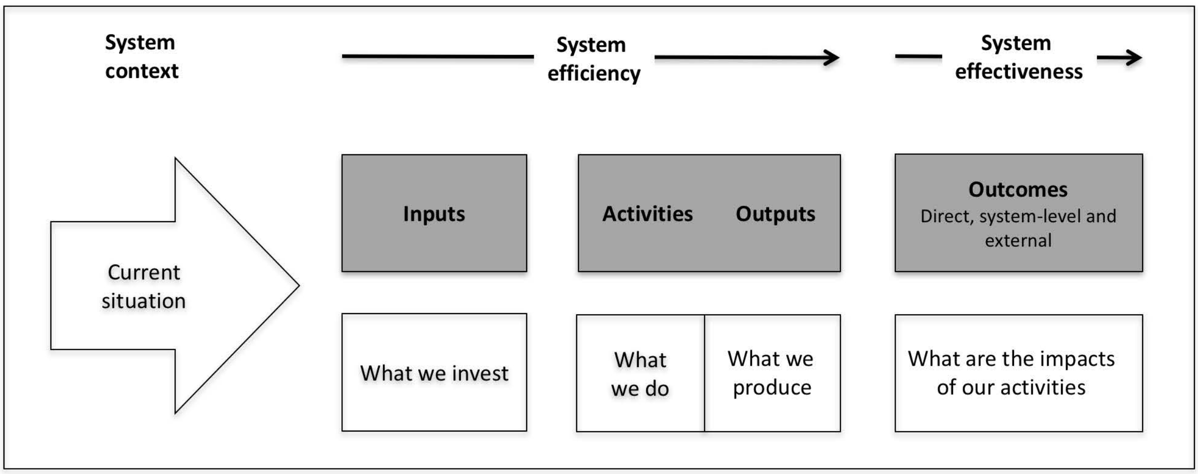


Figure 2: Key elements of the program logic structure

4.2 Define the biosecurity system as complex.

Australia's biosecurity system shares many of the characteristics of complex systems outlined in the literature review. Key among these are that the system:

- has many components. These include multiple participants, extensive resource inputs, many separate but frequently linked activities, and multi-layered objectives;
- displays emergent behaviour, such that the outcomes generated by the system cannot be readily predicted on the basis of known components, that is, there is some uncertainty in the interactions within the system;
- contains some degree of spontaneous order or self-organisation that allows it to withstand failures and perturbations over time;
- is characterised by non-linear relationships between inputs and outputs – small changes in inputs can have large changes on outputs and impacts and vice versa;
- has interacting components;
- contains feedback loops between different elements of the system; and
- is context dependent such that the same intervention can lead to different outcomes and impacts depending on external factors.

There are elements and activities in the biosecurity system that can be characterised as simple – well defined and predictable – and complicated – having many components and needing expertise and coordination. But at the overarching system level, the biosecurity system is characterised by complexity. Hence, understanding how complexity influences the operation of the biosecurity system is important to framing an appropriate performance assessment system. As observed in the literature review, most evaluation procedures for complex systems are conducted at multiple levels of a system – from individual activities to whole of system; in multiple contexts; and over long time frames. These layers of the evaluation framework will be developed in the second phase of the project.

4.3 Take a cumulative approach – from individual elements to whole of system

The proposed performance evaluation framework will build a picture of performance of each element, or set of activities, in the biosecurity system individually, and then seek to build the links between the elements. The elements of the system are outlined in the program logic model and consist of activities to anticipate and prevent biosecurity risks approaching the Australian border; to screen biosecurity risk material at the border; to prepare for and detect any incursions of exotic pests and diseases; and to respond to, recover from and adapt to pests and diseases that establish and spread in Australia.

The framework recognises that biosecurity risk management is a sequential, or cumulative, process, such that activities under one element of the system have an impact on outcomes of subsequent elements. For example, activities to better anticipate biosecurity risk will also contribute to preventing risk material arriving at the Australian border. Similarly, activities designed to enhance the capacity to detect incursions of pests and diseases will support

more efficient and effective responses to incursions. These links between elements of the system and the achievement of system outcomes will be made explicit in the performance evaluation framework.

4.4 Define the attributes of health against which performance will be evaluated

In order to evaluate the health of the biosecurity system it is necessary to define the characteristics, or attributes of the system that are considered desirable, that is, those attributes that will contribute to achieving the desired outcomes of the system. This is partly subjective – different stakeholders in the system might have different views about the key attributes of health. It is worth noting that efficiency outcomes in the biosecurity system may be driven by non-technical issues, including political considerations that may affect the allocation of resources.

Table 2 proposes five broad attributes of a healthy biosecurity system that will be used to inform the evaluation framework. These are the effectiveness of the system, its efficiency, its robustness and resilience to external stress, its capacity and its sustainability over time. Not each of these attributes of health will be relevant to each element of the system.

The *effectiveness* of the biosecurity system is an overarching measure of its health and seeks to address whether the investments and interventions in the system are delivering appropriate outputs and achieving their intended outcomes. Effectiveness can be measured for each element of the system and for the system as a whole. It can also be measured at different levels – at the output level and at the direct, system-wide and external outcomes levels. It is conceptually easier to link the effectiveness of activities to outputs or direct outcomes than it is to higher level outcomes. For example, relatively direct links can be made between the activities designed to anticipate biosecurity risk and the outputs defined in the project logic structure such as the number of intelligence reports generated and the number of import risk assessments that are reviewed. It is also reasonably straightforward to link activities to the direct outcome that the risk profile is identified, assessed and prioritised. It is more difficult to attribute causality between activities undertaken and the system level objective to reduce the likelihood of exotic pests and diseases entering, establishing or spreading in Australia. The difficulty is amplified when seeking to link activities to the external outcomes of a stronger economy, functioning ecosystems, healthy people and resilient communities. This is because there are many more influences on the higher level outcomes than the activities undertaken to anticipate biosecurity risk.

At the broadest level, a measure of the effectiveness of the biosecurity system might be the extent to which all risk management interventions across all elements of the system reduce the residual risk in the biosecurity system to a level at or below Australia's appropriate level of protection.

The *efficiency* of the biosecurity system is a measure of how well the inputs to the system are used to deliver outputs and outcomes. Linking the total resource inputs in a system to a measure of outputs and outcomes provides an indication of the productive, or technical, efficiency of the system. Productive efficiency is achieved when output is produced at minimum cost. Subject to the availability of appropriate data, productive efficiency can be calculated at any point in the biosecurity system from an individual activity or element to whole of system.

Resources in the biosecurity system can be used in many different ways, for example, they can be allocated to different elements of the system and to different activities in each element. Some of these activities yield better returns on investment than others. A biosecurity system with the maximum allocative efficiency will distribute resources optimally between these activities such that they contribute most to the achievement of the system's objectives. Measurement of allocative efficiency should be conducted at the whole of system level. It is worth noting that efficiency outcomes in the biosecurity system may be driven by non-technical issues, including political considerations that may affect the allocation of resources.

Table 2: Proposed attributes of system health

Effectiveness	The system or intervention meets expectations, it completes the tasks for which it was created (Productivity Commission, 2013).
Efficiency	Productive efficiency is maximised when the goals of the system or intervention are achieved at the lowest possible cost. A system that maximises productive efficiency uses the least costly combination of inputs to produce the desired output. Allocative efficiency is maximised when resources are invested across the system such that it achieves the best overall outcome from scarce resources (Productivity Commission, 2013).
Robustness and resilience	The system's stability despite stresses and its capacity to recover after stress, that is the time taken to return to normal functioning after stress.
Capacity	The extent to which the system can cope simultaneously with all biosecurity threats.
Sustainability	How well the system performs through time.

The *robustness and resilience* of the biosecurity system refers to how well the system operates – how stable it is – under conditions of stress and how quickly it reverts to 'normal' operations after a period of stress. For example, pest and disease incursions create stress in the biosecurity system – they require resources to be diverted from their usual activities to address the stress and they may require additional resources to be made available to cope with the circumstances. A robust and resilient system will absorb these perturbations with minimal impact on other elements of the system and will revert to normal activity in the shortest time possible after the stress has been resolved. Measuring the robustness and resilience of the biosecurity system should be conducted on the basis of observation of the system after a period of stress. The nature of the observed stress will determine at what level of the system the performance evaluation should be conducted.

A related attribute is the *capacity* of the biosecurity system to respond to multiple stresses at the same time. At any time, the biosecurity system may be subject to more than one event that requires a response. For example, global circumstances may change and require additional investment in environmental scanning to understand the implications for Australia's risk profile. One or several incursions may occur at the same time that occupy the same resources, such as diagnostic facilities or scientific capability. Having the surge capacity to manage simultaneous events without over investment in the system helps ensure that the system can cope with multiple stress events. The capacity of the system can be measured for different inputs, for example, diagnostic capacity, veterinary capacity. It is also desirable to develop an aggregate measure of capacity at the whole of system level.

The *sustainability* of the system refers to its ability to meet its objectives over the medium to long term. Over time the pressures on the biosecurity system are expected to grow with increasing volumes of trade and passenger movements and increasingly diverse import pathways. The global distribution of pests and diseases is also likely to change in response to factors such as climate, while international supply chains are expected to become more complex over time. These contextual factors will have an impact on the biosecurity risk profile facing Australia and the volume of risk that needs to be managed. A sustainable system will have the appropriate support mechanisms in place to ensure that the objectives of the biosecurity system can be met in the face of these pressures. These support mechanisms will include, among others, sustainable funding processes to ensure the appropriate allocation of resources to the system, effective training processes to develop the human resource capability necessary to operate the system, and the research and development effort to generate innovative and cost effective solutions to biosecurity problems. The sustainability of the system can be measured for different elements of the system as well at the whole of system level.

4.5 Develop indicators of system performance

Performance indicators are a critical component of the evaluation framework for the biosecurity system as they seek to link changes in activities with the achievement of outputs and outcomes – if well designed and implemented they provide objective evidence of the

impacts of system activities. Many organisations have adopted criteria for performance indicators that meet their specific needs but good performance indicators possess some common characteristics across organisations.

The literature review in this report identified five fundamental qualities of good performance indicators that are used by the European Commission Directorate-General for Regional and Urban Policy. These are that indicators should be:

- relevant: be directly related to the objective being measured
- measureable: be directly and reliably measured
- timely: be measurable at time intervals relevant to objectives
- understandable: be readily interpreted;
- cost-effective: provide a benefit commensurate with the cost.

Other related qualities of indicators used by organisations are that they should be clear – able to be articulated as simply as possible to ensure common understanding by all stakeholders; achievable – can be realistically gathered and interpreted; limited – as few as required to achieve the objectives; useful for management – provide a meaningful measure of change over time to inform management decision making; and practical – able to be collected on a timely basis and at reasonable cost.

These criteria will be used to inform the development of appropriate performance indicators for the biosecurity system.

4.6 Use quantitative and qualitative indicators of performance

Good performance indicators can be quantitative or qualitative in nature. Quantitative measures are numerical and include objective and replicable measures such as counts of activities and quantifiable changes in outputs and outcomes. Qualitative indicators require some subjective evaluation. Qualitative data can sometimes be reported in quantitative form but these numbers do not have arithmetic meaning on their own. An example might be the number of positive answers to a qualitative statement in a survey. When developing quantitative or qualitative indicators it is important that the indicator be constructed in a way that permits consistent measurement over time. The use of both quantitative and qualitative indicators can add richness to the evaluation framework.

4.7 Have overarching quantitative indicators linked to objectives that provide a high-level picture of performance

While a mix of quantitative and qualitative indicators will be developed for each element of the biosecurity system, there will be a number of high level summary indicators that link activities to direct and system level outcomes. For example, the first high level indicator will link activities under the anticipate and prevent activities to the biosecurity risk approach rate. The second high level indicator will link screening activities to the border leakage rate. Together, these indicators will be used to assess how well the biosecurity system is meeting IGAB objective 1 – to reduce the likelihood of exotic pests and diseases from entering,

becoming established or spreading in Australia. Similar levels of indicators will be developed to link activities to direct outcomes and the system level outcomes expressed as IGAB objectives 2 and 3. As referred to above, at the very highest level, the health of the biosecurity system might be measured as the extent to which all risk management interventions across all elements of the system reduce the residual risk in the system to a level at or below Australia's appropriate level of protection. Inferring a value for Australia's ALOP and forming judgements about whether residual risk is at or below this level would be subjective and require extensive consultation with stakeholders.

4.8 Develop targets and benchmarks for performance indicators in conjunction with stakeholders

While performance indicators are essential to understanding the links between activities in a system and outcomes, they do not of themselves define whether a system is healthy. Establishing targets for performance and benchmarking them against an appropriate comparison point is a way of understanding the relative performance of the system. These targets or benchmarks might be considered minimum levels of performance required for a system to be considered healthy, or levels required to be considered 'best practice'. Defining targets and benchmarks will require consultation with stakeholders. An external agency such as CEBRA is not in a position to define targets and benchmarks as the desired level of system performance should be defined by system participants who have an understanding of the constraints around the operation of the system such as its financing. Different participants may have different initial views regarding target performance and appropriate benchmarks in a healthy system but it is important that, through consultation, they are accepted as valid by the broad stakeholder community. Consultation on targets and benchmarks will be undertaken in the third phase of this project.

4.9 Build a narrative of the performance story using the selected indicators

The evaluation of the biosecurity system should be presented as a narrative that incorporates relevant quantitative indicators and qualitative information that together provide a coherent and integrated performance story. The narrative is designed to enhance and enrich the evaluation information provided in quantitative form.

4.10 Use case studies to build the performance story element by element

Case studies will be used to develop the indicators of performance for each element of the biosecurity system. The first case study addresses quantitative indicators of the effectiveness of preventing and screening biosecurity risk material on the interational air passenger pathway and is reported in the following section. Subsequent case studies will

address other elements of the system in order to link these to the objectives of the system articulated in the IGAB.

5 Case Study – screening of international air passengers

5.1 Introduction

Air travel presents a substantial risk of introducing biosecurity risk material (BRM) to Australia. Managing the risk of the air passenger pathway is challenging. In the financial year 2015-16, 19 million passengers arrived in Australian ports, and the scope for biosecurity intervention is limited by issues of space and time: the area for staging and processing passengers is limited in each airport, and stakeholders invariably prefer speedy outcomes. Nonetheless, regular interceptions are made of materials that present a clear biosecurity risk.

Australia has nine international airports, one in each state and territory capital except Hobart, and one each in Cairns and Coolangatta. Here we omit the statistics from Canberra, because its relatively recent introduction prevents a useful analysis of performance data or comparison with other airports. Other airports do provide international flights on an ad-hoc basis but they lack the infrastructure for biosecurity processing.

The purpose of this case study is threefold:

(i) to demonstrate the application of indicators to measuring attributes of health,
(ii) to provide some assessment of the health of an aspect of the biosecurity system, and
(iii) to discuss opportunities and challenges associated with collecting and analysing the data that are needed for such exercises. It is not intended to provide a definitive analysis of the data.

5.2 Methods and materials

This case study is constructed from international passenger inspection and interception data provided by DAWR. Briefly, the activity at the airport that is germane to these data is as follows. Passengers arrive at the airport on international flights and are profiled by various means, which may include questioning and may use the passenger's data provided on the incoming passenger card, which includes their declaration of whether they are carrying any potential BRM. The outcome of the profiling is the direction of the passenger to one or more intervention channels, as listed below. After intervention, an endpoint, or leakage, survey is carried out. This survey involves the selection of a random passenger and the recording of the passenger's details and the inspection of one article that has not previously been opened. The purpose of the endpoint survey is two-fold: first, to verify that passenger profiles are correct and being applied appropriately; and second, to form an estimate of the effectiveness of the different kinds of intervention.

The data are monthly passenger counts by airport (each of nine international ports), passenger declaration status (declarant/non-declarant); and intervention channel:

1. Direct Exit, meaning the release of passenger with no assessment by biosecurity officer;
2. Assess & Release, meaning the release of passenger after assessment by biosecurity officer, which may include viewing their incoming passenger card (IPC) and/or asking questions to establish the risk of them carrying goods of biosecurity concern;
3. Border, meaning manual inspection by Border Protection officials;
4. Detector Dog Unit;
5. X-ray; and
6. Manual inspection.

The passengers were counted in the following groups: (i) all passengers, (ii) passengers with goods seized, (iii) passengers who subsequently undergo an endpoint survey (previously called a leakage survey, see CEBRA Project 1301b), and (iv) passengers who undergo an endpoint survey and have goods seized. The data are the same as are used by Compliance Division to compute performance indicators that are used to manage the pathway risk. The data have undergone pre-processing, but still contain minor errors.

Figure 3 provides a snapshot of the airport system activity in terms of the number of declarant and non-declarant passengers processed by each different intervention method in each international airport for the financial years 2012/13 to 2016/17.

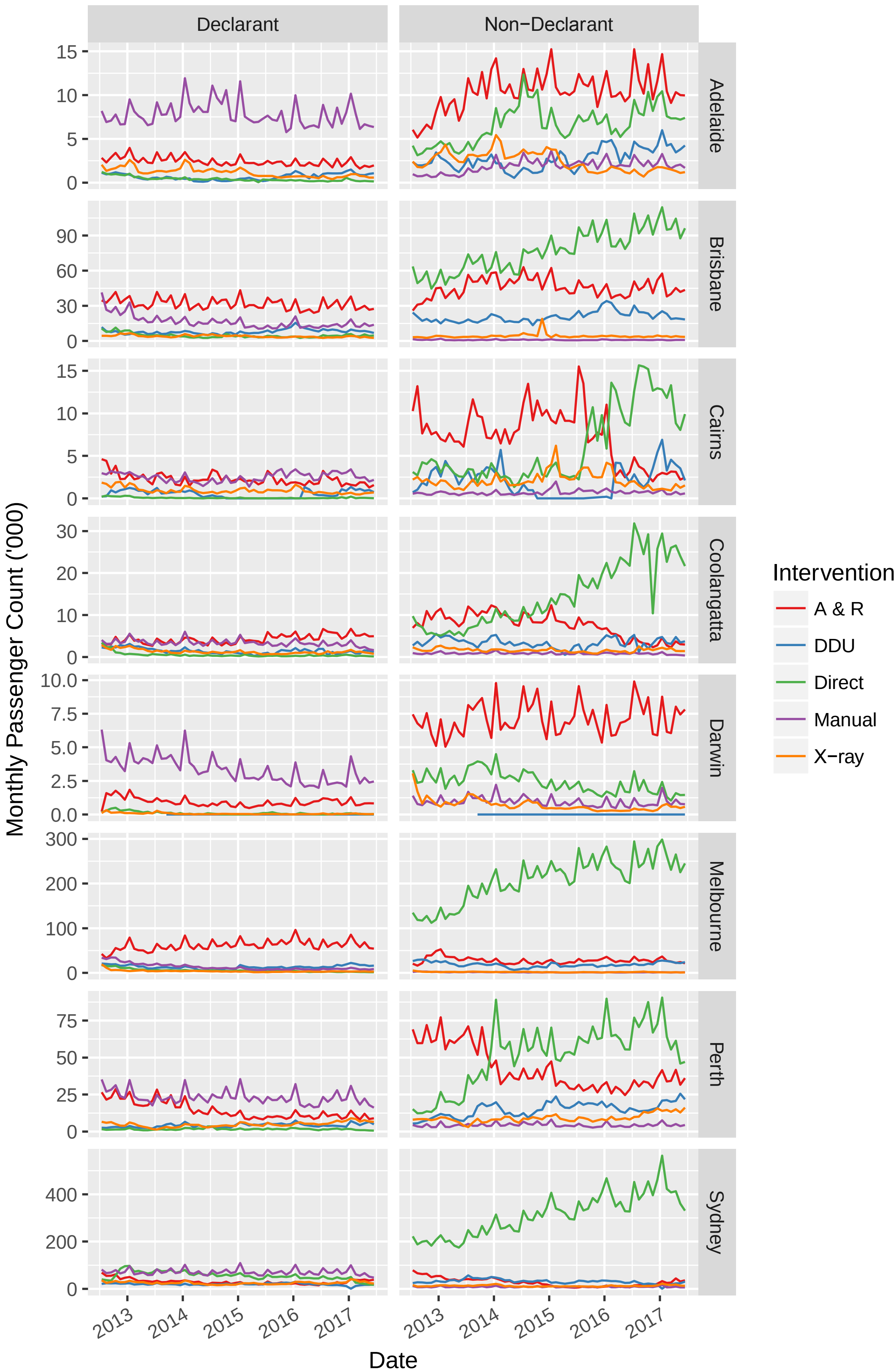


Figure 3: Monthly passenger arrivals by airport, intervention, and declaration status.

As can be expected, passenger counts are increasing over time, most notably in the larger airports, namely Melbourne and Sydney. However, the increase is only in non-declarant passenger counts. Declarant passengers are reasonably constant over time.

All but Adelaide and Darwin have managed the surge in non-declarant passenger counts by increasing the profiling rates to Direct Exit; Adelaide (after 2014) and Darwin's passenger numbers are fairly constant and are managed mainly via Assess and Release. Perth and Coolangatta switched from emphasis on Assess and Release to Direct Exit for non-declarant passengers in 2013. The airports each differ in the rates at which declarant passengers are inspected. Melbourne and Brisbane assess and release the largest proportion of declarant passengers, whereas the other ports – including Sydney – apply manual inspection.

This case study focuses on two attributes of system health: effectiveness and efficiency. These attributes are assessed using quantitative measures and qualitative arguments.

Effectiveness – the objective of the system is to intercept BRM that is carried by international passengers. To assess its effectiveness, or whether it is achieving its intended objective, we report the number of passengers that are intercepted with BRM, across time (Figure 4). We assume that the more BRM that is intercepted, the more effective the system is. The system is also intended to have a net effect of ensuring that international passengers show high compliance with Australia's biosecurity regulations. We assess the post-intervention compliance (PIC, also called residual compliance) against this objective (Figure 5). The PIC is documented in ACERA reports 1001i and 1101d. We assume that the closer PIC is to 1, the more effective the system is.

Efficiency – the system uses profiling to increase the efficiency with which passengers can be processed. We assess the efficiency of the system by showing whether passengers that are profiled to screening or inspection (cost intensive forms of intervention) are more likely to carry BRM than those that are profiled to Direct exit or Assess and Release (Figure 6). The system also uses various devices for screening and inspecting passengers, such as the DDU, X-ray, and manual inspection. We will assess the efficiency of these devices using a metric called (unfortunately) *effectiveness,* which is defined as the proportion of the BRM that is presented to an intervention that is correctly screened or found by the intervention (Figure 7).

These indicators of efficiency are proxies for the productive efficiency attribute defined in section 4 of this report.

The analyses reported here are intended to be indicative rather than definitive. More appropriate results might be possible if more complex modelling is applied, and the selection of different statistics may lead to more useful insights

5.3 Results

Effectiveness

A representation of the effectiveness of the international air passenger biosecurity system can be found by examining Figures 4 and 5. Figure 4 shows that substantial quantities of BRM are seized annually from declarant passengers, and also large amounts from non-declarant passengers. DDU units consistently caught the largest quantity of non-declared BRM in Melbourne and Brisbane, and in Sydney until 2017. X-ray intercepted the highest quantity of non-declared BRM in the other cities. Manual inspection yielded the highest return for declarant passengers across all pathways. In Sydney, Cairns, and Adelaide, the X-ray performed better than the DDU for declarant passengers. Regardless of the detail, it is clear that large quantities of BRM are routinely seized from passengers.

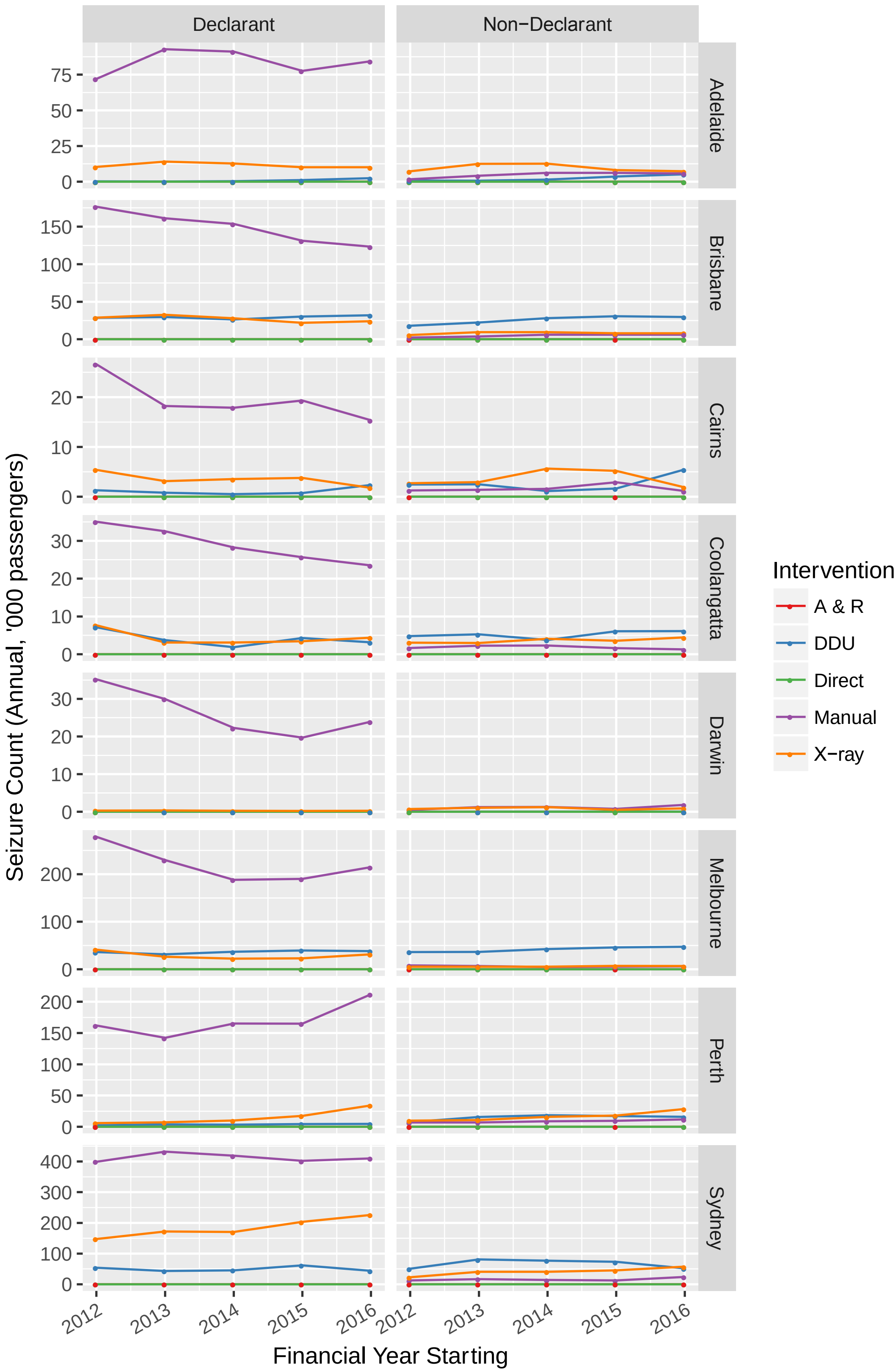


Figure 4: Annual counts of international passengers intercepted with BRM.

Figure 5 shows that the post-intervention compliance rates of the pathways are high. The biosecurity system has two complementary effects on the post-intervention compliance rate. First, by means of public relations exercises, messaging, and reputation, the system encourages passengers to be compliant. Second, by devices such as screening and inspection, BRM is intercepted at the border and therefore the pathway is made more compliant. When thinking about the impacts on overall compliance of these different combinations of port, declaration status, and intervention method, it is important to keep in mind that their effect will be proportional to the number of passengers.

Efficiency

We interpret efficiency in the international passenger pathway in two ways: first, is the Department inspecting the right passengers, that is, the passengers carrying BRM? And second, is the Department inspecting the passengers with sufficient attention and effort? The efficiency of the system is summarised by two graphics: Figures 6 and7. Figure 6 reports the relative contamination rates of the inspected or screened passengers compared with the contamination rate of the Direct Exit and Assess & Released passengers. This is computed by adding the seizures that are counted for each intervention to the estimated leakage, and dividing by the volume. The sum of these quantities represents the number of non-compliant passengers correctly identified by the profiling exercise. We correct for the baseline non-compliance rate by dividing by the same value computed from the passengers that were not screened (here, we assume that Assess and Release is not screening because it usually results in a follow-up screening, and the data are insufficiently detailed to discern these cases.) In short, this figure tells us how much more valuable the profiled interventions are than they would be if applied to the passengers that are not profiled to intervention. Above 1 is good; a horizontal line is added at 1 to aid interpretation.

The results provided by Figure 6 are mixed. In general, declarant passengers that are profiled to the dog detector units have less BRM than those profiled to X-ray or manual inspection, even when taking appropriate account of the leakage. Adelaide and Sydney both show estimated non-compliance rates for passengers profiled to X-ray and Manual to not differ substantially from those of passengers profiled to Assess and Release or Direct Exit. In most cases, non-declarant passengers that were profiled to the DDU had the highest relative non-compliance rates, again, after taking account of contamination.

Figure 7 shows the effectiveness of the different interventions. As a general rule, the higher this quantity is the better – if all possible non-compliance is detected then effectiveness is 1. However, this quantity is computed from the endpoint sample, among other things, and is known to be quite volatile. Consequently, the values should be interpreted with some caution. Any values close to 1 (or 0) should really be viewed with suspicion; we know that the interventions aren't as good (or bad) as that.

Effectiveness is high for declarant passengers, showing that the majority of non-compliance is detected, although the DDU returns in each port in which they are used are notably lower

than the other interventions. Manual inspection and X-ray are reasonably comparable with one another for non-declarant passengers. Overall these figures show that the department is quite consistently finding a significant proportion of the non-compliant passengers that are being correctly profiled into one of the interventions.

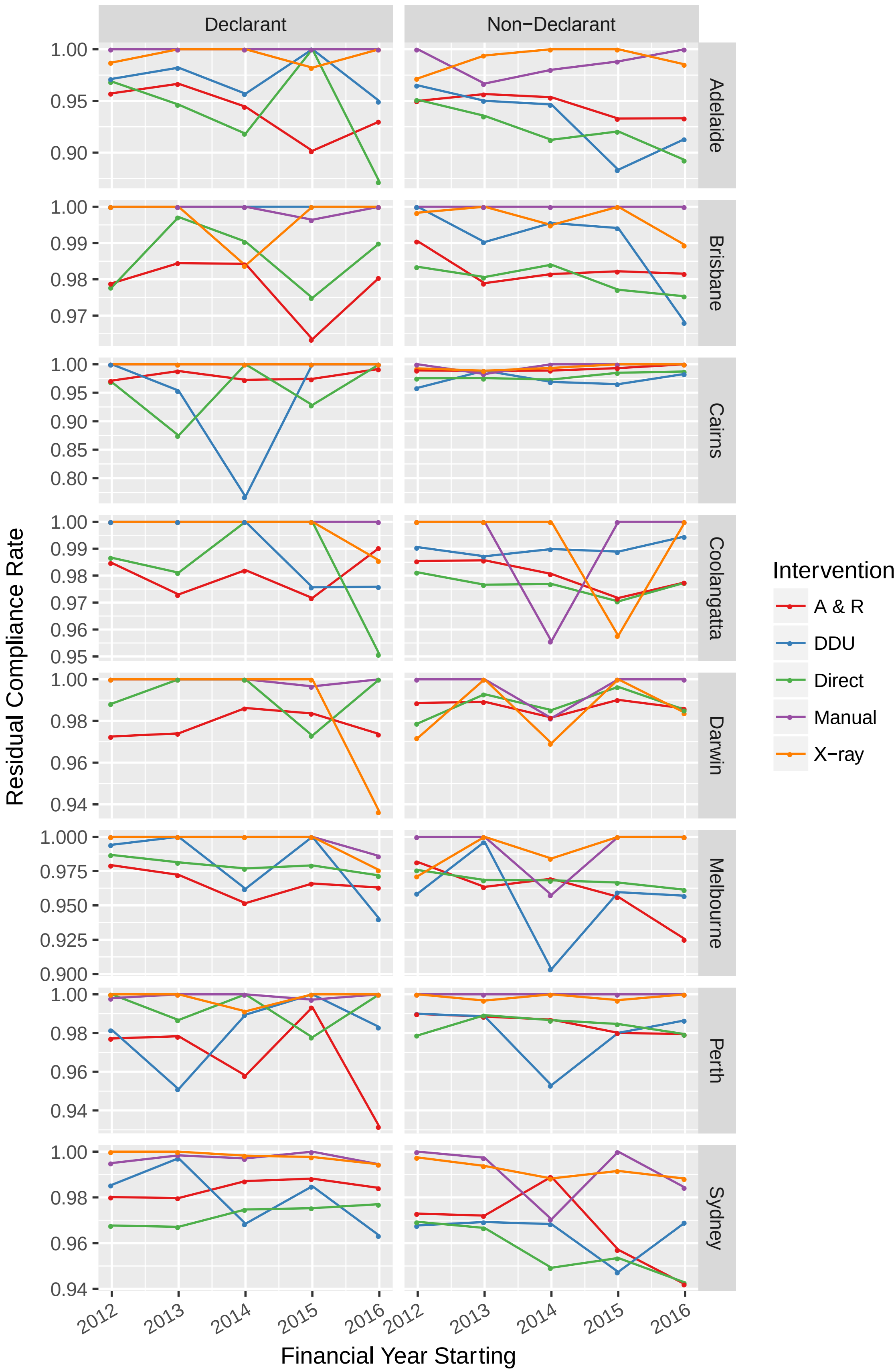


Figure 5: Post-Intervention Compliance for international passenger data.

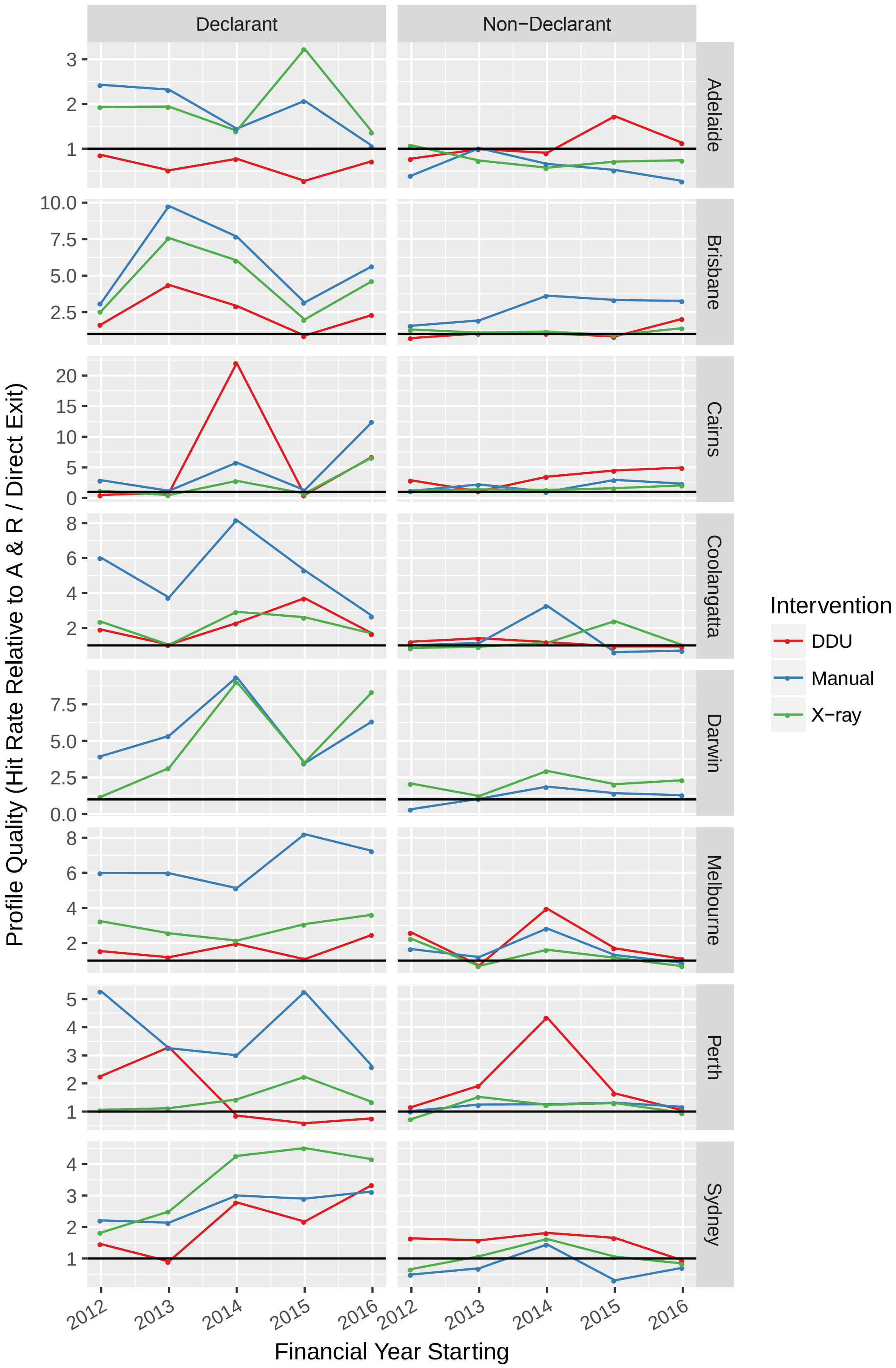


Figure 6: Estimated relative contamination rate of passengers inspected or screened over the average rate of passengers profiled to Direct Exit and Assess & Release.

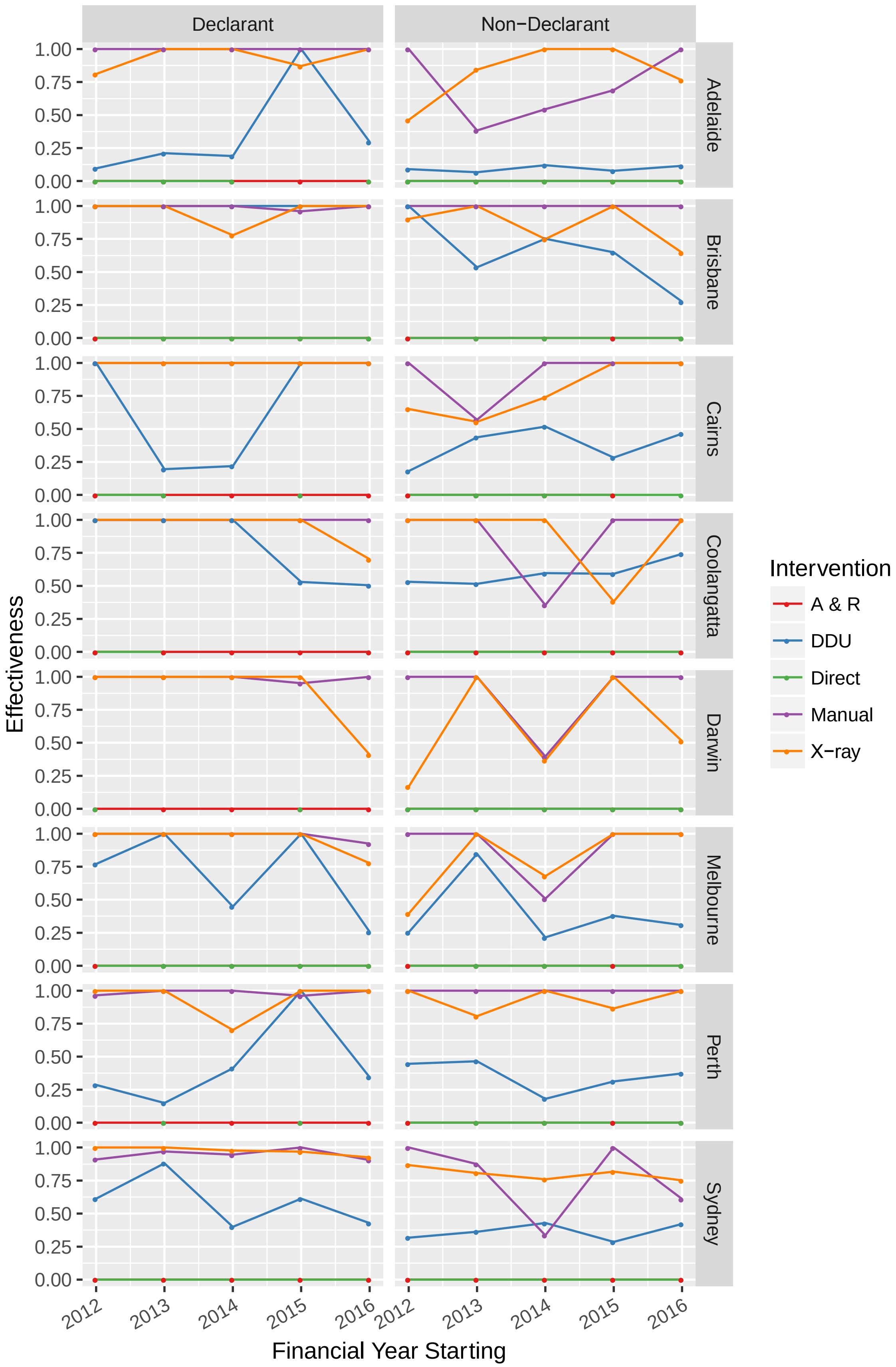


Figure 7: Effectiveness of each intervention. Interventions under both Assess and Release and Direct Exit have zero effectiveness by definition.

5.4 Discussion

This section covers the three points introduced as the rationale for this case study.

Demonstrate the application of indicators to measuring attributes of health.

Here we measured two attributes of health, namely effectiveness and efficiency, using various indicators. We assessed the effectiveness by asking whether the system is performing as designed – namely to intercept BRM and to affirm that the pathways are acceptably compliant after border intervention has been performed. We assessed efficiency by asking whether the system is making best use of its resources – does it direct the expensive interventions, such as manual inspection, appropriately, and when they are carried out, are they carried out successfully?

Provide some assessment of the health of an aspect of the biosecurity system.

Based purely on the two attributes discussed, namely effectiveness and efficiency, and keeping in mind the caveats below, we assess the health of the international passenger system as being reasonable. The system is operating in a somewhat predictably fluctuating environment (Figure 3), intercepting a substantial amount of risk material (Figure 4), affirming that the pathways are in reasonably high compliance (Figure 5), generally inspecting many of the right passengers, although there is apparent scope for improvement (Figure 7), and performing the relevant interventions with reasonable effect (Figure 6).

The methodological challenges raised by the case study include how to aggregate measures of health across multiple pathways and in what circumstances it is meaningful to do so. The case study focuses on the international air passenger pathway only but similar analyses can be undertaken on other pathways, subject to data quality and availability. A second challenge is how to apply and interpret qualitative conclusions regarding health. In this case study we have assessed the health of the international passenger system as 'reasonable'. In the absence of performance benchmarks, some calibration of a qualitative statement is required in order to make comparisons across elements of the biosecurity system and to draw conclusions about the health of the system as a whole. These issues will be explored further as additional case studies are undertaken.

Opportunities and challenges associated with collecting and analysing the data.

This case study shows that activities on some pathways managed by the Department are captured with sufficient detail that reasonable indicators can be computed and interpreted from the point of view of system health. Indeed, this study was greatly assisted by the fact that the Department collects and reports these data routinely. The data were largely clean and had few obvious inconsistencies. Had we been required to analyse the data from raw sources then the analysis would have taken far longer.

A shortcoming of the data is that we don't know how risky the seized goods were. Items such as fruit are seized because they may be a vector for fruit fly, for example, but unless infestation is obvious the fruit is likely just discarded. From the point of view of regulation, the passenger who carried an apple was non-compliant, but this does not mean that they

presented a clear biosecurity risk. This distinction calls for a nuanced interpretation of the statistics presented. Ideally, follow-up analysis would be available for all or a sample of the seized goods to more closely determine the material risk of the pathway.

A further shortcoming is that the endpoint survey does not provide a complete picture of the quality of the intervention. This is because the endpoint survey requires the manual inspection of one unopened bag.

As noted above, the simple analyses reported here are not intended to be definitive. Future work by interested parties may try some statistical smoothing of the noisy signals, such as the statistics that are based on the endpoint survey, by means of fitting a statistical model such as a generalised linear model. Furthermore, it may be worth trying to represent the uncertainty that is a consequence of the fact that the endpoint survey is a sample, rather than the whole population. It is also possible that we have misinterpreted some aspect of the data or the processes, and we welcome feedback as to the fidelity and suitability of our analyses.

6 Implementing the evaluation framework

Year one of CEBRA project *1607B Health of Australia's Biosecurity System* has delivered:

- a comprehensive review of the performance evaluation literature of relevance to the biosecurity system, including performance evaluation of complex systems in the public sector in Australia and internationally;
- a detailed description of Australia's biosecurity system;
- a framework for evaluating the health of the biosecurity system based on ten principles;
- a list and definition of the attributes of biosecurity system health against which the performance of the biosecurity system can be evaluated; and
- a case study that demonstrates the application of indicators to measuring attributes of health on the international air passenger pathway and discusses some of the opportunities and challenges associated with collecting and analysing the data that are needed for such exercises.

Together, these deliverables provide guidance on developing a framework and methodology to evaluate the health of Australia's biosecurity system that can be used repeatedly at the national and sub national level to support decision making, particularly in relation to the quantity and allocation of investment in the system.

6.1 Next steps

The CEBRA Advisory Board and the DAWR Biosecurity Research Steering Committee have agreed to a set of deliverables in the second year of the project. These are to:

- propose a preferred framework for the performance evaluation of the national biosecurity system;
- resolve technical and conceptual difficulties identified in year 1, including how to aggregate measures of health across various layers of a complex system; how to integrate information from indicators at different temporal or spatial scales; and, generally, how to present data in a way that answers the question "how healthy is the biosecurity system" as well as providing information about where it could be improved;
- provide preliminary estimates of those measures for which the department holds sufficient data; and
- make recommendations for capturing and analysing the data required for those measures for which insufficient data are available.

The project will progress these deliverables through a series of case studies on each element of the biosecurity system, separately or collectively where appropriate. The case studies will be:

- **anticipate** biosecurity risk and **prevent** the entry, establishment and spread of exotic pests and diseases;
- **screen** goods and people at the border to detect potential incursions of pests and diseases;
- **prepare** for an outbreak or incursion of exotic pests and diseases;
- **detect** any pest and disease outbreaks or incursions within Australia;
- **respon**d to an incursion of an exotic or established pest or disease; and
- **recover** from an incursion and **adapt** to the new circumstances created by an incursion.

These case studies will be undertaken sequentially. They will be based on desk top reviews supported by stakeholder workshops.

The intention of the case studies is to demonstrate the links between activities in each element of the biosecurity system, as described in the program logic documents, the outputs they deliver and the outcomes they generate. Indicators of health will be developed at appropriate levels of the system that link activities and outputs to direct and system level outcomes. The intention is to develop a number of key quantitative indicators that are supported by both quantitative and qualitative assessments, and reported in both numerical and narrative form. Methodological issues identified in the case study undertaken for this report will be examined and addressed progressively.

Progress on each case study will be dependent on the availability and quality of data and other forms of information. A key output of each case study will be an assessment of the data, identification of critical data gaps and recommendations for how data might be captured to support the evaluation framework.

The results of each case study will be submitted to the department for review on its completion. The learnings from each case study will inform subsequent work.

The above approach does not include the development of an evaluation framework for the enabling functions that support the biosecurity system. As outlined in the program logic documents, these include its governance arrangements, information management, funding arrangements and research and development strategy. The final stage in the project will include an assessment of how to evaluate the performance of these components of the biosecurity system.

7 References

ABARES (2014) Implementation of improvements to the National Livestock Identification System for sheep and goats: Decision Regulation Impact Statement. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Agriculture and Agri-Food Canada (2015) Evaluation of the control of diseases in the hog industry. Office of Audit and Evaluation, Government of Canada.

AHA (2017) Animal health in Australia 2016. Animal Health Australia, Canberra.

Almahmoud, E.S., Doloi, K.h. & Panuwatwanich, K. (2012) Linking project health to project performance indicators: Multiple case studies of construction projects in Saudi Arabia. *International Journal of Project Management*, 30, 296-307.

Arah, O.A., Westert, G.P., Hurst, J. & Klazinga, N.S. (2006) A conceptual framework for the OECD health care quality indicators project. *International Journal for Quality in Health Care*, September 2006, 5-13.

Beale, R., Fairbrother, J., Inglis, A. & Trebeck, D. (2008) One Biosecurity. A working partnership. The independent review of Australia's quarantine and biosecurity arrangements. Report to the Australian Government.

Biosecurity Victoria (2009) Biosecurity Strategy for Victoria. Department of Primary Industries, Melbourne.

Biosecurity Victoria (2010) Invasive Plants and Animals Policy Framework. Department of Primary Industries, Melbourne.

Blondeau, V., Anquetil, N., Ducasse, S., Cresson, S. & Croisy, P. (2015) Software metrics to predict the health of a project? An assessment in a major IT company. IWST 15 International Workshop on Smalltalk Technologies, Brescia, Italy.

Cabrera, D., Colosi, L. & Lobdell, C. (2008) Systems thinking. *Evaluation and Program Planning*, 31, 299-310.

Canada Border Services Agency (2016) Evaluation of the Canada Border Services Agency targeting program. Internal Audit and Program Evaluation Directorate, Government of Canada.

CIHI (2012) A performance measurement framework for the Canadian health system. Canadian Institute for Health Information.

CIHI (2017) Wait times for priority procedures in Canada, 2017. Canadian Institute for Health Information, Ottawa ON.

COAG (2012) Intergovernmental Agreement on Biosecurity. Council of Australian Governments, Canberra.

Craik, W., Palmer, D. & 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. Department of Agriculture and Water Resources, Canberra.

Davis, K., Stremikis, K., Squires, D. & Schoen, C. (2014) Mirror, mirror on the wall: how the performance of the U.S. health care system compares internationally. 2014 Update. The Commonwealth Fund 2014.

DAWR (2016a) Biosecurity risk analysis guidelines 2016: managing biosecurity risks for imports into Australia. Department of Agriculture and Water Resources, Canberra.

DAWR (2016b) Annual Report 2015-16. Department of Agriculture and Water Resources, Canberra.

DAWR (2016c) National Environment and Community Biosecurity Research, Development and Extension Strategy 2016 to 2019. Department of Agriculture and Water Resources, Canberra.

DAWR (2016d) National Animal Health Surveillance and Diagnostics Business Plan 2016-19. Department of Agriculture and Water Resources, Canberra.

DAWR (2017) National pest and disease outbreaks. Available at: www.outbreak.gov.au (accessed June 2017).

Department of Finance (2015) Resource Management Guide No. 131: Developing good performance information, Commonwealth of Australia. ISBN: 978-1-925205-17-6 (online).

DIRD (2014) Transport Security Outlook to 2025. Department of Infrastructure and Regional Development, Canberra.

Dodd, A.J., Burgman, M.A., McCarthy, M.A. & Ainsworth, N. (2015) The changing patterns of plant naturalization in Australia. *Diversity and Distributions*, 21, 1038-1050.

Doran, G.T. (1981) There's a S.M.A.R.T. way to write management's goals and objectives. *Management Review (AMA FORUM)*, 70, 35-36.

EC Directorate-General for Regional and Urban Policy (2013) EVALSED: The resource for the evaluation of socio economic development - evaluation guide. European Commission.

European Commission (2015a) Ex-post evaluation of the External Borders Fund 2011-2013. Evaluation and fitness check roadmap.

European Commission (2015b) Mid-term evaluation of the 3rd Health Programme 2014-2020. Evaluation and fitness check roadmap.

Forss, K., Marra, M. & Schwartz, R. (eds.) (2011) *Evaluating the complex. Attribution, contribution, and beyond. Comparative policy evaluation, Volume 18*. Transaction Publishers, New Brunswick, NJ.

Gericke, C. (2014) New Zealand: Health system review. *Health Systems in Transition, 2014, Vol. 4, No. 2*. World Health Organisation (WHO)

Glouberman, S. & Zimmerman, B. (2002) Complicated and complex systems: what would successful reform of Medicare look like? Discussion paper no. 8. Commission on the Future of Health Care in Canada.

Gupta, S. & Dokania, N.K. (2014) Predicting health of a project using metric generator. *Confluence The Next Generation Information Technology Summit (Confluence), 5th International Conference.*

Hulme, P.E. (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, 46, 10-18.

Kelly, E. & Hurst, J. (2006) Health care quality indicators project: conceptual framework paper, OECD health working papers, No. 23, OECD Publishing, Paris.

Ladyman, J., Lambert, J. & Wiesner, K. (2013) What is a complex system? *European Journal for Philosophy of Science*, 3, 33-67.

Lamont, T., Barber, N., Pury, J.D., Fulop, N., Garfield-Birkbeck, S., Lilford, R., Mear, L., Raine, R. & Fitzpatrick, R. (2016) New approaches to evaluating complex health and care systems. *BMJ*, 352, i154.

Lauras, M., Marques, G. & Gourc, D. (2010) Towards a multi-dimensional project performance measurment system. *Decision Support Systems*, 48, 342-353.

Liu, S., Cook, D., Walker, I., Barry, S., White, B. & Paul, D.B. (2014) How do you measure biosecurity impact? Technical report, Plant Biosecurity Cooperative Research Centre, Department of Agriculture and Food, Western Australia.

Marchildon, G.P. (2013) Canada: Health system review. *Health Systems in Transition, 2013, vol. 15, no. 1: pp. 1-179*. World Health Organisation (WHO).

Matthews, K. (2011) A review of Australia's preparedness for the threat of foot-and-mouth disease. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.

Ministry of Education (2016) The Ministry of Education annual report. Wellington, New Zealand.

Mittermeier, R.A., Robles Gil, P. & Mittermeier, C.G. (1997) *Megadiversity: Earth's Biologically Wealthiest Nations*. Agrupacion Sierra Madre, Mexico City.

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M. & Gascon, C. (2011) Global biodiversity conservation: the critical role of hotspots. *Biodiversity hotspots: distribution and protection of conservation priority areas* (ed. by F.E. Zachos and J.C. Habel). Springer, Heidelberg.

Murray, C. & Frenk, J. (2000) A framework for assessing the performance of health systems. *Bulletin of the World Health Organisation*, 78, 717-731.

Nairn, M.E., Allen, P.G., Inglis, A.R. & Tanner, C. (1996) Australian quarantine, a shared responsibility. Department of Primary Industries and Energy, Canberra.

OECD (2015) Health at a Glance 2015: OECD Indicators. OECD Publishing, Paris.

Patton, M.Q. (2011) *Developmental evaluation: applying complexity concepts to enhance innovation and use*. Guilford Press, New York.

Peersman, G. (2017) Making the most of performance indicators. ANZSOG course, August 2017.

PHA (2008) Draft National Fruit Fly Strategy. Plant Health Australia, Canberra.

PHA (2012) National Plant Biosecurity Diagnostic Strategy. Plant Health Australia, Canberra.

PHA (2013) National Plant Biosecurity Surveillance Strategy 2013-2020. Plant Health Australia, Canberra.

PHA (2016) PLANTPLAN: Australian Emergency Plant Pest Response Plan, Version 3.0. Plant Health Australia, Canberra.

PHA (2017a) The national plant biosecurity status report. Plant Health Australia, Canberra.

PHA (2017b) Government and Plant Industry Cost Sharing Deed in respect of Emergency Plant Pest Responses. Plant Health Australia, Canberra.

PIMC (2008) Australian Veterinary Emergency Plan, AUSVETPLAN, Summary Document, Version 3.1. Primary Industries Ministerial Council, Canberra.

Productivity Commission (2013) On efficiency and effectiveness: some definitions. Staff Research Note, Canberra.

Shiell, A., Hawe, P. & Gold, L. (2008) Complex interventions or complex systems? Implications for health economic evaluation. *BMJ*, 336, 1281-1283.

Squires, D. & Anderson, C. (2015) U.S. Health care from a global perspective: spending, use of services, prices, and health in 13 countries. *Issues in International Health Policy. October 2015 Update*. The Commonwealth Fund.

State Services Commission and the Treasury (2008) Performance measurement advice and examples on how to develop effective frameworks. Wellington, New Zealand.

Susaeta, A., Adams, D.C., Carter, D.R. & Dwivedi, P. (2016) Climate change and ecosystem services output efficiency in southern loblolly pine forests. *Environmental Management*, 58, 417-430.

UNESCO (2016) Designing effective monitoring and evaluation of education systems for 2030: A global synthesis of policies and practices (preliminary version, not for quotation). United Nations Educational, Scientific and Cultural Organization.

USAID (2010) Performance monitoring and evaluation tips. Selecting performance indicators. Number 6, 2nd edition.

Victorian DEPI (2014) Biosecurity Evidence Framework (internal document). Victorian Department of Environment and Primary Industries.

Walton, M. (2014) Applying complexity theory: A review to inform evaluation design. *Evaluation and Program Planning*, 45, 119-126.

Walton, M. (2016) Expert views on applying complexity theory in evaluation: Opportunities and barriers. *Evaluation*, 22, 410-423.

Westhorp, G. (2012) Using complexity-consistent theory for evaluating complex systems. *Evaluation*, 18, 405-420.

World Health Organization (2009) Systems thinking, for health systems strengthening. Alliance for health policy and systems research.

Wu, J., Yin, P., Sun, J., Chu, J. & Liang, L. (2016) Evaluating the environmental efficiency of a two-stage system with undesired outputs by a DEA approach: An interest preference perspective. *European Journal of Operational Research*, 254, 1047-1062.

Productivity Commission 2013, *On efficiency and effectiveness: some definitions*, Staff Research Note, Canberra.

8 Appendix A – ABARES Literature Review

Please refer to separate pdf file for the ABARES literature review on Australian public sector agencies' evaluation of system-wide health.