BIOSECURITY
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Australia's Biosecurity Future

Preparing for future biological challenges

Animal Health Australia

Invasive Animals Cooperative Research Centre

CRC Plant Biosecurity

Acknowledgements

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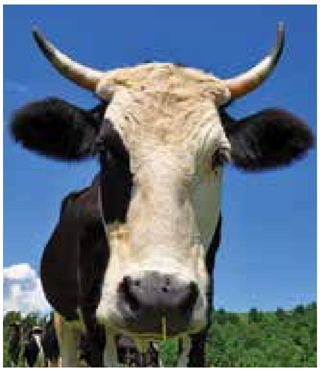
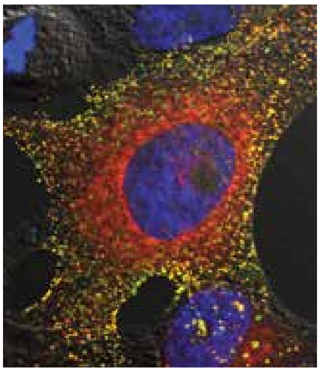
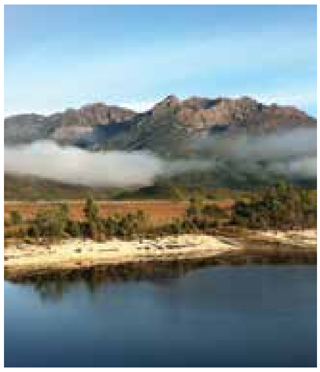

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Executive Summary

As an island nation Australia has, for the most part, been able to maintain an enviable biosecurity status.

A commitment to biosecurity (mitigating the risks and impacts associated with pests and diseases) has allowed us to protect our unique natural habitats and the health of our citizens while at the same time maintain an advantage in primary industries. However, the current status should not be taken for granted.

A number of global megatrends highlight significant change and growing complexity relating to biosecurity challenges, pointing towards a future where existing biosecurity processes and practices may not be sufficient. This report provides an in-depth discussion of five biosecurity megatrends and outlines a number of megashocks that could result if we remain complacent in the face of this growing complexity.

The aim of this report is to stimulate thinking about Australia's biosecurity future by distilling the key opportunities and challenges for our biosecurity system into a format that is easily accessible for a wide audience – including those who are directly or indirectly involved in the biosecurity field, as well as those who are not. The key issues and implications identified in this report are therefore relevant to industry and research leaders, all levels of government, and even the general community.

The findings from this report are based on extensive consultation across the biosecurity community, including representatives from government, industry and science/research. Many of the key themes will therefore be familiar to those already working in the biosecurity field. However, through the foresight tools of megatrends and megashocks (see A Guide to Futures Thinking below for more information on these tools), the reader is encouraged to think beyond the short-term horizon to consider how things may change over the coming 20 to 30 years across all areas of biosecurity.

Instead of focusing on where we are today, this report aims to provoke consideration of where we are heading and what we need to do to protect Australia's enviable biosecurity status. Rather than just looking at one area of the biosecurity system, this report looks at how a number of important trends cut across plant and animal industries (including marine), the environment and human health.

We cannot afford to be complacent; the management of biosecurity will require a step change towards smarter and more efficient strategies that are ahead of, or in line with, the pace of change around the world. This report is not intended to provide all the answers to the challenges we face but to highlight how the biosecurity landscape may change over the coming decades, in order to open up discussion about what needs to be done to secure the biosecurity future that we want for Australia.

A GUIDE TO FUTURES THINKING

There are a number of tools that can be used when conducting foresight studies. This report draws primarily on megatrends and megashocks as they are effective tools for developing an evidence-based narrative about the future that can feed into a strategic planning or decision making process.

Megatrends and megashocks allow for the identification of plausible future directions for the coming two to three decades as they are based on current and historic evidence and can therefore help leaders to make wiser choices and achieve better outcomes.

Megatrends provide a view of a future trajectory based on a number of identified trends. In this report the megatrends point towards a shift in the types of biosecurity risks Australia will face in the future and the way these risks will need to be managed.

The megatrends are all forward-looking, with a 20-30 year time horizon. Although some aspects of the megatrends are already occurring, they will continue to play out and have an impact over the coming decades.

It is not the megatrends in isolation, but the relationships between them, that are most important when using the megatrends to inform decision making. The interaction of a number of different megatrends has the potential to create megashocks.

Megashocks involve significant, relatively sudden and potentially high impact events, the timing of which is very hard to predict, but do not emerge without some warning.

The megashocks in this report are set in the year 2040 – based on a future that has been shaped by the identified megatrends. They include hypothetical examples across plant and animal industries, marine, environment and human health.

Megashocks can vary in scale and occur at an industry, regional, national, or even change to global level.

Biosecurity Megatrends

A megatrend is a significant shift in social, environmental, economic, technological or geopolitical conditions that has the potential to reshape the way an organisation, industry or society operates. This report has identified five biosecurity megatrends (*An Appetite for Change; The Urban Mindset; On the Move; A Diversity Dilemma?; and The Efficiency Era*) that all point towards a shift in the types of biosecurity risks we are likely to face in the future and the way that these risks will need to be managed.

The number of factors placing pressure on our biosecurity system continues to grow and we need to be prepared to respond. Trends relating to agricultural expansion and intensification, urbanisation and changing consumer expectations, global trade and travel, biodiversity pressures, and declining resources could lead to a future where existing processes and practices relating to biosecurity are not sufficient. Importantly, the megatrends should not be considered in isolation as they are all interrelated and the interactions of the different megatrends have the potential to lead to biosecurity megashocks.

A high-level summary of the megatrends and their biosecurity implications is outlined to the right.

SUMMARY OF THE BIOSECURITY MEGATRENDS AND THEIR KEY IMPLICATIONS

AN APPETITE FOR CHANGE

Megatrend Overview

- Growing global food demands are creating opportunities for growth in Australian agriculture
- Rising agricultural pressures (e.g. water scarcity, pesticide resistance) are challenging the productivity of the sector
- In order to remain competitive in a growing global market, we are seeing greater agricultural intensification, vertical integration and expansion into new areas
- At the same time, we are continuing to see growth in niche markets (e.g. organic and bioproducts)

Biosecurity Implications

- Our ‘pest and disease free’ status will increase in importance in a growing and highly competitive global market for primary produce
- Future focus will be on productivity improvements – the way we approach such improvements could either increase or decrease the strength of our biosecurity system
- Agricultural intensification and vertical integration can create single point sensitivities in the biosecurity system
- Vertical integration requires an end-to-end consideration of biosecurity along the entire value chain
- Land-use change associated with agricultural expansion can impact on the resilience of our ecosystems
- The new biosecurity risks created by agricultural expansion will need to be proactively addressed to ensure the future viability of our primary industries
- Foreign investment associated with agricultural expansion has the potential to either increase or decrease the level of biosecurity risk for Australia
- As niche markets grow, we may need to consider entirely new approaches to managing pests and diseases

THE URBAN MINDSET

Megatrend Overview

- We are continuing to see growth in urban populations, particularly in developing countries
- Australian ‘urban dwellers’ are increasingly disconnected from primary industries
- We are seeing growing consumer expectations relating to food production (e.g. organic, free-range, locally-sourced)
- Our cities continue to encroach upon new areas of land
- Peri-urban producers are a diverse group and are generally disconnected from traditional agricultural networks

Biosecurity Implications

- Densely populated urban areas, particularly in developing countries, can act as disease incubators and increase disease outbreak risks
- A general disconnection from primary production in Australia is leading to a lack of understanding of biosecurity issues and their impacts
- Changing consumer expectations require new and adaptive biosecurity capabilities
- The ongoing expansion of our cities is changing interactions between people, wildlife, agriculture and disease vectors, increasing risks such as zoonotic disease
- It is important to engage with peri-urban/amateur producers as part of the biosecurity community to improve their understanding of biosecurity risks and their adoption of biosecurity practices

ON THE MOVE

Megatrend Overview

- The number of international tourist arrivals for Australia continues to increase
- We continue to see an increase in the movement of goods and vessels around the world, in line with growing global trade
- In a globalised world, bioterrorism (including agroterrorism) is a potential threat
- We are also seeing greater movement of goods across our interstate borders

Biosecurity Implications

- Increased travel creates opportunities for infectious diseases, including those resistant to antibiotics and antiviral medications, to enter Australia
- Increased movement of people and goods can help to bring pests or diseases into the country that could impact on our environment or primary industries
- There will remain a need for offshore biosecurity investment
- We need to protect our biosecurity status and maintain our competitive advantage in export markets, while at the same time avoid being perceived as protectionist
- We may see the development of more and/or stronger regional and global biosecurity standards
- Online retailing is creating greater opportunities for the introduction of pests and diseases through illegal fauna and flora trade
- The potential threat of bioterrorism requires ongoing vigilance
- Greater domestic freight movements can help pests and diseases to spread across the country

A DIVERSITY DILEMMA?

Megatrend Overview

- We have experienced biodiversity loss in recent centuries, globally and in Australia, with many species on the brink of extinction
- Many of the drivers of biodiversity loss are related to human activity (e.g. land clearing, invasive species)
- Efforts are being made by a number of countries to preserve biodiversity and limit further losses
- A changing climate is causing shifts in ecosystem diversity
- We are continuing to see a loss of species and genetic diversity within agriculture

Biosecurity Implications

- Significant biodiversity loss can decrease the resilience of our natural environment to pests and diseases
- The management of invasive species can be a valuable and cost-effective tool in curbing biodiversity losses
- Biodiversity can provide a number of benefits, such as ecosystem services (e.g. pollination). Understanding the interconnections between biodiversity and biosecurity may therefore prove to be a vital component of biosecurity management
- Climate change can facilitate the movement of pests and disease vectors into new areas
- The loss of agricultural diversity can create food security risks in the case of a pest or disease outbreak
- Preserving genetic diversity can help in the development of pest and disease resistant crops and animals

THE EFFICIENCY ERA

Megatrend Overview

- An ageing population is leading to a decline in biosecurity specialists and experienced farmers, with a lack of younger talent to fill the gaps created
- Biosecurity investment does not appear to be keeping pace with the growing challenges we face
- Technology and innovation across surveillance and monitoring; data and analytics; communication and engagement; genetics; and smaller, smarter devices will play an important role in addressing future biosecurity challenges
- It is important to identify and address the barriers that could prevent technological innovation from delivering the efficiencies required

Biosecurity Implications

- A lack of biosecurity specialists and investment could limit our ability to prevent and respond to shocks
- Low cost sensors and automated systems create opportunities to better identify pests and diseases
- Improvements in data modelling and visualisation, combined with increased data availability, can improve long-term decision making
- New communication tools, as well as behavioural and social science, can help to improve the flow of information and engage the wider community including citizen scientists, in biosecurity management
- Progress in surveillance and diagnostics in the area of genetics allows for better detection and understanding of pests and diseases, as well as opportunities to breed resistant species
- The development of diagnostic devices that are smaller, smarter and capable of detecting a range of pests and diseases could create a step change in quarantine and surveillance activities
- Issues such as poor design, a lack of funding and poor data integration could limit the potential for technological solutions to address current and future biosecurity challenges

Biosecurity Megashocks

The way that the biosecurity megatrends play out and, importantly, how they interact with one another over the coming decades will be significant in shaping Australia's biosecurity future.

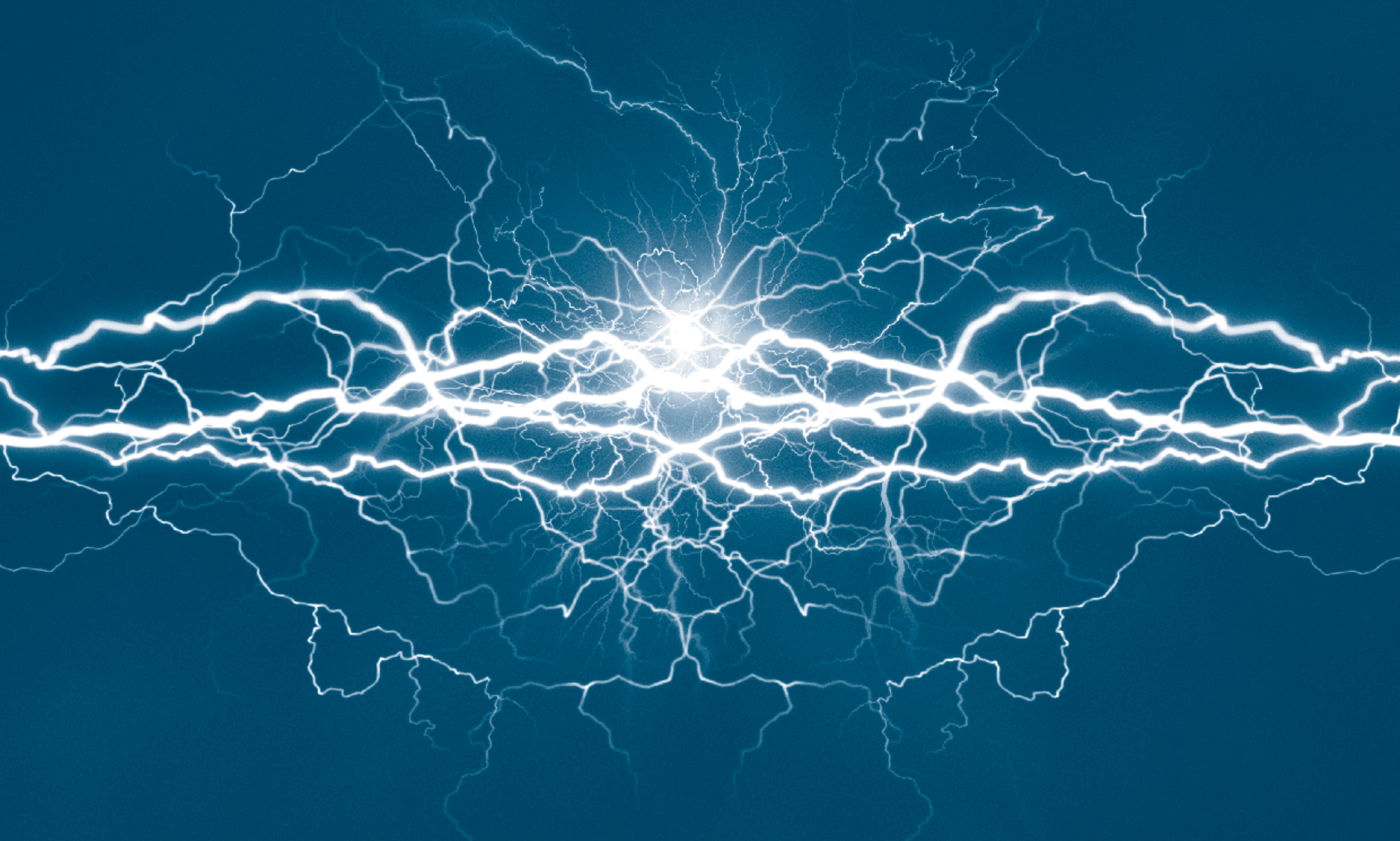
The intersection of the megatrends, and the sub-trends within them, has the ability to expose Australia to a greater level of biosecurity risk with the potential for future 'megashocks' to Australian industry, the environment or even our way of life. For example, agricultural intensification combined with greater levels of trade and declining biosecurity investment could create the conditions for a megashock for Australia's plant or animal industries. None of these trends in isolation have the ability to create such an event, but the way they interact can increase both risk and impact levels for biosecurity threats, with the potential to facilitate megashocks.

Megashocks involve significant, relatively sudden and potentially high impact events, the timing of which is very hard to predict. Numerous hypothetical biosecurity megashocks can be identified across plant and animal industries, marine, environment and human health. This analysis has focused on a selection of two to three potential megashocks within each of these five categories, based on what the biosecurity community identified as some of the most important threats we might face over the coming 20-30 years.

Many of the megashocks discussed are based on known threats that are well understood and that we may be somewhat prepared for. However, the interaction of the megatrends over the coming decades could create the conditions for these potential threats to turn into megashocks. On the other hand, some of the chosen megashocks are based on threats that we may not yet fully understand but that have the potential to become a more serious concern for Australia in the next 20-30 years as the megatrends continue to reshape the biosecurity landscape.

Megashocks can have significant impacts across economic, environmental and/or social dimensions. They can also vary in scale, from more localised or industry-specific megashocks through to those with impacts of national or even global significance. The examples discussed in this report represent a cross-section of megashocks with varying degrees of impact.

While it can be argued that Australia has so far been spared from significant biosecurity megashocks, they are not an uncommon occurrence at a global level. The twelve megashocks outlined on the following pages illustrate that Australia cannot use its relatively fortunate history as an excuse for complacency in the face of growing biosecurity challenges.



SUMMARY OF TWELVE POTENTIAL BIOSECURITY MEGASHOCKS

PLANT INDUSTRIES

MEGASHOCK OVERVIEW	PRIMARY IMPACTS
• A nationwide incursion of a new race of an exotic wheat stem rust – one more virulent than existing races of UG99	• Substantial yield reductions for wheat, with potential yield reductions in other crops (e.g. barley)
• The nationwide loss of pollination services from feral European honey bees due to a multi-state varroa mite incursion	• Major economic losses for several of Australia's fruit, vegetable and nut industries
• A nationwide incursion of a new exotic fruit fly	• Significant economic losses for several of Australia's fruit and vegetable industries

CONTRIBUTING MEGATRENDS

- **An Appetite for Change**– Agricultural intensification and homogenisation are creating single point sensitivities in our biosecurity system
- **The Urban Mindset** – Changing consumer demands (e.g. for organic produce) could create new challenges for pest and disease management
- **On the Move** – Greater global movement of people and goods (particularly imports of plant products) is creating new opportunities for pests and diseases to enter the country
- **A Diversity Dilemma?** – The loss of certain species (e.g. pollinators) could threaten the viability of a number of crops
- **The Efficiency Era** – Declining resources could limit our ability to prevent and respond to an incursion

ANIMAL INDUSTRIES

MEGASHOCK OVERVIEW	PRIMARY IMPACTS
• A nationwide outbreak of a variant strain of foot and mouth disease	• The devastation of a number of Australia's livestock export markets – e.g. beef, pork, sheep
• A bluetongue outbreak across Australia's major sheep producing regions	• Significant economic losses for Australia's sheep and wool industries

CONTRIBUTING MEGATRENDS

- **An Appetite for Change** – Agricultural expansion and intensification could heighten the spread and effects of a pest or disease outbreak
- **The Urban Mindset** – Growth in peri-urban production could heighten the threat and impacts of a pest or disease outbreak if small-scale/hobby producers fail to engage with biosecurity issues
- **On the Move** – Greater global trade is creating new opportunities for pests and diseases to enter the country
- **A Diversity Dilemma?** – A warming climate is allowing the spread of pests, diseases and disease vectors into new areas
- **The Efficiency Era** – Declining resources could limit our ability to prevent and respond to a pest or disease outbreak

ENVIRONMENT

MEGASHOCK OVERVIEW	PRIMARY IMPACTS
• A highly virulent rust spreads across multiple ecosystems	• Widespread environmental damage that threatens several plant species, including food sources for a number of animal species
• The government 'walks away' from environmental biosecurity	• Too difficult to predict

CONTRIBUTING MEGATRENDS

- **On the Move** – Greater global movement of people and goods is creating more opportunities for pests and diseases to enter the country
- **A Diversity Dilemma?** – Agricultural expansion, climate change and other biodiversity pressures are reducing the resilience of our environment to pests and diseases
- **The Efficiency Era** – Rising cost pressures and a push for efficiencies could lead to future disinvestment in environmental biosecurity management

MARINE

MEGASHOCK OVERVIEW	PRIMARY IMPACTS
• The successful establishment of black-striped mussel	• Substantial economic losses for a number of industries (including shellfish, fishing and tourism) and significant costs for wharves, marinas and pumping stations
• An outbreak of infectious salmon anaemia	• The decimation of Australia's salmon industry

CONTRIBUTING MEGATRENDS

- **An Appetite for Change** – Expansion and intensification of aquaculture production could increase the potential impacts of a pest or disease outbreak
- **On the Move** – Greater international vessel movement will increase the opportunities for pests and diseases to enter our waters
- **A Diversity Dilemma?** – Warming ocean temperatures may see pests and diseases move into new areas
- **The Efficiency Era** – Declining resources could limit our ability to prevent and respond to a pest or disease outbreak

HUMAN HEALTH

MEGASHOCK OVERVIEW	PRIMARY IMPACTS
• A nationwide zoonotic disease epidemic	• Widespread human infection with the potential for high fatalities
• A bioterrorist attack	• Significant human infection within a particular region, with likely fatalities, depending on the type of attack
• A rapid spike in antimicrobial resistance	• A significant rise in fatalities associated with bacterial and viral infections

CONTRIBUTING MEGATRENDS

- **An Appetite for Change** – If poorly managed, intensified agricultural production systems and agricultural expansion can increase the risk of a zoonotic disease outbreak
- **The Urban Mindset** – A growing population and urbanisation, particularly in developing countries, are increasing the potential risk for an emerging infectious disease outbreak. Urban encroachment and peri-urbanisation are also changing interactions between people, wildlife, agriculture and disease vectors, increasing the risk of diseases passing from animals to humans
- **On the Move** – Greater global travel increases the risk of any future disease outbreak quickly becoming a global pandemic. It can also help to facilitate the spread of antibiotic and antiviral resistant diseases
- **A Diversity Dilemma?** – Biodiversity loss can increase the risk and incidence of zoonotic diseases
- **The Efficiency Era** – Declining biosecurity resources may limit our ability to develop the vaccines, therapeutics and surveillance technologies required to limit the effects of emerging infectious diseases on the Australian population

The Way Forward

The biosecurity megatrends illustrate the unparalleled change that is increasing the complexity of the biosecurity landscape. This will require us to significantly increase the effectiveness of our biosecurity effort through strategic investments in capability and technology, just to maintain Australia's current level of preparedness. The biosecurity megashocks illustrate the potential consequences of remaining complacent amidst this growing complexity.

Biosecurity can be regarded as insurance against risk; whereby the access to good information and the implementation of good decision making processes makes it possible to act pre-emptively, trading off the risks avoided against the costs of measures imposed. In order to be successful, this approach requires rigour in risk management and decision making to ensure that the costs of biosecurity activities don't outweigh the benefits.

At the same time, biosecurity should not just be viewed as insurance against risk but also as an enabler. A world-leading biosecurity regime can improve market access opportunities. It can also play an important role in enabling the sustainable agricultural expansion and intensification required to realise the growth opportunities that exist for our agriculture sector. Finally, as food safety and security becomes a growing concern around the world, we may see future opportunities to export our biosecurity-related services and knowledge.

Minimising and managing risks while capitalising on the opportunities that a successful biosecurity regime presents will only be possible through a coordinated approach involving government, industry, scientists and the general community. As the biosecurity successes and failures in one area or industry are intertwined with the fate of the others, there needs to be a focus on finding common solutions in order to maximise our return on investment and resources.

Importantly, any future approach needs to optimise and integrate the use of policy, science and technology, and education and engagement. A balance is also required between the initiatives that help us to prepare for, and those that allow us to better respond to and recover from biosecurity threats.

Based on the megatrends and megashocks identified in this report, there are a number of key questions that should be explored if we are to maximise the effectiveness of Australia's biosecurity system. These are outlined in the table on the following page, where the term 'we' is used to refer to the collective biosecurity community (incorporating industry, government, and science and research). While not intended to be exhaustive, this list of questions aims to spur discussion and highlight priorities that should be considered in the development of long-term biosecurity strategies.

With growing complexity and declining resources we seem to be on a path towards an uncertain biosecurity future. The below table outlines some of the most important considerations that provide a starting point for the process of strengthening our biosecurity regime to address growing global challenges. Decisions will need to be made regarding which of these considerations to pursue further in order to ensure Australia's economy, environment, and the health and wellbeing of our citizens are protected and enhanced, through a commitment to securing Australia's biosecurity future.

1 Policy

PREVENTION ACTIVITIES

1.1. How do we secure sufficient funding for long-term biosecurity prevention activities without detracting from other national priorities? Are there opportunities for new funding models such as a national levy, broader industry responsibility for funding along the value chain (e.g. supermarkets), insurance and/or philanthropy?

1.2. How do we make sure prevention activities are proactive and well maintained given that success often breeds complacency? Put another way, how can we maintain investment without having to see a major crisis locally or overseas?

1.3. How do we ensure policy keeps up with changing biosecurity risks driven by changes in market demand? For example, have our policies and practices in poultry kept up with demand for free-range in a way that allows us to appropriately manage the risks involved? Are we well prepared to manage the risks created by the vertical integration of national food supplies?

1.4. What incentives could be created to increase farmer and industry participation in surveillance (onshore and offshore)? Is there an opportunity to incorporate biosecurity responsibilities in land tenure agreements or property registrations?

2 Science & Technology

PREVENTION ACTIVITIES

2.1. How can we best leverage smaller and smarter sensor technologies for monitoring – for example, to monitor for the presence of wild animals (e.g. ducks on free-range farms or feral animals) or to understand environmental conditions (e.g. climate) in order to better predict risk levels?

2.2. Are we fully exploring the potential opportunities that exist for a single monitoring system to detect multiple pests and diseases, rather than developing unique surveillance systems for each potential threat? Are we making the most of the current surveillance and monitoring systems that we have in place?

2.3. How can advancements in diagnostics be leveraged for early identification and understanding of future disease strains and pathogens? How can this be incorporated into long-term preventative strategies such as preventative breeding programs?

2.4. How can we develop and leverage a better understanding of the relationship between biodiversity and biosecurity?

2.5. How can trends related to citizen science be further embedded in national and industry biosecurity efforts? How can we ensure that citizen science data and analysis is scientifically valid and useful?

2.6. How can we develop a more integrated system for managing data that allows decision makers to more easily take a holistic view of biosecurity issues across the country?

2.7. How can we leverage scientific models and predictive analytics to improve decision making and certainty in response situations?

3 Communication/Engagement

PREVENTION ACTIVITIES

3.1. How can social and behavioural sciences be leveraged to improve general public perceptions and behaviours related to biosecurity? Importantly, what level of attitudinal and behavioural change is really appropriate - i.e. how do we ensure we aren't investing in campaigns that don't deliver the necessary benefits?

3.2. How can the Australian biosecurity community better engage and educate hobby farmers and amateur producers across the country?

3.3. How can social media and new online communication channels be maximised to cost-effectively communicate biosecurity values and drivers and create a long-term, two-way dialogue with a wide set of stakeholders, including the community?

RESPONSE ACTIVITIES

1.5. How do we ensure that our response considers all areas of potential impact, such as the potential environmental impact of an industry megashock?

1.6. How do we ensure measured responses to threats? In particular, how do we ensure that improvements in surveillance don't lead to an unnecessary level of response? On the other hand, how do we avoid underestimating seemingly small threats that have long-term implications?

1.7. What policies are required to ensure that Australia has the skills and capabilities to respond to national threats in the context of our ageing workforce and declining resources in biosecurity?

1.8. How do we ensure that resource and funding agreements are in place such that bureaucracy and governance challenges do not stifle our responsiveness? How can we ensure we have the 'fighting funds' required to respond immediately, in the case that the lines of responsibility aren't initially clear?

1.9. How do we ensure that jurisdictions are working together as effectively as possible to allow for a nationally coordinated approach when responding to biosecurity threats?

RESPONSE ACTIVITIES

2.8. How can traceability and surveillance be maximised to increase the speed at which we can regain a disease free status?

2.9. How can technology be used to improve collaboration and knowledge sharing between industry, government and the research community during response situations?

2.10. How might autonomous systems and advances in robotics be applied to improve the effectiveness of our biosecurity response?

2.11. How can we use technology to improve on-farm or on-site real-time diagnostic testing in order to reduce the need for sample collection followed by high cost laboratory-based diagnostics and dramatically improve our speed of response?

RESPONSE ACTIVITIES

3.4. How can we ensure that online communication channels are not hijacked by misinformation or one-sided information during a biosecurity crisis?

3.5. Given the complexity of the national biosecurity landscape, how can education and communication ensure that public overreaction/panic is avoided during megashock events?

3.6. How can we use communication to bring together the disparate biosecurity community in order to facilitate a faster and more effective response? How can we ensure that we quickly mobilise all relevant industries, hobby farmers and even the general public, if and when it is required?

Introduction

When considering the future of biosecurity for Australia it is clear that we are starting from a relatively privileged position. As an island nation with a long-standing commitment to quarantine, Australia remains free from many of the pests and diseases that plague other parts of the world. This privileged position delivers benefits across three dimensions:

Economic
– increases the competitiveness of our primary industries, particularly in relation to gaining and maintaining market access for our agricultural exports

Social
– protects our population from pests and diseases that could be detrimental to human health and wellbeing or social amenity

Environmental
– conserves our unique natural environment and the multiple services it provides

This aligns with the definition of biosecurity provided by the Intergovernmental Agreement on Biosecurity (IGAB) which states that "biosecurity is mitigating the risks and impacts to the economy, the environment, social amenity or human health associated with pests and diseases entering, emerging, establishing or spreading."[1] It is much broader than quarantine, incorporating the entirety of the efforts that go into preventing pests and diseases from entering Australia, establishing, spreading and/or causing harm.

Of course the three areas of the environment, economy, and human health and wellbeing are not mutually exclusive. For example, a competitive agriculture industry provides social benefits for regional communities, such as greater employment opportunities; a healthy population helps to maintain a productive workforce delivering economic benefits; and protecting the natural environment delivers both social and economic benefits through ecosystem services such as access to water, wood, pollination and culturally important areas. The decisions made in one area of biosecurity can have a direct or indirect impact on another. It is because of this interrelation that when it comes to biosecurity management, the whole system is greater than the sum of its parts.

This report highlights how important it will be to recognise these interrelations and achieve greater clarity and strategic direction for biosecurity management in Australia in the coming decades. The number of factors placing pressure on our biosecurity system continues to grow and we need to be prepared to respond. Trends relating to urbanisation, changing consumer expectations, global trade and travel, biodiversity pressures, agricultural expansion and intensification, and declining resources are all pointing to a future where existing processes and practices relating to biosecurity may not be sufficient. The combination of these different trends has the potential to open up Australia to known or unknown biosecurity megashocks that could negatively impact our industries, our environment and our way of life.

While collective and shared governance will play a key role in addressing future challenges, it is not the only solution. Science and technology continues to play an important role in meeting the need for more effective and efficient methods for the surveillance, monitoring and management of biosecurity risks. There are also potential benefits to achieving a more widespread community understanding of biosecurity and its importance through education and communication. Whether it is policy, science and technology, or education and communication, a proactive, strategic and balanced approach to identifying and preparing for existing and new biosecurity threats will be essential in ensuring we remain on top of these trends.

Rather than just focusing on where we are today, this report aims to open up discussion about where we are heading and what we need to do to protect Australia's enviable biosecurity status. The report looks beyond the short-

term horizon to consider how things may change over the coming 20 to 30 years across all areas of biosecurity: plant and animal industries (including marine), environment and human health. It is not intended to provide all the answers, but to encourage Australia's biosecurity community to start asking the right questions in the hope that we can continue to reap the economic, social and environmental benefits associated with a successful biosecurity regime for many decades to come.

The Governance Backdrop

The interconnected nature of the biosecurity system highlights the potential advantages of a coordinated, whole-of-system approach to managing biosecurity where 'shared responsibility' is the paradigm. Unfortunately, the general sentiment from stakeholder interviews conducted with members of the biosecurity community suggests that in Australia biosecurity management often remains relatively siloed, with a lack of coordination across industries and jurisdictions. (See the *Approach* on the following page for more details on stakeholder interviews). There appears to be a lack of consensus regarding exactly what biosecurity entails, why it is important, and which areas within biosecurity Australia should focus on.

The term biosecurity only really began to be widely adopted in Australia following the *Nairn Review* in 1996,[2] which outlined the idea of the 'quarantine continuum': pre-border, border, and post border. Shifting away from quarantine to biosecurity, as recommended by the 2008 *Beale Review*,[3] raises the issue of how much we should focus on activities at each stage of this continuum. Some believe that most of the effort should be on keeping pests out in the first place while others feel strongly that the management of already established pests and diseases should be prioritised.

This tension leads to issues relating to the distribution of responsibility for biosecurity. The general view across the biosecurity community is that the government sector (at a state level) is gradually stepping away from post-border biosecurity and pushing more responsibility onto industry to manage and invest in post-border activities. While this has the potential to deliver benefits such as greater focus and efficiencies, if this shift leads to confusion around roles and responsibilities it could potentially slow down our national ability to respond to incursions. Furthermore, while the government is likely to continue to prioritise human health-related biosecurity concerns, environmental biosecurity may face an uncertain future with no industry body to lobby on its behalf and challenges with demonstrating return on investment.

The *Nairn Review* brought the term 'shared responsibility' into the common vernacular, stating that government, industry and the general public all have a role to play in keeping Australia free from unwanted pests and diseases. The *Beale Review* built on this and recommended a number of significant improvements. While progress towards a more coordinated biosecurity system has undoubtedly been made, many hold the view that the notion of 'shared responsibility' is still heard more in rhetoric than it is seen in practice and that existing cost-sharing programs are laden with challenges in delivery.

While it is generally agreed that shared responsibility is the direction in which we should be heading regarding biosecurity management in Australia, such an approach is not without its own challenges and risks. For example, the 2011 *Matthews Review* pointed out that the consultative arrangements that are in place regarding planning processes for foot and mouth disease (FMD) "have tended to obscure authority, responsibility and accountability for progress in national FMD planning and preparations, and increased the potential for delays, confusion and compromise."[4]

Although it is not within the scope of this report to provide an analysis of Australia's biosecurity governance, it is important to consider the impacts that governance could have in the future as we are forced to face rising pressures created by local and global trends relating to biosecurity. Australia has made significant progress towards the shared responsibility model through processes such as IGAB, cost sharing arrangements, and the roles of Animal Health Australia and Plant Health Australia in bringing together industry engagement with biosecurity awareness and delivery. The biosecurity-related Research, Development and Extension (RD&E) Strategies developed as part of the National Primary Industries R,D&E Framework also aim to promote greater collaboration and shared strategic direction. Continuation of this trajectory towards greater coordination and collaboration is critical for the future and will be a common theme for biosecurity governance in Australia as the biosecurity landscape grows even more complex.

Approach

This report was developed through extensive stakeholder engagement in order to bring together the full spectrum of perspectives across Australia's biosecurity network.

The stakeholder engagement involved senior leaders from across the biosecurity community, including state and federal government departments and agencies, national peak bodies and industry service bodies, not-for-profit organisations and other industry groups, and the science and research community. It was designed to incorporate views from experts working across all areas of biosecurity: plant and animal industries (including marine), the environment and human health.

Specifically, the engagement involved 30 minute to 1.5 hour-long interviews/discussions with individuals or small groups, in which the key biosecurity opportunities and challenges facing Australia were explored. This was followed by two full day workshops held in Canberra in May 2014, which focused on potential megatrends and megashocks and their relevance to the different areas of biosecurity. The below table provides a list of the organisations that were represented by more than 70 experts across the biosecurity community, through the interviews and/or workshops.

In addition, a 1.5 hour-long workshop was conducted at the Plant Biosecurity CRC's Science Exchange in May 2014, in order to explore the megatrends and megashocks in the context of plant biosecurity.

The Biosecurity Flagship and CSIRO Futures would like to acknowledge the contributions made by those who responded to our invitation to provide input to *Australia's Biosecurity Future*. We thank all those who participated via interviews or workshops for their time and for sharing with us their invaluable knowledge and experience.

The perspectives obtained through this widespread engagement were analysed alongside an extensive literature review in order to validate the key concepts raised, distil the key themes down to the most important biosecurity megatrends, as well as clarify the most significant potential threats, or megashocks.

The biosecurity megatrends and megashocks constitute the first two sections of this report and highlight the potential directions in which Australia's biosecurity future could be heading. Following this is an outline of some of the most important considerations for decision makers when thinking about how the actions of today could influence Australia's long-term biosecurity future.

ORGANISATIONS ENGAGED VIA INTERVIEWS AND/OR WORKSHOPS

- AgForce Queensland
- Animal Health Australia
- Apple and Pear Australia Limited
- Australasian Joint Agencies Scanning Network
- Australian Alpaca Association Limited
- Australian Centre for International Agricultural Research
- Australian Chicken Meat Federation
- Australian Dairy Farmers
- Australian Duck Meat Association
- Australian Egg Corporation Limited
- Australian Forest Products Association
- Australian Horse Industry Council
- Australian Lot Feeders' Association
- Australian Pork Limited
- Australian Seafood CRC
- AUSVEG
- Cattle Council of Australia
- Centre of Excellence for Biosecurity Risk Analysis
- CSIRO
- Dairy Australia
- Defence Science and Technology Organisation
- Department of Agriculture (Australian Government)
- Department of Agriculture, Fisheries & Forestry (QLD)
- Department of the Environment (Australian Government)
- Department of Environment and Primary Industries (VIC)
- Department of Fisheries (WA)
- Department of Health (Australian Government)
- Department of Primary Industries (NSW)
- Department of Primary Industries, Parks, Water and Environment (TAS)
- Department of Primary Industries and Regions SA
- Department of Primary Industry and Fisheries (NT)
- Department of the Prime Minister and Cabinet
- Dried Fruits Australia
- Equestrian Australia
- Goat Industry Council of Australia
- Harness Racing Australia
- Horticulture Australia Limited
- Invasive Animals CRC
- Lincoln University
- LiveCorp
- Livestock Biosecurity Network
- Meat & Livestock Australia
- National Aquaculture Council
- National Farmers' Federation
- Northern Australia Taskforce
- Nuffield Australia
- Plant Biosecurity CRC
- Plant & Food Research
- Plant Health Australia
- Ports Australia
- Poultry CRC
- Rural Industries Research and Development Corporation
- Sheepmeat Council of Australia
- Shipping Australia
- Sub-committee on Aquatic Animal Health
- Therapeutic Goods Administration
- University of Melbourne
- University of New South Wales (Australian Defence Force Academy)
- Wildlife Health Australia
- WoolProducers Australia

Biosecurity Megatrends

What is a Megatrend?

A megatrend is a significant shift in social, environmental, economic, technological or geopolitical conditions with the potential to reshape the way an organisation, industry or society operates over several decades into the future. Megatrends occur at the intersection of a number of trends and, as such, point towards a large and substantial shift. In this instance, the megatrends identified all point towards a shift in the types of biosecurity risks we will face in the future and the way that these risks will need to be managed.

Through engagement across the biosecurity community and an extensive literature review, five biosecurity megatrends have been identified for Australia:

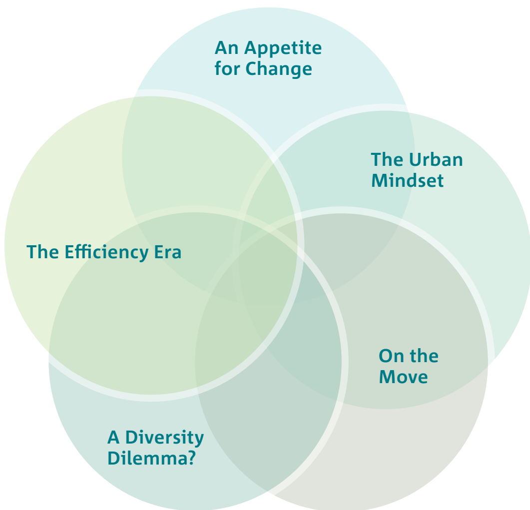
- **An Appetite for Change** – Biosecurity will become increasingly important as agriculture expands and intensifies to meet rising global food demand.
- **The Urban Mindset** – As a country of urban dwellers, Australians are increasingly disconnected from biosecurity issues. At the same time, urban encroachment and peri-urbanisation continue to create new biosecurity challenges.
- **On the Move** – Greater global trade and travel are creating new opportunities for pests and diseases to enter and spread across Australia.
- **A Diversity Dilemma?** – The significance of biosecurity threats relating to declining biodiversity, redistribution of species and declining agricultural biodiversity will become clearer to us over the coming decades.
- **The Efficiency Era** – A trend towards declining resources in biosecurity is seeing a rise in the use of (and reliance on) technology.

These megatrends should not be considered in isolation as they are all interrelated (Figure 1). For example, the biosecurity risks of a growing agriculture industry (*An Appetite for Change*) can only be fully understood when looking at how global trade will affect disease spread (*On the Move*) and how changing consumer demands (*The Urban Mindset*) might influence farming practices.

As illustrated in the next chapter of this report, the interactions of the different megatrends also have the potential to lead to 'megashocks' for Australian industry, the environment or even our way of life. Therefore, it is important for decision makers to consider the relationships between these different megatrends (and the sub-set of trends within them) when planning for the future of our national biosecurity.

The megatrends in this report are defined with a 20 to 30 year time horizon. However, some elements of the megatrends are already occurring and some will continue to have an effect beyond the next 20 to 30 years. In addition, there are elements that will have greater relevance in the short-term, while others will grow in importance over the coming decades.

FIGURE 1: THE INTERRELATION BETWEEN THE FIVE BIOSECURITY MEGATRENDS



An Appetite for Change

A growing population brings with it a growing demand for food. We are seeing greater agricultural intensification and vertical integration in response to this growing demand as the sector looks to improve productivity amidst rising agricultural sustainability pressures such as climate change, water scarcity and pesticide resistance. The impacts of a pest or disease outbreak in a highly intensified and integrated agricultural system can be significant, with the potential to affect food availability. Food security needs will also see the expansion of agriculture into new areas, with the potential to introduce biosecurity threats through new pathways or new hosts for pests and diseases. While agriculture continues to grow and intensify we are simultaneously seeing growth in niche areas such as organic produce and bioproducts, which could require entirely new approaches to biosecurity management.

An ever-hungrier world

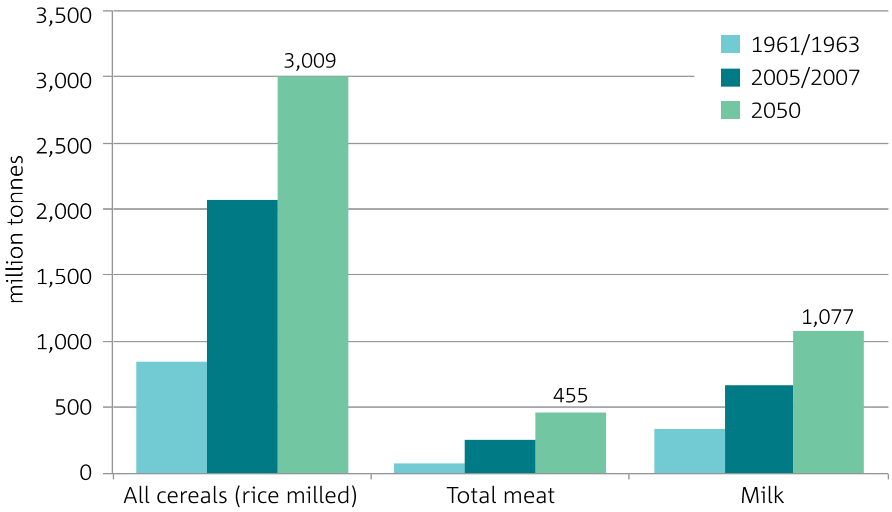
There are currently more than seven billion people in the world and it is projected that we will reach 8.1 billion by 2025 and 9.6 billion by 2050.[5] Based on this, as well as the growth in income levels and changing diets, the Food and Agriculture Organization of the United Nations (FAO) has forecast that food production will need to increase by 60 per cent (compared to 2005/2007 levels) to meet demand in 2050. Cereal production will need to increase by nearly 1 billion tonnes and meat production by almost 200 million tonnes.[6]

This growing demand for food creates significant economic opportunities for Australia, particularly as our status as a nation that is relatively free from agricultural pests and diseases can help to give us a competitive advantage in the global marketplace. This favourable biosecurity status will grow in importance as the international market for agricultural commodities becomes increasingly competitive. In the three decades to 2010-11, Australian farm exports grew at an average rate of five per cent per year – increasing from $8.2 billion to $32.5 billion in value.[7] If Australia remains competitive and captures a large share of the growing global food demand, a 2050 scenario could see the value of Australian agrifood exports increasing by 140 per cent compared to 2007 levels.[8]

We will also see domestic food demand increase as the Australian population is projected to increase to more than 30 million people by 2050.[9] Australia currently produces enough food for around 60 million people but exports approximately 60 per cent (in volume).[10] While the export opportunities will continue to grow, Australia will simultaneously need a sustainable domestic food strategy that ensures our own long-term food security.

FIGURE 2: GLOBAL CEREALS AND LIVESTOCK PRODUCTION – 1961/63 AND 2005/2007 (ACTUAL) VS. 2050 (REQUIRED)

Source: FAO, 2012[6]



Rising agricultural pressures

Australia's agriculture sector faces a number of challenges that together could constrain the industry's ability to sustainably realise ongoing productivity improvements[11] and capitalise on growth opportunities. One such challenge is water scarcity, as it is expected that there will be a 55 per cent increase in global water demand between 2000 and 2050,[12] with Australia potentially experiencing a 76 per cent increase in water consumption in major capital cities by 2056, compared to 2008-09 levels.[13]

While global water productivity in agriculture has increased over the past few decades, a lack of further improvement by 2050 may mean that we would see almost double the amount of water evaporated in crop production compared to 2007 levels.[14] At the same time, the sector is highly sensitive to changes in climate. For example, the 2002-03 drought in Australia led to a 24 per cent fall in agricultural output and approximately 70,000 agricultural job losses[15] (see *A Diversity Dilemma?* for further details on climate change).

Another challenge can be seen through herbicide resistance, which has dramatically accelerated over the last two decades (see Figure 3). According to the International Survey of Herbicide Resistant Weeds, as of June 2014 there were just under 70 unique cases of herbicide resistant weeds in Australia and over 430 unique cases globally across approximately 230 species with resistance to more

Herbicide resistance costs Australian farmers more than $200 MILLION PER YEAR

than 150 different herbicides.[16] At the same time, Heap (2014) highlighted that "industry has not brought a novel herbicide to market in over 30 years."[17] Together these trends add to the cost of weed management[18] and can impact production as weeds directly compete with crops for nutrients, moisture and light.[19] The Grains Research and Development Corporation (GRDC) has estimated that herbicide resistance costs Australian farmers more than $200 million per year.[20]

The same trend is evident with insecticide resistance, with a 2008 analysis identifying 7,600 cases of resistance to insecticidal products – 43 per cent of them in just 16 insects, many of which are major crop pests.[21] Insecticide resistance also brings real challenges to sustainable food production through direct crop losses and increased production costs.

At the same time, there are calls for decreases in pesticide usage in farming to help facilitate trade, improve consumer safety standards and decrease environmental contamination. For example, the European Commission is promoting low pesticide-input farming and it is believed that the UK will have to produce more food with fewer pesticides.[22] Outside of the challenges created for agricultural operations, decreased pesticide usage and effectiveness have long-term implications for biosecurity. In particular, they remove our ability to rely on some of the common biosecurity tools of the past and may spur discussions on the use of new tools like genetic modification (see *The Efficiency Era* for details on genetic modification).

Other trends such as an ageing population, accompanied by the loss of key skills (see *The Efficiency Era*), high labour rates, changing consumer expectations (see *The Urban Mindset*) and increasing imports (see *On the Move)* are also creating challenges for the sector.

Industry pressures are driving significant changes in Australian agriculture, particularly in relation to intensification and expansion, as the sector aims to remain competitive in the growing global market. These changes could potentially help to boost agricultural productivity, which has seen a slowdown in growth over the last 15 years.[23] However, it is also important to recognise that from a biosecurity perspective, the way we manage these changes in the coming years could either increase or decrease the risks we face in the future which, in turn, will either support or undermine all potential productivity gains.

Big farms, big business

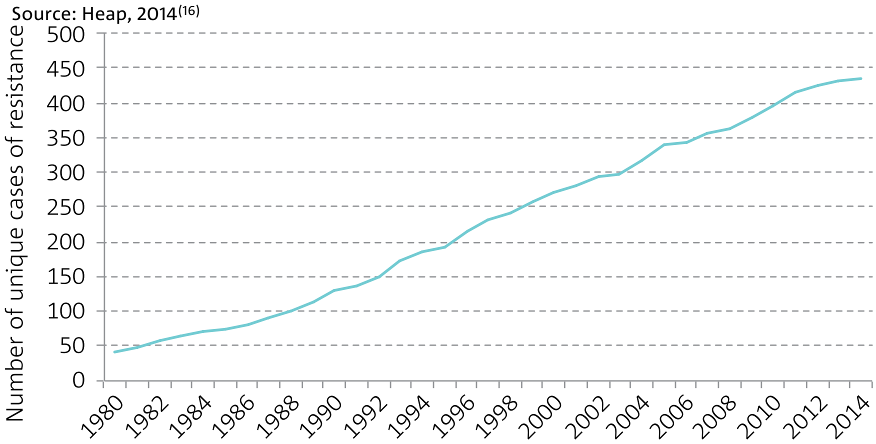
In order to meet growing demands and reduce costs, the agriculture industry has been intensifying operations in an attempt to gain more output from fewer inputs. For example, since 1982 the average dairy herd size in Australia has increased from 90 cows to 258 cows, with a trend toward operations of more than 1,000 cows.[24]

Australia's agriculture sector is highly distributed and diverse, with a large number of small businesses (often family owned) and a small number of very large businesses (family and corporate) – some that occupy a land area more than twice the size of the Australian Capital Territory.[7] However, there is a clear global shift towards fewer and larger farms that have the capacity to take advantage of technical advances and economies of scale[25] and Australia is likely to continue to follow suit in order to remain competitive in the export market.

Biosecurity should be a central component of all farming operations as farms of any size, if not well managed, can pose a biosecurity risk. However, it is important to consider how the trend towards larger farming operations may require more stringent biosecurity practices due to factors such as the large amounts of waste they produce compared to smaller operations.

FIGURE 3: CHRONOLOGICAL INCREASE IN RESISTANT WEEDS GLOBALLY (1980–2014)

Source: Heap, 2014[16]



Since 1982 the average dairy herd size in Australia has increased from 90 cows to 258 cows, with a trend toward operations of more than 1,000 cows.

Even in the case that large, intensified operations adopt high biosecurity standards, it is still important to recognise the risks that exist. While the likelihood of an incident may be relatively low (due to the implementation of good biosecurity management), the potential impacts are significant and can even affect food availability, as a single breach jeopardises a larger amount of produce. For example, H7 Avian Influenza was confirmed in a large flock of 400,000 layer hens in NSW in 2013, leading to the culling of the entire flock.(26) This was reported to have caused short falls in Australia's egg supply over Christmas, with production down by 30 per cent.(27)

There are also some potential concerns regarding antibiotic use in large operations. For example, in the US, growth-promoting antibiotics are substantially more likely to be used on large hog operations.(28) There are concerns that the overuse of antibiotics in farming could increase the risk of drug-resistant bacteria in the food chain,(29) with potential consequences relating to both animal and human health.

Running in parallel with agricultural intensification is a trend towards homogenisation (i.e. using a small number of plant and animal species for the bulk of production) as farmers select breeds that can deliver higher production volumes and, therefore, higher profits. While homogenisation can improve yield and consistency, from a biosecurity perspective a dependence on fewer breeds (locally and globally) creates food security issues if an outbreak of a pest or disease targets a specific crop or animal (see *A Diversity Dilemma?* for more information on biosecurity risks related to homogenisation).

In addition to intensification of operations, there has also been a trend towards greater concentration and vertical integration in agriculture both locally and globally. For example, a single entity in each state accounts for the majority of Australian grain handling and storage facilities; a large portion of food and fibre processing is undertaken by four poultry processors, three sugar millers, three dairy processors, four wool processors and five meat processors; and groceries are dominated by two retailers.(23) This consolidation leaves a small number of companies responsible for biosecurity across the entire supply chain. A contaminant or pathogen that is introduced at one point along a company's 'farm-to-fork' continuum could rapidly spread and multiply throughout the continuum.(30)

If these integrated organisations do not prioritise biosecurity in their operations, we could see problems emerge. In March 2014 it was reported that Woolworths immediately recalled almost three tonnes of plums across 72 South Australian stores after fruit fly larvae was discovered in a single store in Adelaide.(31) The high level of consolidation and lack of traceability led to a large number of producers being negatively affected, even though only one Victorian supplier was thought to have been the source of the infested produce.

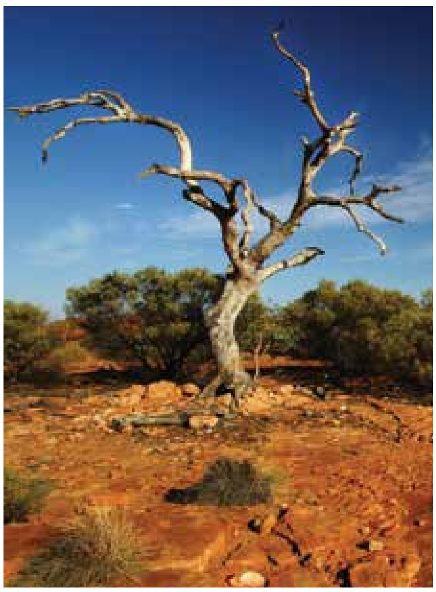
While intensification and integration can create a number of challenges, we may begin to see larger producers, in collaboration with government agencies and those within the industry value chain, make investments in education and training, sustainable processes, coordination, and science and technologies that reduce biosecurity threats. This would allow for more sustainable growth, helping to manage the economic risks to individual operations while also improving the overall productivity of the sector. In this way, consolidation provides opportunities for enhanced biosecurity outcomes.

Expanding into new areas

As we move to a world with fewer, larger farms, we will see the continued expansion of agriculture into new natural habitats. A key driver behind this is the knowledge that intensification alone may not be sufficient to meet long-term food production demands. For example, Ray *et al*. (2013) found that yield improvements for maize, rice, wheat and soybean are occurring at a rate far lower than those required to meet projected 2050 global food demands.(32)

Although expansion creates new opportunities, it can create environmental pressures (see *A Diversity Dilemma?*). It also has the ability to introduce new biosecurity threats (some that we may not fully understand) through new pathways or new hosts for pests and diseases. Biosecurity considerations are therefore important in facilitating sustainable agricultural expansion.

Recently, discussions have been reignited about significant expansion opportunities in northern Australia.(23) In addition to using the northern coastline to expand pond-based marine aquaculture (e.g. prawns),(33) the Northern Australia Land and Water



The north currently carries around 30 PER CENT of Australia's cattle and produces 80 PER CENT of live cattle exports.

Taskforce highlighted that there is potential to double beef cattle production. The north currently carries around 30 per cent of Australia's cattle and produces 80 per cent of live cattle exports.(34)

In addition to infrastructure and investment requirements, a key challenge with the northern expansion will be the access to and use of water resources. While northern Australia has the potential for approximately 17 million hectares of crops and 32 million hectares of forestry,(35) the Taskforce estimated there is only enough groundwater to irrigate approximately 40,000 to 60,000 hectares of intensive agriculture.(34)

The uniqueness of the northern region may require new or different agricultural practices. For example there may be a need for a shift from traditional irrigation to irrigation mosaics which, although beneficial, have largely unknown long-term environmental impacts.(36) It is important to recognise that any activity that modifies an environment can create short and long-term biosecurity challenges. For example, dry seasons can act as a natural control for agricultural pests and diseases by depriving them of essential nutrients. However, irrigation throughout the dry season has the ability to counteract this, helping maintain the northern conditions that favour these pests and diseases. In addition, irrigation has the potential to increase nutrient levels in northern rivers and estuaries creating the conditions for toxic blue-green algae that pose a risk to human and animal health.(35)

We are also seeing the potential for expansion in other parts of the country. In recent times, Tasmania has seen significant growth in its fisheries industry, with the gross value of salmon production in the region growing by around 200 per cent between 2001-02 and 2011-12.(37) Furthermore, an approval in 2012 to expand salmon farming on Tasmania's west coast (from 5.5 km^2 to

9 km^2) is reported to create the largest fish farming site in Australia.(38) This expansion supports expectations that the salmon industry will continue to grow – potentially doubling by 2030.(39)

In the future, foreign investment may play a key role in enabling the sustainable expansion of agriculture in Australia. While foreign investment in agriculture is currently low, with 99 per cent of Australian farm businesses and just under 90 per cent of agricultural land entirely Australian owned, there are signs of growth in foreign investment,(40) particularly given the potential offered by the northern region. The Northern Territory has the highest level of foreign ownership of agricultural land, with 32 per cent of its land reported as having some level of foreign ownership in 2013 (17.7 million hectares),(41) up from 24 per cent (14 million hectares) in 2010.(40)

From a biosecurity perspective, foreign investment has the potential to create new biosecurity challenges, such as if a foreign country wanted to grow a different crop species in Australia. However, there is also the potential for a foreign country to increase biosecurity investment and standards due to the vested interest they have in our industry and in keeping Australia free from pests and diseases. Simply put, foreign investment, like any other change in agriculture, requires close management.

Agricultural expansion in neighbouring countries also needs to be considered when managing biosecurity risks for Australia. For example, Indonesia's agriculture industry is forecast to grow at a rate of around 14 per cent annually between 2013 and 2018.(42) If agricultural expansion and intensification in nearby countries create increased biosecurity risks abroad, it is important to remain vigilant with regards to the potential for these risks to enter Australia, given our close proximity and the trading relationships that exist.

Opportunities for niche areas

In conjunction with a rise in agricultural expansion and intensification, we continue to see new opportunities emerge for niche areas of agricultural production. One such area that is rapidly growing is organic production. The number of organic producers in Australia increased by almost 50 per cent between 1990 and 2011-12, from 1,260 to 1,865.(43) While organic produce currently represents around 1 per cent of farmgate income for Australian farmers,(44) the revenue it delivers for agriculture is expected to grow from $655 million in 2014 to $981 million in 2019.(45) This growth will be "driven by continuing consumer demand for food that is healthy, safe, chemical-free and grown in a manner that is kinder to the environment and animals."(44) The total retail value of the Australian organic market (including both fresh and processed products) reached $1.15 billion in 2012, up from $947 million in 2010.(46)

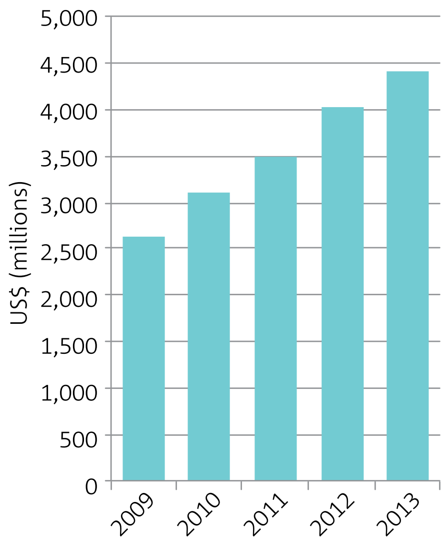
The organic farming trend raises interesting challenges and questions for biosecurity management. For example, pest management is a major challenge for Australia's organic grain industry, worth more than $17 million in 2012, as an incursion of a pest could adversely affect production and/or interrupt organic certification if the only option for effective control involves chemical management.(47) Beneficial insects often prove to be insufficient and the pesticides able to be used in organic production are expensive.(48)

Significant consideration of these challenges will be required as the organic market continues to move from a niche area to more of a mainstream position. This is highly likely given the growth that is expected and, in particular, the export opportunities that exist. For example, the Chinese organic food market grew at a compound annual growth rate (CAGR) of 17 per cent between 2009 and 2013.(49)

Free range poultry is an example of an industry that has expanded significantly to move from being a niche area of production to being responsible for

FIGURE 4: THE ASIA-PACIFIC ORGANIC FOOD MARKET

Source: Marketline, 2014(49)



one-quarter of all eggs produced in Australia.[50] In the future we may even see the growth of new niche markets, perhaps from within the range of smaller animal farming industries (e.g. goats, deer, emus) that currently operate in Australia. Alternatively, we may see completely new industries evolve. For example, a Tasmanian sea urchin processing plant has recently started exporting to China, turning an Australian marine pest into a new market opportunity.[51]

Another potential future growth market is insect farming. Since 2003, the FAO has been investigating the use of insects as a valuable source of protein for animal feed and human consumption – a practice that already exists in Southern and Central Africa and Southeast Asia.[52] Insect farming for human consumption has also begun in the United States with the first farm opening in Boston.[53]

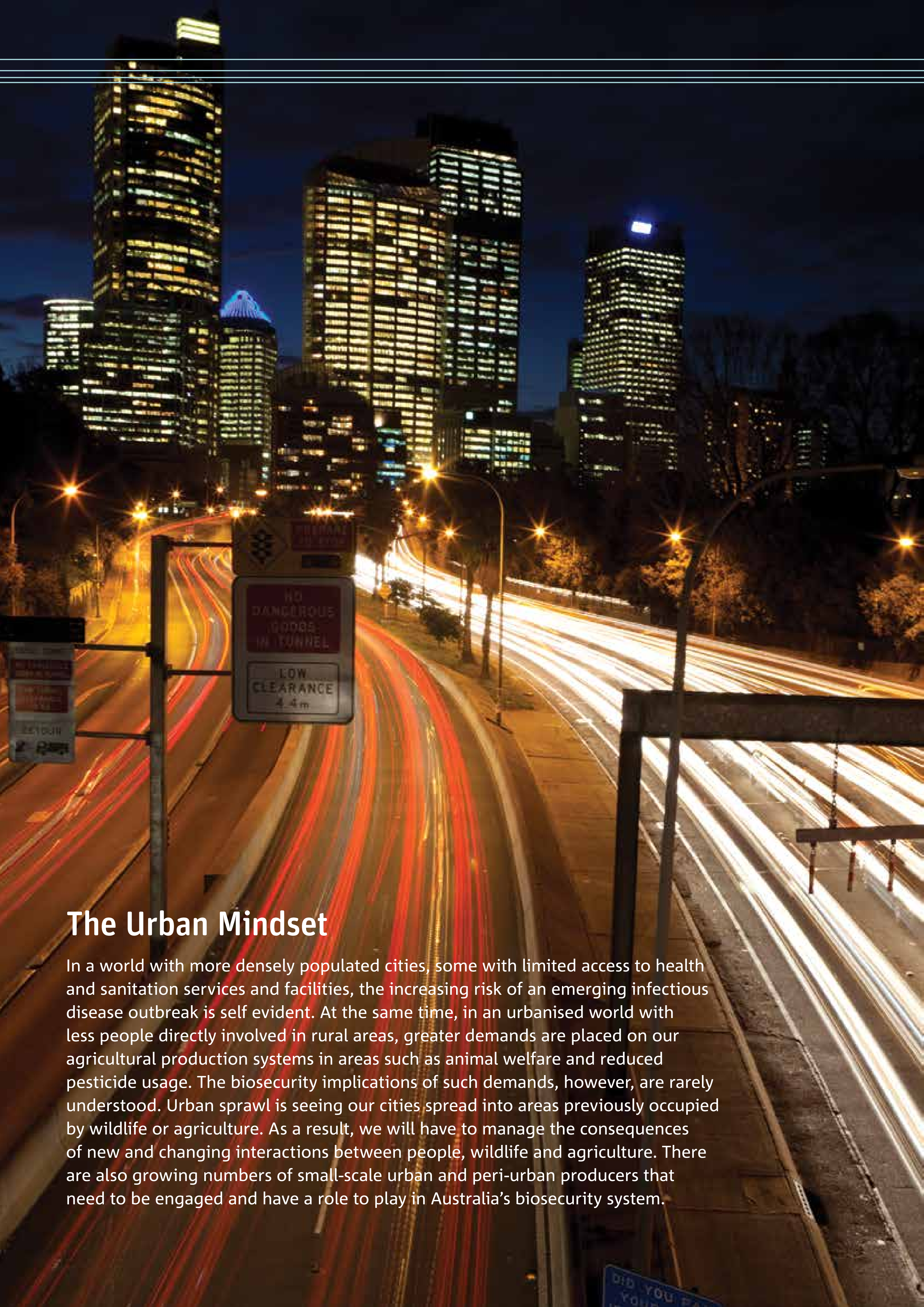
Outside of the growth in niche food production markets are opportunities for agricultural growth in the sustainable production and use of biomass for a range of purposes – otherwise known as the bioeconomy. This could lead to crops and plant waste being used as sources of fuel[54] or crops that can produce oils for the manufacturing of plastics and other products.[55]

It is important to stay abreast of shifts in market trends and consumer expectations (see *The Urban Mindset*) to ensure that our biosecurity practices and processes keep up with the changing farming practices of future growth or niche markets.

A Tasmanian SEA URCHIN processing plant has recently started exporting to China, turning an Australian marine pest into a new market opportunity.

Key Implications:

- Our 'pest and disease free' status will increase in importance in a more competitive global market for primary produce, particularly in relation to maintaining market access
- Future focus will be on productivity improvements – the way we approach such improvements could either increase or decrease the strength of our biosecurity system
- Agricultural intensification and vertical integration can create single point sensitivities in the biosecurity system
- Vertical integration requires an end-to-end consideration of biosecurity along the entire value chain – from farmers through to the retailers
- Land-use change associated with agricultural expansion can impact on the resilience of our ecosystems
- Agricultural expansion (e.g. in Northern Australia) will generate new biosecurity risks that need to be proactively addressed to ensure future business viability. This can help us to 'get it right' from the beginning and to take a more proactive and preventative approach
- Foreign investment has the potential to either increase (through the introduction of new crops or animals) or decrease (through a vested interest in strengthening the health of Australia's production system) the level of biosecurity risk for Australia
- As organic production continues to grow, with declining use of synthetic pesticides, chemical fertilisers and antibiotics, we may need to consider an entirely new approach to managing pests and diseases
- New approaches may also be required if significant growth occurs in other niche markets (e.g. insect farming, bioproducts)



The Urban Mindset

In a world with more densely populated cities, some with limited access to health and sanitation services and facilities, the increasing risk of an emerging infectious disease outbreak is self evident. At the same time, in an urbanised world with less people directly involved in rural areas, greater demands are placed on our agricultural production systems in areas such as animal welfare and reduced pesticide usage. The biosecurity implications of such demands, however, are rarely understood. Urban sprawl is seeing our cities spread into areas previously occupied by wildlife or agriculture. As a result, we will have to manage the consequences of new and changing interactions between people, wildlife and agriculture. There are also growing numbers of small-scale urban and peri-urban producers that need to be engaged and have a role to play in Australia's biosecurity system.

The great migration

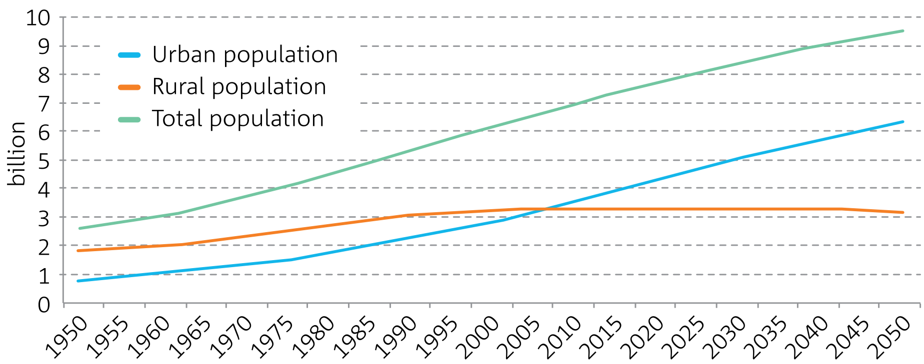
As we continue on a trajectory to a world with more than nine billion people by the middle of this century, we are seeing urban populations grow at the expense of rural regions. In 1950 just 30 per cent of the world's population lived in urban areas. By 2010 this had grown to 52 per cent and it is expected that 66 per cent of the world's population will be urban dwellers in 2050.[56]

Most of the growth in urban populations in recent decades has been, and will continue to be, driven by developing regions, particularly in Africa and Asia.[56] It is estimated that each year, around 44 million people in Asia migrate from rural areas to Asia's cities.[57]

Urban areas have a high risk of disease transmission due to the heterogeneity in health of urban dwellers, increased rates of contact, and mobility of people. As a result, cities can become "incubators", meeting all of the conditions required for a serious disease outbreak to occur.[58] This is of particular concern in emerging economies with densely populated cities that lack universal access to health and sanitation facilities and services. For example, in India just 60 per cent of the urban population has access to improved sanitation facilities. This figure is slightly higher for China and Brazil, at 74 per cent and 87 per cent, respectively, but is still significantly lower than in developed economies such as Australia, the US and the UK where 100 per cent of the population has access to improved sanitation facilities.[59]

FIGURE 5: GLOBAL POPULATION LIVING IN URBAN AND RURAL AREAS

Source: United Nations, 2014[56]



Growing expectations

In the developed world, such as Australia, the migration from rural to urban areas is mostly complete. Australia is well and truly a country of urban dwellers and we are seeing a new set of biosecurity challenges emerge as a result.

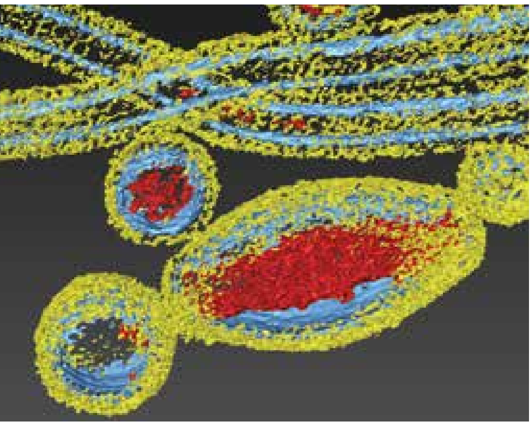
At around 90 per cent urbanisation (up from 77 per cent in 1950),[60] very few Australians are connected to or have an in-depth understanding of our agricultural production systems. This was demonstrated in a 2011 survey conducted by the Australian Council for Educational Research, which found that 75 per cent of year six students and 42 per cent of year ten students thought that cotton socks came from animals, while more than one-quarter of year six students identified yoghurt as a plant product.[61] Coupled with a general growth in consumer expectations across the board, this lack of connection is leading to urban residents placing increasing demands on rural Australia, sometimes without full consideration of the biosecurity and food safety implications.

With rising animal welfare concerns, the demand for free-range poultry products continues to grow. Retail sales of free-range eggs have more than doubled since 2000, and they now account for one-quarter of all eggs produced in Australia.[50] A CHOICE consumer survey of 900 Australians found that 60 per cent of people say that it's "essential" the eggs they buy are free-range, while a further 25 per cent say it's "important".[62] This trend is also being fuelled by the retailers as Coles and Woolworths look to animal welfare as a means of building greater brand equity and consumer loyalty. In October 2012 Coles made the decision to remove all company-branded caged eggs from its shelves and Woolworths is in the process of phasing out caged eggs altogether over a five-year period.[63]

While this trend may continue to have positive implications relating to animal welfare, free-range production systems can pose an increased biosecurity risk as the animals have greater exposure to wild birds that carry disease. Koch and Elbers (2006) highlighted that of the 24 outbreaks of highly pathogenic

Retail sales of **FREE-RANGE EGGS** have more than doubled since 2000, and they now account for one-quarter of all eggs produced in Australia.

In Australia, **ORGANIC PRODUCTS** represent around 1.5 per cent of the packaged food market, up from 0.7 per cent in 2002.



Artificially coloured microscopic image of Influenza A virus.

avian influenza (HPAI)* reported globally between 1959 and 2004, it was shown in 19 of these cases that the virus was introduced from wild fowl and then mutated into an HPAI variant. Wild birds, such as ducks and waterfowl, are natural reservoirs for the virus and infection occurs without causing any symptoms. In contrast, poultry and humans are spillover hosts, where infection with HPAI can cause severe disease and high mortality. HPAI continues to pose a significant threat and outbreaks in poultry have occurred even on farms managed at high biosecurity levels, such as in Chile in 2002.(64)

Five outbreaks of HPAI occurred in Australia between 1976 and 1997, all of which had evidence of contact with wild waterfowl or surface water contaminated by wild waterfowl, or an association with free-range farmed ducks. More recently, in November 2012, HPAI H7N7 virus was detected in a New South Wales free-range chicken flock on a property with a range of dams that attracted wild ducks. Furthermore, in 2013, HPAI H7N2 virus was detected in a free-range and cage bird flock at another property in NSW. These recent outbreaks led to the destruction of 50,000 and 400,000 birds, respectively,(65) with significant impacts on egg production.

Generally speaking, avian influenza in birds does not easily cause disease in people and not all strains are highly pathogenic.(66) However, it is still a significant concern because of the potential for new, more virulent human pandemic strains to emerge either from adaptive mutation (change in the genes of a virus) or reassortment (mixing of the genes of an animal virus with a human influenza virus).(67) A 2003 outbreak of H7N7 in the Netherlands led to the death of a veterinarian(64) but thankfully no outbreaks of HPAI in Australia have led to human infection.(68) We also remain free from the highly pathogenic H5N1 virus, which has caused almost 400 deaths globally since 2003,(69) and the more recently emerged H7N9 virus that has led to 165 deaths in China and Hong Kong since February 2013.(70)

Another growing consumer expectation relates to the use of synthetic chemicals (e.g. pesticides and artificial fertilisers) in agricultural production. The global organic food market grew at a CAGR of 8 per cent between 2009 and 2013.(71) In Australia, organic products represent around 1.5 per cent of the packaged food market, up from 0.7 per cent in 2002.(72)

Without the ability to rely on synthetic pesticides, pest management is an ongoing concern for organic farmers. If organic production is to continue to grow in line with growing consumer demand, greater investment will be needed in developing pest management solutions to not only help growth in organic production but also to minimise the risk of pests to Australian agriculture in general (see *An Appetite for Change* for more on organic production).

We are also seeing changing consumer expectations regarding where their food is sourced, with a growing demand for local produce and a rise in the popularity of urban farms and community gardens. This is often wrapped up in the idea of the 'local food movement' as 'locavores' seek out healthy, more sustainable produce that has a positive impact on their community.(73) Many buildings in Sydney and Melbourne have expansive rooftop gardens,(74) and kitchen gardens are now common-place in primary schools across the country. The Department of Agriculture has also identified that a review of suburban press media indicates a return to the trend of keeping backyard poultry.(75)

While urban and community gardens can have significant benefits, they may also exacerbate biosecurity challenges by creating additional pathways for pest or disease establishment outside the regulatory oversight of mainstream farming. Similarly, with more people keeping backyard chickens there is the potential for increased risk relating to salmonella and even avian influenza. At the same time, however, increased interest among the general public in the process of food production presents an opportunity to create more widespread understanding of and connection to biosecurity issues.

*HPAI is a category of avian influenza viruses that can cause severe clinical signs and/or high mortality in birds.

Urban encroachment

The Bureau of Rural Sciences define the peri-urban landscape as "the transitional zone between rural and urban Australia".[76] The concept of peri-urban or 'fringe' regions, however, is not unique to Australia and around the world these areas are undergoing rapid land use change as a result of urban expansion.[77]

As our cities continue to expand and encroach upon new areas of land, we are seeing changing interactions between people, wildlife, agriculture and disease vectors. For example, in Northeast USA, reforestation of peri-urban areas, coupled with growing urban sprawl, increased the proximity of humans and deer. These residential communities then became exposed to Lyme disease, which is transmitted by ticks.[78] It is currently estimated that there are around 200,000 wild deer across Australia[79] and the Invasive Species Council regards them as "probably Australia's worst emerging pest problem".[80] However, the bacterial species that could cause a Lyme Disease-like syndrome in Australia is yet to be formally identified.[81]

The feral pigs spread across the country, with numbers estimated at up to 24 million,[82] including in peri-urban areas, can act as reservoirs for several zoonotic diseases. While direct contact with the animals (e.g. through hunting) is typically required to become infected,[83] wild pigs could transmit diseases to piggeries in peri-urban regions, particularly in free-range operations.[84] This could then potentially lead to a viral outbreak in surrounding neighbourhoods if the farmers or visitors to the farm contract a virus that, similar to the H1N1 strain responsible for the 2009 swine flu pandemic, can spread from person to person. Hendra virus is also a concern for areas of peri-urban Australia where both flying foxes and horses are found in close proximity, as the virus can spill over from flying-foxes to horses to humans.[85]

It is currently estimated that there are around 200,000 WILD DEER across Australia.

Another challenge often faced in peri-urban areas is the increased restrictions on farmers' abilities to use pesticides to manage pests and diseases. The proximity of peri-urban farmers to a large, wealthy consumer base can provide benefits but at the same time can also lead to negative effects as they face greater restrictions relating to noise, odour, stock movements and agricultural sprays than their rural counterparts.[86] If the chemical tools available to peri-urban farmers are restricted or removed as urban areas encroach upon agricultural land, alternative solutions will need to be found in order to manage biosecurity risks in peri-urban areas.

Another effect of ongoing urban sprawl is its potential to accelerate biodiversity loss. The advancement of urbanisation has coincided with environmental degradation, greater consumption of natural resources, habitat loss and ecosystem change. Continued expansion of a city can lead to fragmentation of the remaining blocks of natural habitat which, in turn, increases the isolation of certain species, reducing population and gene flow, and restricting seasonal and intergenerational migration. It can also facilitate the introduction and establishment of invasive species[87] (see *A Diversity Dilemma?* for more on biodiversity loss).

The peri-urban producer

The 1970s and 1980s were characterised by 'sea changes', as people gave up city life to relocate to coastal areas, but more recently we have seen 'tree changes' rise in popularity and transform traditional farming regions, as people occupy small parcels of land in rural and bush areas.(76) Peri-urban producers can range from part-time hobby farmers through to larger scale commercial producers.

Peri-urban lands are among the country's most productive, generally incorporating the market gardens that supply city populations. For example, the Melbourne region represented just 2 per cent of the total area of agricultural holdings in Victoria in 2010-11 but was responsible for 13.4 per cent of Victoria's total value of agricultural commodities produced (VACP).(86) However, the smaller hobby or 'lifestyle' farmers in these regions are often disconnected from traditional agricultural networks. They often have lower levels of knowledge and understanding relating to biosecurity risks and may be less likely to maintain good biosecurity standards.(76)

Interviews with 106 pig producers in Australia found that small-scale pig producers (<150 sows) generally incorporated less on-farm biosecurity practices, such as footwear precautions, provision of overalls to visitors and shower facilities, when compared to large-scale producers. Small-scale producers were also less likely to ask visitors about prior pig contacts before allowing them entry to their piggery.(88) With regards to herd health practices, a study found that only 54.6 per cent of small-scale producers kept some form of herd health records, compared to 100 per cent of large-scale producers.(89) If peri-urban producers do not adopt the same biosecurity standards as their rural counterparts they have the potential to act as a weak link within the biosecurity system, increasing our vulnerability and reducing our ability to respond to pest and disease threats.

One reason for concern regarding peri-urban producers is their relative proximity to major ports of entry for pests and diseases. There is a possibility that these regions could help to facilitate the establishment of certain pests and diseases that would otherwise not establish due to the large distance between ports and major rural areas.

Effectively engaging with small-scale producers can be a daunting challenge as they are diverse and highly mobile. Some small-land holders in peri-urban Australia may keep farm animals simply as 'pets', others may be involved in agricultural production to remain self-sufficient (e.g. growing vegetables and keeping chooks for eggs), while others will derive some income from this production. The values and motivations across small-scale producers will therefore differ significantly and many of these land holders also come from culturally and linguistically diverse backgrounds.(76) A strategic and coordinated approach will be required to see more widespread adoption of biosecurity standards across peri-urban producers, in order to ensure they pose no greater risk than any other stakeholders in Australia's agricultural production system.

Key Implications:

- Densely populated urban areas, particularly in developing countries, can act as pathogen incubators, increasing the risk of infectious disease outbreaks
- Australians are increasingly disconnected from primary production, leading to a lack of understanding of biosecurity issues and how they affect everyone on a day-to-day basis
- Our biosecurity capabilities haven't grown in line with the rapid increase in demand for free-range, organic and locally-sourced produce, which has been driven by changing consumer priorities
- The ongoing expansion of our cities is creating changing interactions between people, wildlife, agriculture and disease vectors, increasing risks such as zoonotic disease
- There is a need to better engage peri-urban/amateur producers as part of the biosecurity community, to improve their understanding of biosecurity risks and their adoption of biosecurity practices

On the Move

The relative isolation that once helped to limit biosecurity threats for Australia no longer exists. While the increased movement of people, goods and vessels around the world allows for a more interconnected world, this movement also increases the probability of biosecurity threats hitting our shores. A widespread view within Australia's biosecurity system is that in today's world it's not a case of 'if' a new threat will get here, it's a case of 'when' it will arrive. Greater interstate freight can also allow pests and diseases to spread across the country. Finally, if the trend towards globalisation continues, the threat of bioterrorism will be impossible to ignore.

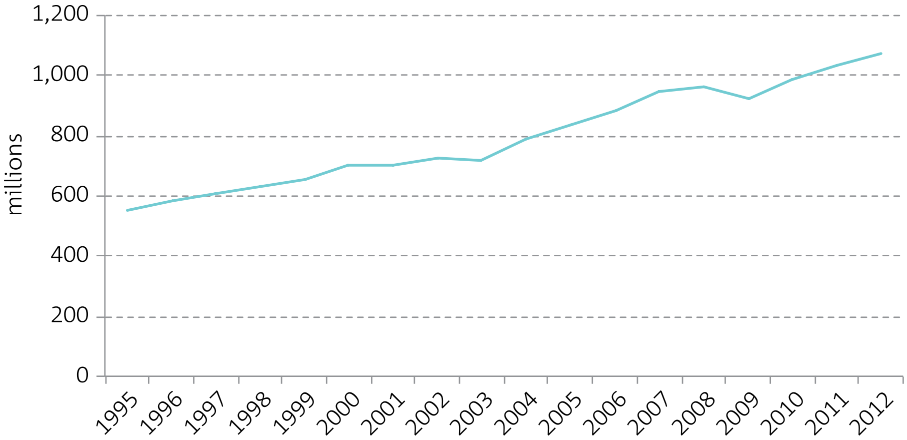
The travel bug

Globally, the number of arrivals of inbound tourists (i.e. trips abroad) has increased from just under 550 million arrivals in 1995 to more than one billion in 2012.[90]

In the year ended June 2014, there were a record 32.6 million crossings of Australia's international borders. There has been a significant increase in international movements in the last decade, with just 18.6 million border crossings ten years ago.[91] Inbound arrivals for Australia are expected to grow at an average rate of 4 per cent per year to 2022-23.[92] International passenger movements through Australia's capital city airports will almost triple between 2012 and 2030.[93]

FIGURE 6: GLOBAL NUMBER OF INTERNATIONAL TOURISM ARRIVALS

Source: The World Bank Group[90]



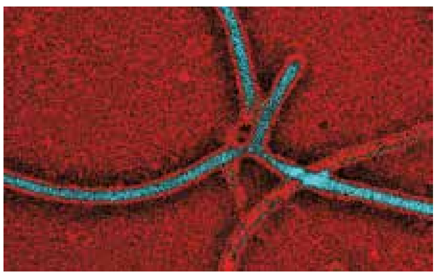
Increased movement of people inevitably increases the opportunities for infectious diseases to spread and enter Australia. Budd, Bell and Brown (2009) write that "in an era of unprecedented global aeromobility when hundreds, if not thousands, of human pathogens are circulating the world's airways, the global airline network plays an important role in the worldwide spread of infectious diseases." This was evident in 2003 when the SARS virus spread from East Asia to more than 25 countries in line with the global airline network,[94] and in the 2009 outbreak of H1N1 influenza which, after initially being reported in Mexico, quickly spread around the world and was associated with 191 deaths in Australia that year.[95]

The more recently identified Middle East respiratory syndrome (MERS), which was first identified in Saudi Arabia in 2012 and has caused at least 291 deaths,[96] has spread via travellers with cases reported in 17 countries across the Middle East, Europe, Asia, Africa and North America. While these travel-related cases of MERS generally do not appear to have infected others in their countries, cases exported to France and the UK in 2013 led to limited human-to-human transmission.[97] Furthermore, in response to the outbreak of the Ebola virus disease in West Africa in 2014, which has become a humanitarian crisis, Australian airport border agencies started monitoring the health of people arriving in Australia who originated their travel from affected areas.[98]

Travel also has the potential to spread bacterial infections that are immune to antibiotics, adding to the growing problem of antimicrobial resistance. For example, a study by Australian researchers found that people with an antibiotic resistant *E. coli* urinary tract infection were up to six times more likely to have recently travelled to India than those with a typical *E. coli* urinary tract infection. The prevalence of antibiotic resistant *E. coli* has increased in Asia and South America due to unregulated antibiotic use by livestock farmers.[99]

Travellers also have the potential to bring pests or diseases into Australia (intentionally or unintentionally) that could impact on our environment or primary industries. For example, between 1999 and 2010 at least 355 birds were intercepted as illegal imports at the Australian border, mostly parrots and poultry smuggled as eggs concealed on passengers.[100]

Perhaps a less obvious example relates to the wine tourism industry, which continues to increase in Australia and around the world, creating opportunities for movement of pests and diseases that affect viticulture. An exploratory assessment of biosecurity risks associated with wine tourism conducted in New Zealand found that many wine tourists did not recognise vineyards or wineries in the current descriptors used on the customs declaration forms for Australia and New Zealand. In fact, more than 60 per cent of respondents did not consider a vineyard as a 'farm'.[101] This could mean that the recent activities of tourists entering or re-entering Australia may not be accurately reflected in their customs declaration forms and highlights the need for quarantine systems and processes to continue to adapt to increased international travel and tourism trends.



Artificially coloured microscopic image of the *Zaire ebolavirus*.

Trade in a globalised world

Apart from a slight dip during the 2008 financial crisis, global trade has experienced ongoing growth since the 1970s. When looking at the indexed growth in total merchandise exports, it is clear that most of the growth has occurred in the last two decades. Global exports increased almost five-fold between 1993 and 2013, while Australia's exports have grown almost six-fold, from US$42.7 billion in 1993 to US$252.7 billion in 2013.(102)

The total volume of cargo passing through Australian ports (including imports and exports) doubled between 2000 and 2013, driven largely by increasing exports.(103) HSBC predicts that Australian trade will increase by 129 per cent between 2011 and 2025, a rate nearly double the pace of expected world growth in trade (73 per cent) and significantly higher than the growth in trade expected in Asia (96 per cent) over the same period.(104) The expanding network of free trade agreements (FTAs) is another indicator of an ongoing trend towards increasing global trade. Australia currently has seven FTAs in force and, apart from the trade agreement established with New Zealand in 1983, these agreements have all been established since 2003. Australia has also recently concluded negotiations with Korea and Japan, and is engaged in seven other FTA negotiations. The countries represented by the current FTAs in force and under negotiation account for almost three-quarters of Australia's total trade.(105)

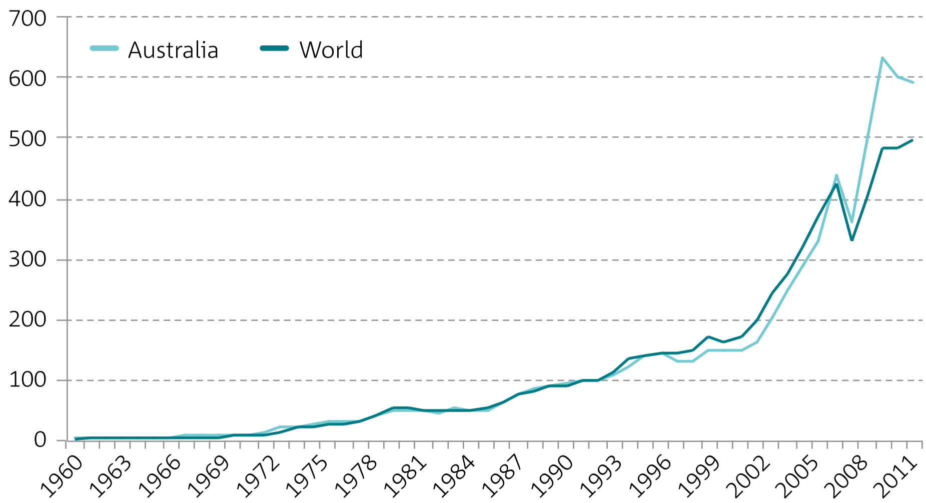
We are also seeing growth in the trade of animal and plant material, which is likely to continue as international trade can help to address food security issues and imbalances in food production and consumption around the world. Total global meat exports (both volume and value) grew at a CAGR of around 6 per cent between 1990 and 2010. The value of total global exports of fruit and vegetables grew at a CAGR of 6.5 per cent over the same period and the total value for exports of agricultural products grew at a rate of 6.2 per cent.(106) This growth is much higher than general global population growth, which increased at a CAGR of just 1.3 per cent between 1990 and 2010.(60) In line with increasing globalisation, Australia has also increased its agricultural imports. While

still a net exporter of food products, the amount of meat imported into the country (both volume and value) increased at a CAGR of around 19 per cent between 1990 and 2010. With regards to plant products, the amount of imported cereals grew from just US$15.2 million in 1990 to US$187.8 million in 2010, and fruit and vegetable imports grew from US$313 million to more than US$1.4 billion over the same period.(107) Over the last 25 years imports of agricultural and food products have grown at nearly twice the rate of Australia's exports.(11)

This increased movement of plant and animal products, as well as other goods, in a globalised world can help to facilitate the spread of invasive species(108) and can affect the magnitude and diversity of biological invasions.(109) International trade can therefore act as a pathway for pests and diseases that could be detrimental to Australia's primary industries or environment. For example, fire ants were unknowingly imported into Brisbane sometime in the last two decades. While the exact pathway of entry is unknown, it is thought that it was possibly a shipping container from the United States.(110) Fire ants can alter an entire ecosystem by reducing plant populations and competing with native species for food.(111) They are also a social menace because of their painful sting.(112)

FIGURE 7: INDEXED GROWTH IN TOTAL MERCHANDISE EXPORTS (VALUE), 1993 = 100

Source: World Trade Organisation (WTO)(102)



Increased ship movements can also heighten the risk of a marine pest incursion as shipping has been shown to be responsible for the majority of marine bioinvasions.[113] Pests can find their way into new waters through biofouling (attaching to boat hulls, anchor chains or other equipment) or by travelling in a boat's seawater system, including inside pipes and in bilge and ballast water. There are 1,582 marine and estuarine species that have been transported by human-mediated activities or have human-mediated invasion histories around the world, of which 494 species are known to be established in Australian waters.[114] While some have proved to be relatively harmless, others have had significant impacts on marine ecosystems and industries. The northern Pacific seastar, for example, preys on native species with impacts on aquaculture and fisheries operations.[115]

By 2030 the volume of container movements through Australian ports will be around 2.5 times what it was in 2007.[93] A significant amount of work has already been done to facilitate effective management of marine biosecurity risks. For example, in 2001 Australia introduced mandatory ballast water management requirements, consistent with the International Maritime Organization's (IMO) Ballast Water Management Convention adopted in 2004.[116] Marine biosecurity efforts will need to continue and intensify, as Australia's ports become more exposed to risk in an increasingly globalised world.

The IMO's Ballast Water Management Convention is one example of how biosecurity standards that span multiple countries are likely to become more commonplace. The Convention was adopted in 2004 to help prevent the spread of harmful aquatic organisms from one region to another and entered into force after ratification by 30 States, representing 35 per cent of world merchant shipping tonnage.[117] In a world with growing global trade there will be a need for more and/or stronger regional and global standards relating to biosecurity. We will also see a need for greater international collaboration in biosecurity research in order to improve the effectiveness and efficiency of the development of knowledge, management policies and practices relating to biosecurity threats.

As trade increases there may be greater investment in traceability solutions and systems to differentiate Australian products in the international marketplace. One example can be seen via the National Livestock Identification System (NLIS), which traces livestock from property of birth to slaughter, allowing Australia's red meat industry to ensure meat quality and safety.[118] Traceability may also help with the verification of an Australian product, such as merino sheep that also exist in Middle Eastern countries and are superficially indistinguishable from Australian born and exported sheep.[119]

From a biosecurity perspective, traceability solutions like the NLIS play an invaluable role in emergency disease response, allowing an outbreak to be traced, contained and eradicated faster, minimising costs and protecting market access.[120] In addition to traceability, there are other opportunities to improve our biosecurity through technology, as new or improved infrastructure is required to keep up with growing trade volumes. For example, there is an opportunity to develop cargo infrastructure that integrates biosecurity technologies, such as through the incorporation of sensors and sensor networks.

There will also remain a need for offshore biosecurity investment as part of the 'pre-border' stage of the biosecurity continuum. Pre-departure inspections and treatment, as well as risk profiling, can help to reduce the risks posed by potential vectors of pests and the diseases they carry.[121] In a more globalised world with continued growth in international trade, we may require increased investment in pre-border biosecurity management as a means of preventing risks from reaching our shores. This will require the establishment and maintenance of strong relationships with our international trading partners and a continued shift towards a more global view of biosecurity. In this way, Australia's biosecurity community can be considered to extend beyond our national borders.

There is an opportunity to develop cargo infrastructure that integrates BIOSECURITY TECHNOLOGIES, such as through the incorporation of sensors and sensor networks.

When talking about trade and biosecurity it is important to recognise that Australia's biosecurity system is viewed by some trading partners as protectionist, as highlighted in the *Beale Review*. These perceptions could potentially threaten market access for Australian exports as frustrated trading partners may use biosecurity barriers against Australia in retaliation.[3] In a more globalised world with a growing number of free trade agreements, Australia may continue to face pressure regarding trade policy.

At the same time, our general pest and disease free status is important in ensuring market access for many of our exports. In this way, biosecurity plays a role in facilitating trade and creating a competitive advantage in export markets. Australia currently has an advantage in a number of markets due to our favourable biosecurity status. One example is in the international beef market due to the absence of foot and mouth disease in Australia – an advantage that would cease to exist if this disease became a feature of all beef producing nations.

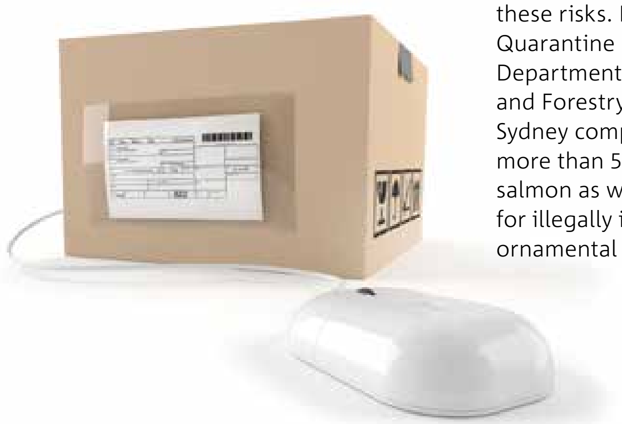
An outbreak of an exotic pest or disease in Australia can close down export markets overnight or enhance the competitiveness of other countries. In the future, importing countries may also increase their level of scrutiny regarding Australia's ability to prove its pest and disease free status. Therefore, biosecurity efforts can be just as important in protecting and enabling our export markets as they are in protecting the health of our animals, people and environment. New tools and technology, such as improved risk modelling and cargo scanning, will be crucial in ensuring that Australia is able to capitalise on the economic and social benefits that can be gained through increased trade, while at the same time minimising the potential biosecurity risks involved.

It is worth mentioning that although the common assumption is that globalisation and trade will both continue to increase, there is the possibility of a future scenario in which countries around the world prioritise self-reliance for natural resources and self-sufficiency. A wildcard event such as a world war, a severe global recession or a major food security shock could see the world's major exporters of food, energy and other products focus on serving their own needs, with less emphasis on export markets. While the likelihood of this scenario may be considered very low, it would completely reshape the way we think about biosecurity. There are also a small number of countries that are already focusing on improving their ability to be self-sufficient (e.g. Indonesia[122] and Thailand[123]), indicating that this potential future scenario warrants consideration.

Postal pressure

While travel and trade can help facilitate the inadvertent introduction of pests and diseases, online retailing is creating greater opportunities for these threats to reach Australia through illegal fauna and flora trade. The value of internet retailing in Australia grew at a CAGR of 18.2 per cent between 2000 and 2013 compared to just 1.6 per cent for store-based retailing.[72] Online shopping accounts for 70 per cent of prepaid packages sent through Australia Post[124] and there has been a steady increase in inbound international parcels in recent years.[125-127] With more parcels coming into Australia and moving around the country, there is increased risk of the movement of plant, animal and other infected materials and our postal biosecurity measures will need to continue to strengthen in response to this.

The internet is commonly used by illegal flora and fauna traders to advertise and sell goods. Over a six week period in 2008, the International Fund for Animal Welfare found more than 7,000 sale listings for live animals and animal products from endangered species on 126 websites. More than 90 per cent of these listings were suspected of being in violation of the Convention on International Trade of Endangered Wild Fauna and Flora (CITES).[128]



More than 17,000 illegal wildlife imports and exports were seized in Australia between 1999 and 2007.[129] At least 155 snakes were detected in smuggling incidents between 1999 and 2010 and nearly all of these were found in international mail items.[100] As of September 2007, more than 2,500 parcels had been seized by Australia Post containing weight-loss products derived from a plant listed on CITES that had been sold over the internet.[130]

Illegally imported flora and fauna can pose significant biosecurity risks. For example, exotic fish that are illegally imported and then discarded carry a significant risk of introducing exotic fish diseases and parasites into Australian waterways. Between 1999 and 2010 more than 7,000 fish were detected as illegal imports from 16 incidents, mostly found in air cargo and aquarium imports.[100]

As the importance of quarantine for international mail and cargo continues to increase, we will need to develop more efficient methods for screening incoming goods and intercepting potential biosecurity risks. Regulation will also continue to play an important role in managing these risks. In 2011, for example, Quarantine Officers from the former Department of Agriculture, Fisheries and Forestry successfully prosecuted a Sydney company for illegally importing more than 50 kilograms of Scottish salmon as well as a Sydney woman for illegally importing prohibited ornamental fish into Australia.[131]

Globalisation and bioterrorism

In a globalised world it appears impossible to avoid conflict of religious and political views. Unfortunately this conflict has the potential to incite terrorism, including bioterrorism, which is defined by Robertson (2000) as “the deliberate use of biological weapons by a terrorist group.” Biological weapons are not a new threat. From Spanish soldiers giving French forces wine mixed with the blood of leprosy patients in 1495, through to the anthrax attacks in the United States in 2001, the potential for infectious agents to be used as bioweapons has been recognised for centuries.[132] However, the biomedical community, governments and the United Nations have all placed greater emphasis on the threat posed by bioterrorism since the turn of the century.[133]

In a paper for the UK’s standing commission on national security, Tom Daschle, a co-chairman of Obama’s presidential campaign and former US senate majority leader said, “the threat of bioterrorism will increase exponentially because biological agents used to carry out such attacks will continue to become more accessible and more technologically advanced, just as our social networks become more interconnected as a result of globalisation.”[134]

Australia has been tightening regulation in this space, in line with growing global concerns regarding bioterrorism. The Security Sensitive Biological Agents (SSBA) Regulatory Scheme aims to “limit the opportunities for acts of bioterrorism or biocrime to occur using harmful biological agents and to provide a legislative framework for

Online shopping accounts for 70 PER CENT of prepaid packages sent through Australia Post.

Managing our internal borders

managing the security of SSBAs."[135] In order to strengthen Australia's export controls, the Defence Trade Controls Act 2012 includes provisions aimed at "stopping goods and technologies that can be used in conventional, chemical, biological, nuclear and weapons of mass destruction programs from getting into the wrong hands."[136]

The potential threat of agroterrorism (attacks against food and agriculture infrastructure), most likely motivated by economic gain, also needs to be considered. Parker (2013) argues that targets could run the full farm-to-fork spectrum, from field crops, farm animals and animal feed, through to food items in processing and distribution, and even market-ready foods.[30]

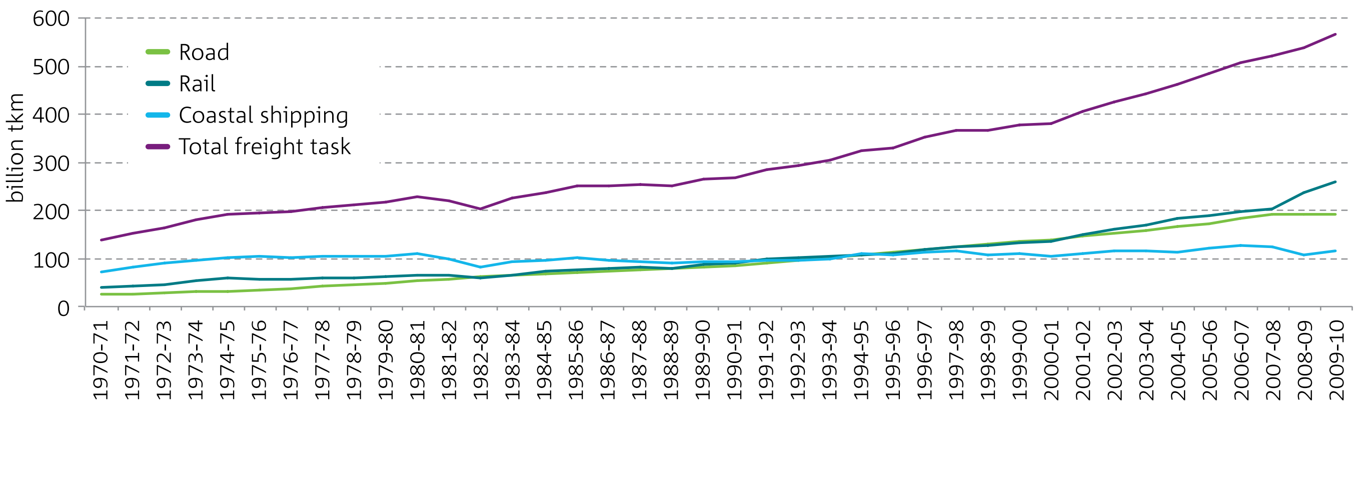
As well as increased global movement creating new pathways for pests and diseases to enter the country, increased domestic movement also has the potential to increase our level of biosecurity risk as it can facilitate the spread of both exotic and endemic pests and diseases.

Between 1970-71 and 2009-10, total domestic freight (billion tonne-kilometres* of bulk and non-bulk freight) quadrupled and interstate road freight increased by 656 per cent over the same period.[137] The total interstate freight task is expected to grow at an average annual rate of 3.6 per cent between 2008 and 2030.[138]

While monitoring our international borders will likely remain a priority, it is important to consider how we effectively manage interstate border crossings. For example, the European wasp surveillance program run by the Department of Agriculture and Food, Western Australia, has allowed the state to remain as the only place in the world to have successfully prevented the establishment of European wasps,[139] even though wasp queens are continually brought into the state in road and rail transport freight.[140] The importance of interstate surveillance will grow, not only to prevent the spread of pests already established but also to limit the impact of exotic pests and diseases that will continue to enter the country through increasing international travel, trade, vessel movements and even parcel post.

FIGURE 8: TOTAL, BULK AND NON-BULK DOMESTIC FREIGHT, BY TRANSPORT MODE, AUSTRALIA (1970-71 – 2009-10)

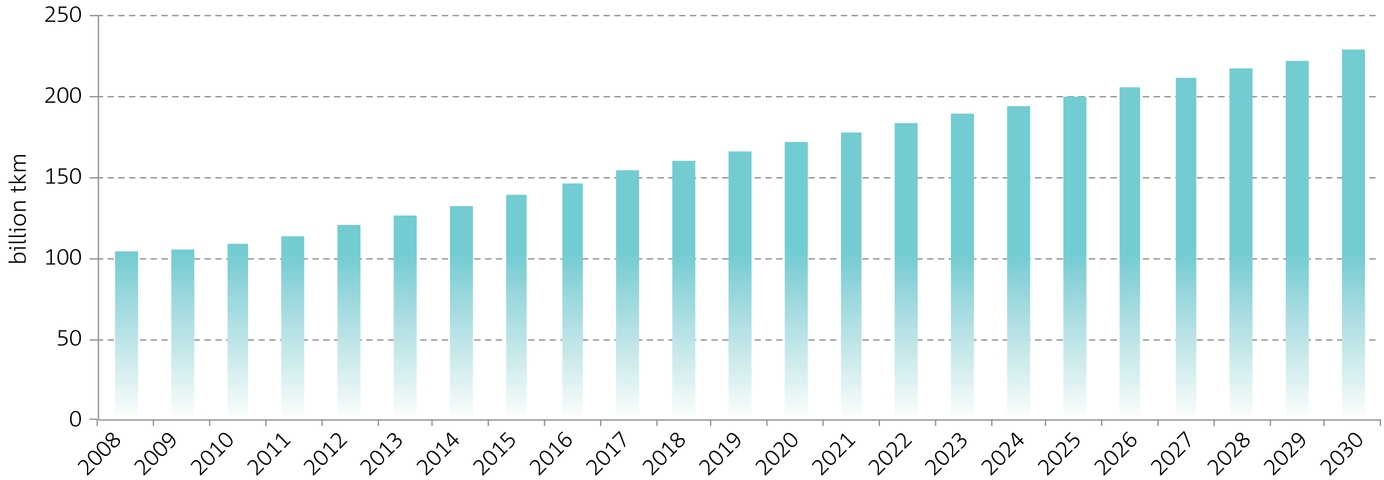
Source: Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2013[137]



* Total tonne-kilometres represents the number of tonnes moved multiplied by the distance travelled in kilometres – e.g. 25 tonnes of freight moved a distance of 100 kilometres is 2500 tonne-kilometres (tkm)

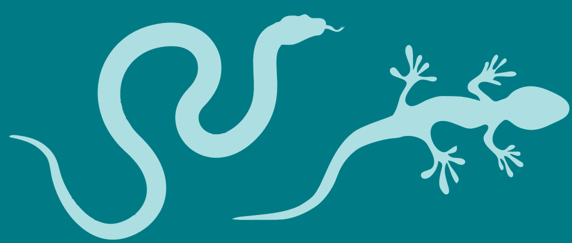
FIGURE 9: TOTAL INTERSTATE FREIGHT FORECASTS, AUSTRALIA

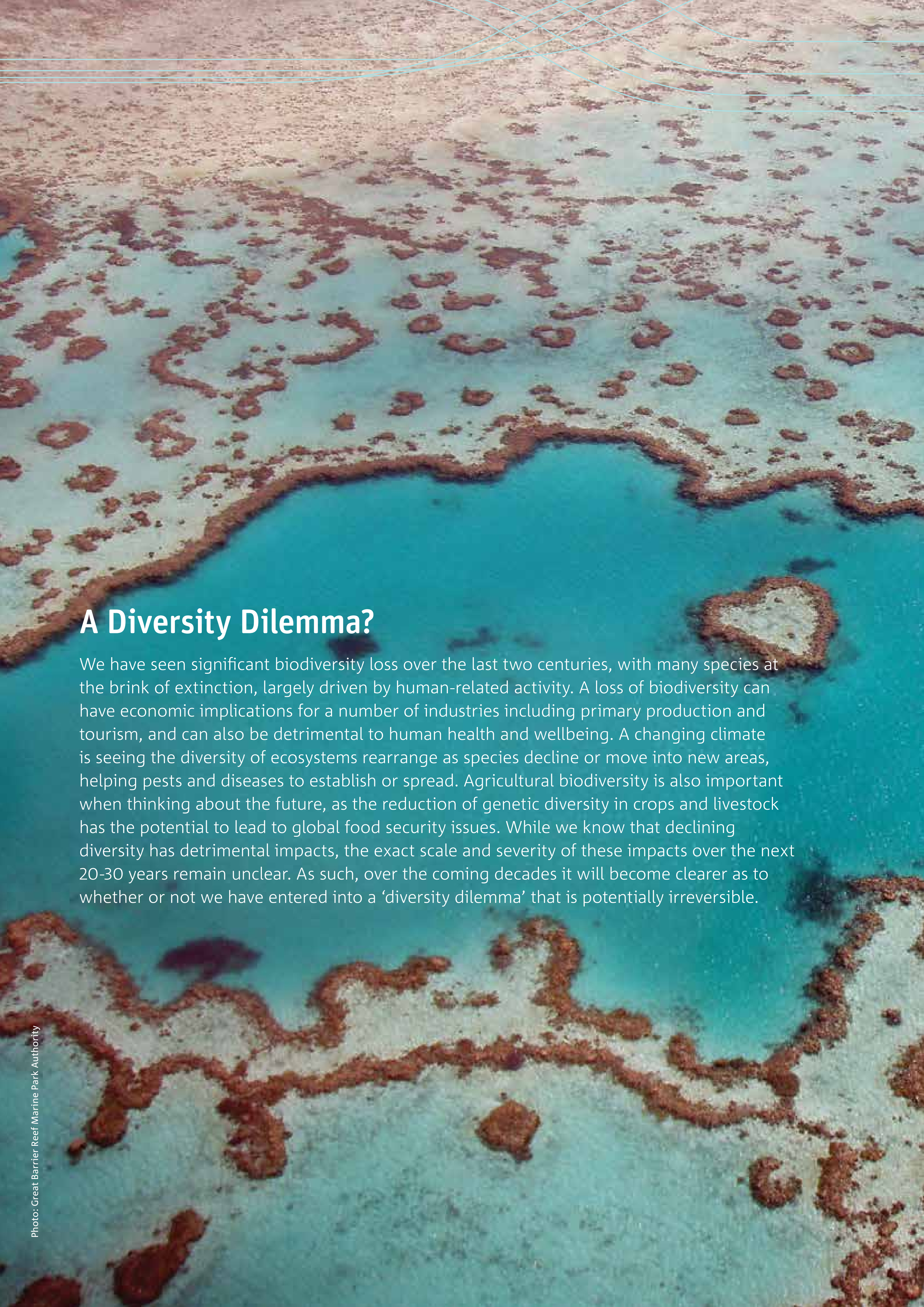
Source: Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2010[138]



Key Implications:

- Increased movement of people inevitably increases the opportunities for infectious diseases, including those resistant to antibiotics and antiviral medication, to spread and enter Australia
- Travellers also have the potential to bring pests or diseases into the country that could impact on our environment or primary industries
- Increased movement of goods, including plant and animal products, can help to spread pests and diseases, as well as disease vectors, around the world
- There will remain a need for offshore biosecurity investment (e.g. pre-departure inspections and risk profiling)
- A balanced approach is required in order to protect our biosecurity status while avoiding being perceived by international trading partners as protectionist
- We may see the development of more and/or stronger regional and global biosecurity standards
- Online shopping and demands for ornamental plants and pets have led to increased postal biosecurity risks from illegal flora and fauna trade
- The potential threat of bioterrorism, including agroterrorism, requires risk assessment and ongoing vigilance
- Greater domestic freight movements will increase the need to monitor our internal borders to manage threat containment





A Diversity Dilemma?

We have seen significant biodiversity loss over the last two centuries, with many species at the brink of extinction, largely driven by human-related activity. A loss of biodiversity can have economic implications for a number of industries including primary production and tourism, and can also be detrimental to human health and wellbeing. A changing climate is seeing the diversity of ecosystems rearrange as species decline or move into new areas, helping pests and diseases to establish or spread. Agricultural biodiversity is also important when thinking about the future, as the reduction of genetic diversity in crops and livestock has the potential to lead to global food security issues. While we know that declining diversity has detrimental impacts, the exact scale and severity of these impacts over the next 20-30 years remain unclear. As such, over the coming decades it will become clearer as to whether or not we have entered into a 'diversity dilemma' that is potentially irreversible.

Photo: Great Barrier Reef Marine Park Authority

The brink of extinction

Containing a mixture of varied ecosystems, from deserts and tropical rainforests, to marine environments spanning from the Antarctic to the Great Barrier Reef, Australia is one of the world's most biologically diverse countries. It contains more than 500,000 different species and, as an island continent, a large percentage of its species are not found anywhere else in the world (e.g. 92 per cent of our higher plant species, 87 per cent of our mammal species and 93 per cent of our reptiles only occur in Australia).[141] Consequently it is considered one of the seventeen mega-diverse countries that together account for 70 per cent of the world's biological diversity across less than 10 per cent of the world's surface.[142]

However, Australia's environmental uniqueness and richness is currently being threatened with more than 50 animal species listed as extinct and 48 known extinct plants.[143] In total, around 1,600 known plant and animal species, as well as many native ecosystems, particularly in south-eastern and south-western Australia, are listed as threatened.[144] This decline in diversity is part of a major global extinction event,[145] with reports suggesting that our decisions over the next few decades will have implications for global biodiversity beyond this century.[146]

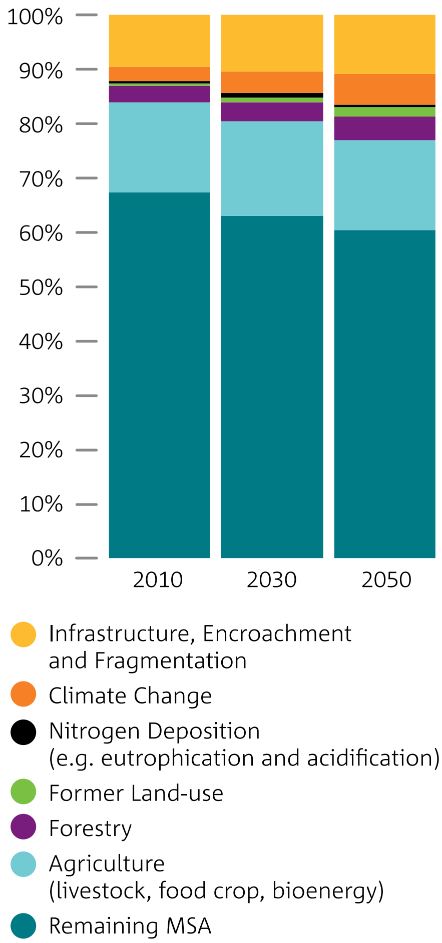
One pervasive threat is the loss of key species (keystone or otherwise) that support other species within their foodwebs and ecosystems. One such species is the cassowary, which eats the seeds of more than 238 species of plants and plays a vital role in long distance dispersal, helping to maintain the diversity of the tropical forests in northern Queensland.[147] Marine seagrasses adapted to nearshore environments help stabilise coastal sediments and provide food and shelter for inshore communities containing a high diversity of shrimp and fish.[148] The complexities of ecosystems make it extremely difficult to predict the long-term implications of a loss of any one species. However, based on findings from the recent book *Biodiversity: Science and Solutions for Australia* (2014),[149] we do know that:

- Biodiversity loss can reduce the efficiency with which ecosystems acquire resources, produce biomass, and decompose it to recycle nutrients;
- Maintenance of biodiversity allows ecosystems to keep working in the face of ongoing change and to recover functions more readily after a shock;
- The impact of a decline in biodiversity on the ecosystem accelerates as the loss increases;
- Diverse communities may be more productive because species differ in the way they capture energy and nutrients, leading to a potentially greater collective uptake;
- Loss of diversity at multiple levels within a food chain (e.g. from grasses through to grazing animals and their predators) can influence ecosystems more than loss within just one level; and
- Effects of extinction range from undetectable (for species having small roles in ecosystem functions) to profound (for those that dominate the working of the ecosystem).

Unfortunately, drivers of biodiversity loss from either direct or indirect human activities appear to be strong, with legacy, ongoing and emerging pressures (such as land clearing, invasive species and climate change respectively) expected to have lasting effects for years or decades, even in the most optimistic scenarios.[150] The OECD Environmental Outlook to 2050 highlighted how different pressures from areas relating to human activity, such as urban encroachment, climate change and agriculture, have contributed to a decline in biodiversity (measured via mean species abundance) and will continue to do so into the future (see Figure 10).[12]

FIGURE 10: EFFECTS OF DIFFERENT PRESSURES ON GLOBAL TERRESTRIAL MEAN SPECIES ABUNDANCE (MSA): BASELINE, 2010 TO 2050

Source: OECD, 2012[12]



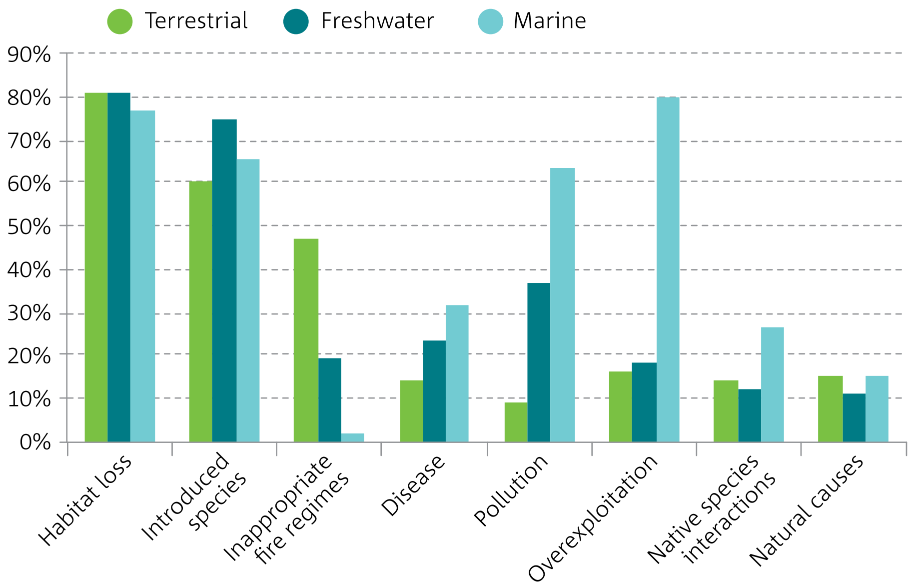
From a biosecurity perspective, biological invasions (by pests and diseases) can reduce local biodiversity and, in turn, reduce ecosystem resilience (the capacity of invaded native communities to recover following disturbance).[151] Invasive species are known to be one of the most significant threats to biodiversity and ecosystem services around the world,[152] with severe impacts on all Australian habitats[153] (see Figure 11).

Some invasive predators contribute to native species extinction. Globally, Australia has the highest recorded level of native mammal extinction over the last two centuries at nearly 10 per cent, with feral cats and foxes being major driving factors behind this loss.[154] Invasive species can also transform ecosystems to the permanent detriment of the resident native species.[155] The introduction of the rabbit in Australia has led to 75 plant species becoming threatened and has caused soil destabilisation and erosion.[156] Furthermore, invaded communities provide fewer ecosystem services and have lower levels of ecosystem productivity than pristine communities.[157, 158]

Therefore, management of invasive species, when well targeted, is a valuable and cost-effective tool in curbing biodiversity losses. For example, an assessment of management strategies for protecting conservation-significant plants and animals in the Pilbara found that the most cost-effective strategies for protecting biodiversity were managing feral animals and creating predator proof sanctuaries.[159]

FIGURE 11: SUMMARY OF THE PREVALENCE OF EIGHT MAJOR THREATS TO AUSTRALIA'S THREATENED SPECIES, EXPRESSED AS THE PERCENTAGE OF SPECIES AFFECTED BY HABITAT

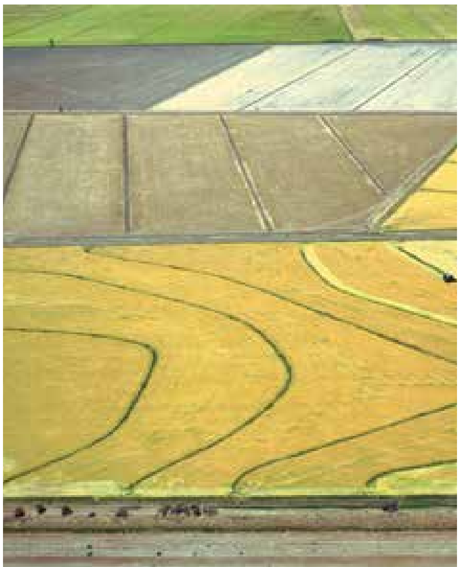
Source: Evans *et al.*, 2011[153]



In an effort to maintain biodiversity, genetic resource banks collect and preserve genetic material. Some of these banks facilitate the global collection, maintenance, preservation and distribution of germplasm and frozen cells containing DNA. The Frozen Ark Project, a genetic resource bank in the United Kingdom, has collected 48,000 samples from more than 5,500 endangered and non-endangered animal species.[160] The Millennial Seed Bank, also based in the UK, has collected seeds from more than 13 per cent of global wild plant species and aims to store 25 per cent of the world's bankable plants by 2020.[161]

In addition, around 170 countries have developed national biodiversity strategies with some progress already being made, such as the estimated 31 bird species that are believed to have been saved from extinction through conservation efforts.[146] International biodiversity conservation targets are also in progress through the Secretariat of the Convention on Biological Diversity[162] and the Intergovernmental Platform on Biodiversity and Ecosystem Services.[163]

The preservation of biodiversity has implications for all segments of society that depend on our natural environment. Genetic and species diversity has been linked to ecosystem provisioning services, such as increasing



commercial crop yields, enhancing production of wood in plantations, and improving stability of fishery yields.[164] A common example of an ecosystem service can be seen through the value of pollinators (e.g. bees, bats and birds) that are estimated to be responsible for pollination of 80 per cent of all flowering plant species, 35 per cent of the world's crops[165] and are worth more than US$200 billion per year to the global food economy.[146]

Australia's natural flora and fauna also support a broad range of recreational and nature-based activities, which in 2011 accounted for over 60 per cent of international visitors and their estimated spend of more than $18 billion.[166] Aside from tourism, the study of our natural environment continues to offer opportunities for new pharmaceutical drugs either by providing leads in the development process or active ingredients in medicines.[167] In addition to the strong cultural benefits gained from living in a biodiverse environment, evidence suggests that greater exposure to microbial diversity can lead to lower rates of allergy, hay fever and asthma.[168] A biodiverse environment can also protect people against exposure to zoonotic pathogens, as biodiversity loss exacerbates the risk and incidence of infectious diseases.[169]

When it comes to biosecurity, Cardinale *et al*. (2012) warn against making sweeping statements regarding the benefits of biodiversity. There are some instances where increased diversity can have adverse affects, as diverse natural enemy communities sometimes inhibit biocontrol and more diverse pathogen populations can create higher risks of infectious disease.[164] While ongoing research is required, understanding the complexities and interconnections of biodiversity and biosecurity may play a vital role in the future management of biosecurity and environmental decision making.

A changing climate

A rapidly changing climate is helping to drive biodiversity loss and is causing shifts in diversity across entire ecosystems. There is now unequivocal evidence of global warming. It is highly likely that human influence, through increases in greenhouse gases, has been the dominant cause of the observed warming since the mid-20th century. Human influence has been detected in warming of the atmosphere and the ocean, changes in the global water cycle, reductions in snow and ice, global mean sea level rise, and changes in some climate extremes.[170]

In Australia the mean surface air and ocean temperatures have risen by just under 1 degree Celsius since 1910, with more warm weather and fewer cool extremes. Further increases in greenhouse gases are expected to cause an increase in extreme heat, extreme fire weather, extreme rainfall events, tropical cyclone intensity, extreme sea-level events, and droughts in southern areas.[171, 172]

These changes will pose significant challenges for disaster risk management, water and food security, ecosystems, forestry, infrastructure such as transport and energy, as well as health and tourism.[171] Furthermore, greater levels of carbon dioxide are dramatically altering the chemistry of sea water, resulting in ocean acidification[170] that has significant effects on corals, plankton, and other marine organisms with carbonate skeletons,[173] and has been linked to increased stress and declines in coral within the Great Barrier Reef.[174]

Changes in Australia's climate are causing profound and potentially irreversible biodiversity ecosystem shifts. These include the disappearance of environments as well as the creation of novel environments unlike those that currently exist.[175] We are also witnessing changing migratory bird patterns and the movement of plant and animal species into new areas such as higher elevations and southerly

NASA, Geoscience Australia, CSIRO

latitudes[176] or, in the case of marine, the movement of species from warmer to cooler waters.[146] This is particularly important when considering the establishment and spread of invasive species.

Although successful establishment of an invasive species requires particular environmental and ecological conditions to be met, our changing climate can tip conditions in favour of the invader, facilitating its establishment or spread,[152] as is the case with the movement of sea urchins to the now warmer waters in Tasmania.[177] These urchins are reported to have led to significant losses in biodiversity, with impacts on fisheries.[178] The combination of growing international trade and vessel movement (see *On the Move*) with a changing climate could see exotic pests establish in Australia that previously were unable to do so.

Another important consequence of climate change is that it could lead to the spread of infectious diseases and vectors. A study of climate change and infectious diseases indicated that warmer temperatures have the ability to create favourable conditions for mosquitoes – increasing their reproduction, biting activity and the maturation rates of pathogens within them. The study also highlighted that an extreme weather event, such as a flood, could help precipitate water-borne diseases and leave breeding sites for mosquitoes.[179] However, Russell (2009) concluded that although a warming climate may lead to some increases in mosquito-borne disease in Australia, there are significant complexities that could influence the type of mosquito and the type of pathogen that might spread, when and where this is likely to happen, as well as the likelihood of human health effects.[180]

Loss of diversity in food production

In addition to global biodiversity losses and changes to ecosystem diversity, we are also seeing the loss of species and genetic diversity within agriculture. Driven by growing food demands and increasing agricultural intensification (see *An Appetite for Change*), the global food production system has become homogenised. Today, just fifteen plant and eight animal species account for 90 per cent of our food energy and protein[181] and four crops (rice, wheat, maize and potato) account for over 60 per cent of our energy intake.[182] In Australia, commercial egg layers primarily use one of three major genetic lines of brown egg layers,[183] and approximately 65-70 per cent of all dairy cattle are the Holstein breed.[24]

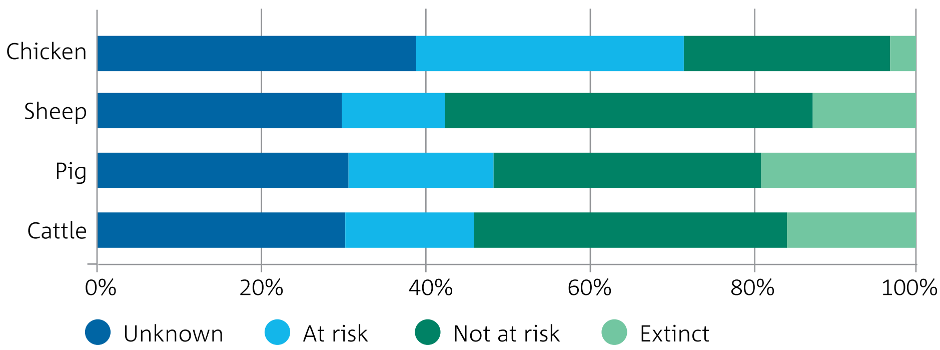
Homogenisation is a result of an increasing focus on species that are able to support high-output and large-scale operations, allowing global food demands to be serviced.[184] When considering livestock markets, this trend towards homogenisation is currently more pronounced in the developed world but developing nations are increasingly using non-local breeds to help intensify animal production systems.[146]

While homogenisation can be valuable for meeting growing food needs, the lack of diversity in production creates global food security risks. Throughout human history around 7,000 species of plants have been cultivated for human consumption. This diversity has played an important role in guaranteeing food supply amidst a backdrop of pests, diseases and environmental events such as climate fluctuations, floods and droughts.[182] With the loss of approximately 75 per cent of genetic diversity in agricultural crops over the last century,[181] a major pest or disease outbreak could have long-term implications for our food supply, including issues for the supply of feed (e.g. grain) used in livestock production.

An example of the potentially devastating consequences caused by a lack of agricultural diversity was seen with the Great Irish Famine of 1845-1852. A disease decimated the Irish potato crop for three harvests between 1845 and 1848, and an over-dependence on the crop led to mass emigration, starvation and the loss of one million lives.[185] Another example was seen in the US in the 1970s, where the southern corn leaf blight epidemic devastated the

FIGURE 12: GLOBAL RISK STATUS OF ANIMAL BREEDS USED IN AGRICULTURE

Source: FAO, 2007[190]
Note: The 'at risk' category includes critical, critical-maintained, endangered and endangered-maintained



in China local RICE VARIETIES declined from 46,000 to just over 1,000 between the 1950s and 2006.

industry, reducing yield per acre by 50 per cent in some regions,[186] with total national economic losses estimated at around $1 billion.[187] Genetic uniformity in crop breeding programs and extensive monoculture were identified as major factors contributing to the epidemic.[188]

More troubling is the fact that the level of diversity in crop and livestock breeds is continuing to decrease.[146] In the six years to 2007, 62 livestock breeds became extinct (a loss of approximately one breed per month) and 20 per cent of the 7,616 reported livestock breeds are classified as at risk,[184] indicating that further losses are likely. Similar examples of diversity loss can be seen in crops. For example, in China local rice varieties declined from 46,000 to just over 1,000 between the 1950s and 2006.[146] It is important to note, however, that not all food production systems are homogenised. For example, aquaculture still maintains a large amount of diversity, although domestication of cultured aquatic species only began at the beginning of the twentieth century.[189]

A number of genetic resource banks have been created to conserve agricultural biodiversity. The Svalbard Global Seed Vault in the Arctic Circle holds more than 820,000 samples in a facility designed to withstand the test of time. The vault holds the most diverse collection of food crop seeds in the world, from unique varieties of maize, rice and wheat, through to South American varieties of eggplant, lettuce and potato.[191]

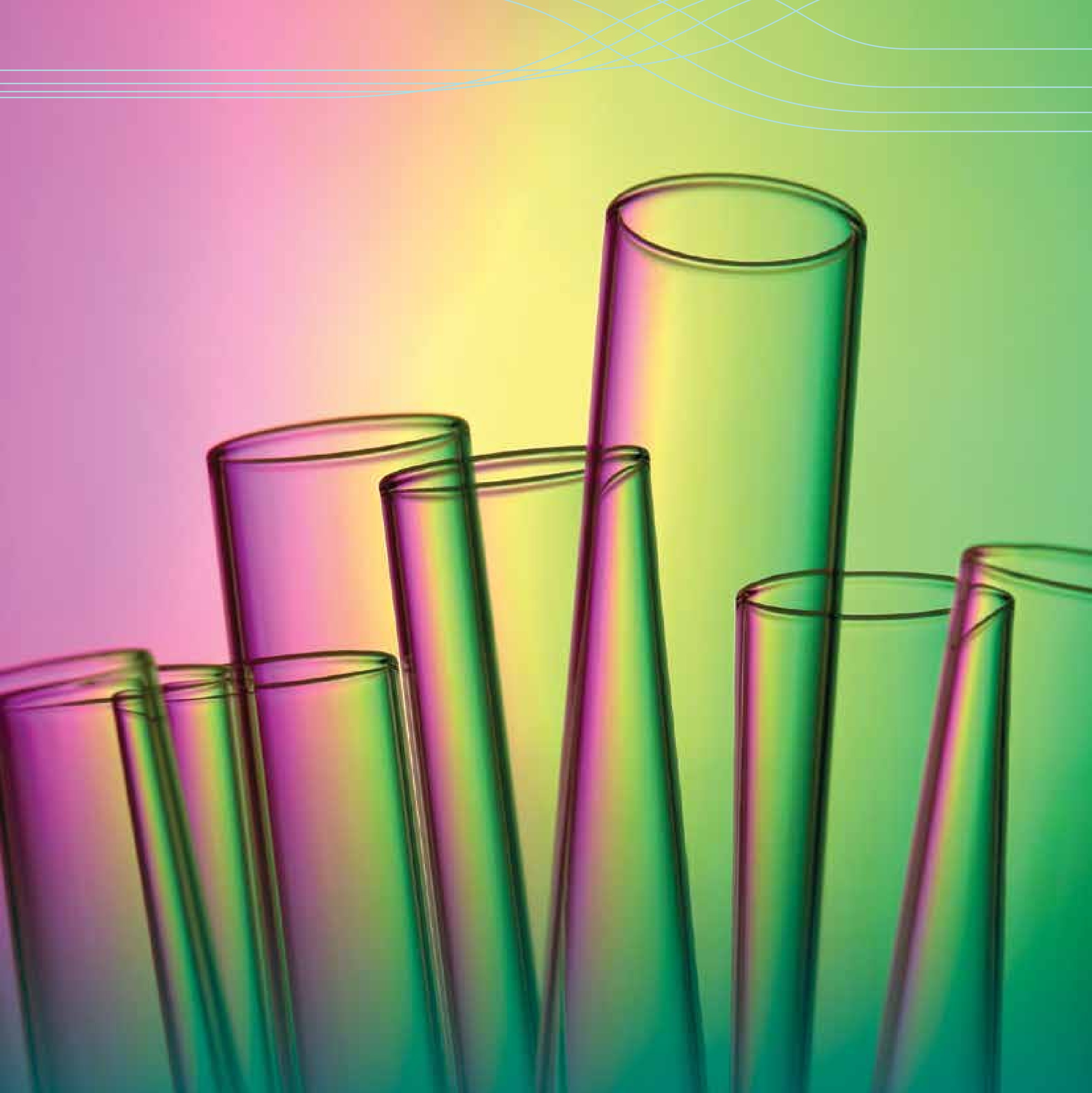
In addition to collecting and preserving genetic diversity, some of these resource banks are extremely valuable for research and plant breeding. They can assist in the development of future crop or animal improvements, including modifying crops to be resistant to pests, diseases and other environmental stresses, or to improve yields.[192]

It should also be noted that the increased food security challenge will not be solved by technology and science alone. Sustainable agricultural and social practices, including a reduction in food waste and improvements to distribution, will all contribute to a more secure future. However, it is safe to say that pest and disease threats will continue to evolve and we will need to remain vigilant of the rise of new disease strains. At the same time, climate change, urbanisation (see *The Urban Mindset*) and the increased movement of people and goods (see *On the Move*) will create greater opportunities for pests and diseases to establish and spread. Therefore, it is essential that we develop approaches to meet growing food demands while at the same time maintaining the diversity required to improve food security.

Although declining and changing diversity across our food production and environmental ecosystems can impact biosecurity, the severity and full effects of these trends may not become apparent for many years. As such, the coming decades will help to establish whether or not we face a true diversity dilemma. Regardless, improving our understanding of the interconnections between biodiversity, climate change and biosecurity may prove invaluable to increasing the resilience of ecosystems, improving food security and reducing the ability of pests and diseases to spread.

Key Implications:

- We are experiencing significant and ongoing biodiversity loss, which can decrease the resilience of our natural environment against pests and diseases
- The management of invasive species can be a valuable and cost-effective tool in curbing biodiversity losses
- Biodiversity can provide a number of benefits, such as ecosystem services (e.g. pollination). Understanding the interconnections of biodiversity and biosecurity may therefore play a vital role in the future management of biosecurity and environmental decision making
- Climate change can facilitate the spread, establishment and impacts of species (including pests and the diseases they carry) into new areas
- The loss of agricultural diversity can create food security risks in the case of a pest or disease outbreak
- Preserving genetic diversity can help in the development of pest and disease resistant crops and animals



The Efficiency Era

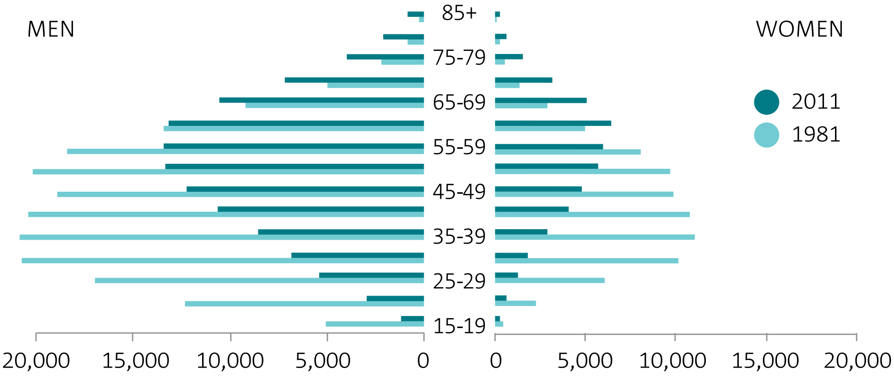
Although Australia has had an extremely successful biosecurity track record to date, declining biosecurity and agricultural resources and investment have the potential to create significant gaps in biosecurity capability. Importantly, there is a continuing decline of specialists in key areas such as diagnostics, as long-time specialists retire and there is a lack of upcoming talent to take their place. This means that the system is forced to do more with less and, given the increasing biosecurity challenges highlighted across all the megatrends, we will need to see a step change in the efficiency of biosecurity prevention, management and response activities. Technological developments in the areas of surveillance and monitoring, data and analytics, communication and engagement, as well as genetics and smaller, smarter devices, will play a key role in helping to achieve this. However, there are a number of potential barriers that will need to be addressed if technological innovation is to deliver the efficiencies required.

Declining resources – agriculture and biosecurity

One of the biggest challenges facing Australia and our biosecurity capability is our ageing population. By 2060 it is expected that people aged 75 or more will represent 14.4 per cent of the Australian population, up from 6.4 per cent in 2012.[193] While this trend will hit all sectors, it has the potential to cause irreversible stress on agriculture. In 2011, the median age of a farmer was 53 years, compared with 40 years for people in other occupations, with almost one-quarter of Australian farmers aged 65 years or over. The proportion of farmers aged less than 35 years fell from 28 per cent to just 13 per cent between 1981 and 2011 (see Figure 13).[7]

FIGURE 13: COMPARISON OF AUSTRALIAN FARMER AGE PROFILES – 1981 VS. 2011

Source: ABS, 2012[7]



A long-term decline of farmers has been seen over several decades, with numbers dropping by approximately 40 per cent between 1981 and 2011.[7] If not urgently addressed, Australia's agriculture sector will face a significant loss of knowledge and skills. This not only affects the long-term viability of the sector, but also leads to the loss of tacit biosecurity knowledge related to particular production systems or regions. This loss of knowledge could reduce the level of on-farm biosecurity activity as we lose the deep understanding of the day-to-day activities that can protect properties and reduce the spread of pests and diseases across the country.

We are also seeing a large proportion of agricultural scientists reach retirement, a noticeable decline in the number of student enrolments in agricultural sciences, as well as an erosion of agricultural training capacity. This has caused a significant shortfall in the number of agricultural graduates in Australia.[10]

Another major concern for Australia is the loss of biosecurity-specific human resources. These declines are occurring broadly across the biosecurity landscape, reducing our overall pest and disease response capability. For example, there have been major declines in taxonomists (an important part of diagnostics), with estimates that 50 per cent of Australia's diagnostics capability will be lost by 2028.[194]

In addition, many experienced staff in fields such as epidemiology and entomology are approaching retirement, with a lack of younger people available to take their place and meet immediate needs.[3] A 2012 survey, commissioned by the Australasian Plant Pathology Society and the Australian Entomological Society, identified that the number of plant pathologists and entomologists in the over 55 age bracket had increased since 2006, alongside a decline in numbers in the under 35 age brackets. The study highlighted that to maintain the status quo, 50 per cent of current capacity in these areas will require replacement within 15 years.[195]

Even if we maintain the biosecurity specialists we have, biological knowledge is constantly updated, revised and modified. Therefore, another challenge is the need for ongoing revision and retraining of the underpinning knowledge basis for biosecurity which, in turn, requires ongoing investment.

While a national audit of Australia's biosecurity research and development capability was conducted in 2012 by the IGAB Research, Development and Extension Working Group,[196] interviews across the biosecurity community revealed that many believe that there has been a noticeable reduction in capability since the audit was conducted. As such, another audit would likely be required to get an accurate gauge of Australia's current (and projected) biosecurity R&D capability.

When looking at total public investment in R&D, there has been a clear decline in agricultural R&D intensity.* In Australia, agricultural R&D intensity fell from a peak of more than five per cent in the late 1970s to just above three per cent of gross value of agricultural production in 2007, with declines also seen at a global level.[10]

*Agricultural R&D intensity: Agricultural research intensity, measured as the ratio of agricultural R&D investment to the gross value of agricultural production

We have seen a decline from a peak of approximately 33 scientists supporting Australia's weed biocontrol efforts in the 1980s and early 1990s to approximately seven to eight scientists today.

While comprehensive data for biosecurity investment trends is unavailable, interviews conducted with a broad range of scientific, industry and government stakeholders suggested that biosecurity investment is not keeping pace with the growing challenges we face. One example can be seen in relation to the number of scientists supporting Australia's weed biocontrol efforts. We have seen a decline from a peak of approximately 33 scientists in the 1980s and early 1990s to approximately seven to eight scientists today.(197) Another example of declining resources relating to biosecurity facilities is the decision made by the Queensland Government in 2012 to close the Biosecurity Queensland Tropical and Aquatic Animal Health Laboratory in Townsville.(198)

The 2008 *Beale Review* highlighted that "Australia's biosecurity agencies are significantly under-resourced" and recommended an increase in investment in the order of $485 million across the biosecurity system, including upgrades to information technology and business systems.(3) While significant investment was made in a number of areas following this review, the general sentiment across the biosecurity community is that even more will be required if we are to protect our biosecurity status. Furthermore, it is clear that funding cycles are often short-term, creating a mismatch between research efforts and biosecurity challenges, which are often experienced over a longer timeframe.

The role for technology and innovation

With an ongoing decline in resources there are opportunities for new technologies to address biosecurity challenges. However, improving the efficiency of how we manage biosecurity in line with the growing challenges we face will require a step change in how we approach the landscape as a whole. This includes greater levels of research and application in surveillance and detection, sensitive diagnostics, as well as preventative pre-border technologies.

Surveillance and monitoring

Science and technology are helping to create greater levels of efficiency in biosecurity surveillance and monitoring. This is particularly important for remote locations where management occurs over vast distances (requiring long travel times) or when inspection is labour intensive. In Queensland, a unique infrared and thermal camera system mounted on a helicopter is being used to detect fire ant nests. This remote-sensing technology allows large areas to be searched in a fraction of the time taken by conventional surveillance methods, with minimal disruption to properties.(199) It is estimated that the use of remote-sensing surveillance for detecting fire ants in Queensland will save more than $24 million per year when compared to ground-based surveillance approaches.(200)

As these systems and approaches mature there is potential for them to be applied to monitoring across a range of ecosystems to capture and communicate information about the arrival or spread of a pest or disease and reduce workforce requirements and costs. For example, the Remote Microscope Network allows quarantine officers to upload images of plants and pests to a virtual network of taxonomists around the world, enabling rapid identification of diseases or invasive species.(201)

Outside of helping to address any shortfalls in resourcing, global virtual networks can be integrated into other national systems that track animals, plants and pests, creating greater visibility of the entire biosecurity landscape. In the long-term, these virtual networks may help to promote national and international partnerships and can play a valuable role in achieving future biosecurity outcomes.

Sensors already play a role across the biosecurity landscape, from monitoring environmental conditions to tracking the movement of animals, plants and

diseases. However, in recent years, both cameras and sensors have gone from being something that you have to carry, such as a mobile phone, to something you can wear[202] or even ingest.[203] These advancements (in size, cost and power requirements) have opened the door to more specialised monitoring, including the tracking of some of our smaller species. The use of sensors that are smaller than the size of a pea helps us to monitor the real-time health of oysters,[204] and the use of sensors that are small and light enough to be attached to bees helps us to understand their behaviour.[205] There is also potential to apply non-invasive sensors (e.g. infrared thermography, accelerometers) to understand if an animal is infected prior to using time consuming manual inspections or laboratory-based diagnostics.[206]

With advancements in automation, there are opportunities to apply these sensors to unmanned vehicles and systems, enabling surveillance to be extended into areas that are not easily accessible to people. Unmanned vehicles have, for a number of years, been roaming the sea monitoring and surveying ocean ecosystems like the Great Barrier Reef.[207] Current research in plant biosecurity is exploring the use of maturing unmanned aerial vehicle (UAV) technology, with advanced sensors to collect large amounts of detailed information that can be used for plant health monitoring or early pest detection.[208]

Autonomous systems can also be used to conduct surveillance on hard-to-track animals such as the flying fox, which is nocturnally active and can travel vast distances.[206] The near real-time data captured by these vehicles can serve as an input to analytical models that help predict the future movement of pests and diseases. Through the use of analytical models and advanced sensors, the future generation of autonomous vehicles has the potential to evolve to a closed-loop system that incorporates both automated detection and response capabilities.

It is also important to note that physical sensors and cameras are not the only tools that provide greater efficiencies for surveillance and tracking. For example, molecular tools, such as DNA markers, can be used to understand how weeds spread (more detail on advancements in genetics is provided later in this megatrend).[209]

Data and analytics

The growth of data and data-intensive science has the ability to improve long-term decision making capability. For example, it can be applied to increase foundational knowledge of diseases and pests and the mechanics of establishment. It can also help to model risk, understand biosecurity return on investment, identify pre-emptive solutions, and explore long-term knock-on effects. This is particularly important in light of increasing government transparency and accountability trends linked to the broader movement towards open government.[210]

Decisions related to biosecurity are often complex with trade-offs and implications across industrial, societal and ecological systems and large amounts of uncertainty. They also include long and short-term considerations related to public policy.[211] Therefore, improvements in data modelling and visualisation and greater data availability have the potential to help decision makers better understand threats and rapidly act with greater confidence levels.

We are seeing a new paradigm of data-intensive science with scientists

Greater sharing and availability of LARGE DATASETS could help to enhance multi-disciplinary biosecurity research, integrating resources and information across plant, animal, environment and human health disciplines, as well as climate change, economics, systems modelling and social sciences.

analysing and interpreting mind-boggling volumes of data. For example, in the climate domain observational and simulation data is expected to reach exabytes (1 million terabytes) by 2021, and it is expected that light source experiments will generate hundreds of terabytes (1,000 gigabytes) per day.[212] Within the healthcare domain, Stanford University and the Lucile Packard Children's Hospital are leveraging data-intensive science to convert 400 trillion points of molecular, clinical and epidemiological open data into diagnostics, therapeutics and disease insights.[213]

An example from the biodiversity field is the Atlas of Living Australia, a biodiversity 'Yellow Pages' that brings together, in real time, more than 40 million specimen records from multiple data sources hosted in museums, herbaria and biological collections across Australia. The Atlas also allows individual users to contribute data and images. In addition, it provides open source analytical tools to allow users to explore potential species distribution and impacts on biodiversity.[214-216] The Atlas may prove to be a valuable data source for biosecurity management in Australia.

Greater sharing and availability of large datasets could help to enhance multi-disciplinary biosecurity research, integrating resources and information across plant, animal, environment and human health disciplines, as well as climate change, economics, systems modelling and social sciences. While large amounts of processing power are required to manage the large volumes of data available, there are organisations that are offering to offset the costs of owning your own supercomputer by using cloud computing, such as DNAnexus, which offers genomic analysis in the cloud.[217]

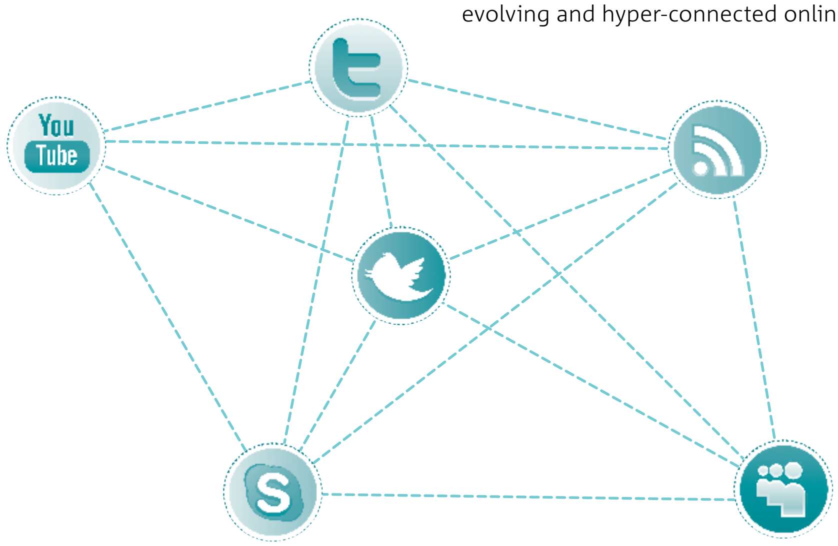
While data-intensive science can help with decision making, analytical skills and capabilities will need to increase to avoid decision makers becoming overwhelmed or misinterpreting data. In particular, it will be important to ensure that increased surveillance and data does not lead to unnecessary responses or knee-jerk reactions. While the volume of data we have access to today could be considered overwhelming, this problem is likely to grow at an exponential rate due to the increasing velocity at which data is being collected (e.g. via sensors).[212] For example, the use of sensors in the surveillance of the flying fox in Australia could lead to 100 million observations per year (under the assumption of 1,000 sensor tags that capture multiple variables at 15 minute intervals, 24 hours a day).[206] Nevertheless, this new era of data-intensive science is set to alter the way we test, analyse and understand the world and the biosecurity challenges we face.

Communication and engagement

Another important change to biosecurity management has been through the ability to disseminate science-based information to relevant individuals or communities. Communication and engagement strategies will play an important role in cutting across the diversity (e.g. cultural, geographical) that exists in Australia and making biosecurity a priority for everyone. While large-scale campaigns have proved to be valuable in the past, the Bureau of Rural Sciences' 2009 *Engaging in Biosecurity: Gap Analysis* report highlighted that too many engagement programs rely on one-way, top-down communication or information supplies. As such, there is a need for biosecurity engagement programs that are participatory, targeted, and allow for evaluation and monitoring.[218]

Social media and online communication can be used as important tools for biosecurity management. Social media has already transformed information flow and collaboration, growing at a rapid pace. Over a 10 year period since its launch, Facebook has grown to have more than 1.23 billion monthly users, with approximately nine million Australian users per day.[219] Online behaviours may also prove to be a valuable source of biosecurity surveillance, as publically available information and search terms can be used to detect biosecurity issues such as influenza epidemics.[220]

However, the pace and scale at which information can be distributed can also lead to challenges. For example, the World Economic Forum's 2013 report on *Global Risks* examined how the rapidly evolving and hyper-connected online



world could lead to a scenario where the rapid spread of misinformation online (e.g. via social media) creates widespread panic or reduces trust.[221] Our maturity in this new form of communication will therefore need to continue to increase in order to counteract future risks. As highlighted in the 2014 *Biosecurity Incident Public Information Manual,* prepared by the Biosecurity Incident National Communication Network, "social media is a demanding communication channel that cannot be ignored."[222]

Online communication also offers greater opportunities to engage with and tap into the world of citizen science. Building on open science trends, citizen science allows members of the non-scientific community to get involved in the research process. A notable Australian example is the Atlas of Living Australia, which relies on citizen science as an important source of biodiversity data.[223] Another example is the Range Extension Database and Mapping project (Redmap) that involves citizens in the monitoring of Australia's expansive coastline and encourages them to share sightings of marine species that are 'uncommon' to their local region.[224]

Similar activities are occurring internationally, with citizen science offering unique opportunities for new discoveries and innovations. The Natural Products Discovery Group of the University of Oklahoma is involving citizens in the identification of microorganisms in soils (using a soil collection kit) with hopes of identifying new natural products that may one day be used in medicine.[225] While the term 'citizen science' may be relatively new, the activities are comparable to past crowd sourcing efforts that have been used for the capture of knowledge (e.g. Wikipedia), to raise funds for projects (e.g. AgFunder – an investment marketplace for agricultural start-ups), and for predictive modelling and data analytics (e.g. Kaggle – a data science competition platform).

Underpinning communication and engagement strategies are the important fields of behavioural and social sciences. The *Queensland Biosecurity Strategy: 2009–14* highlighted that biosecurity risks are inherently social and that a better understanding of human behaviours, values and attitudes has the ability to improve engagement and decision making, helping to ensure that communication efforts produce results.[226] Furthermore, the 2007 New Zealand *Biosecurity Science Strategy* indicated that the application of social research could increase biosecurity compliance and reporting, and support post-border incursion response programs.[227]

Genetics and smaller, smarter devices

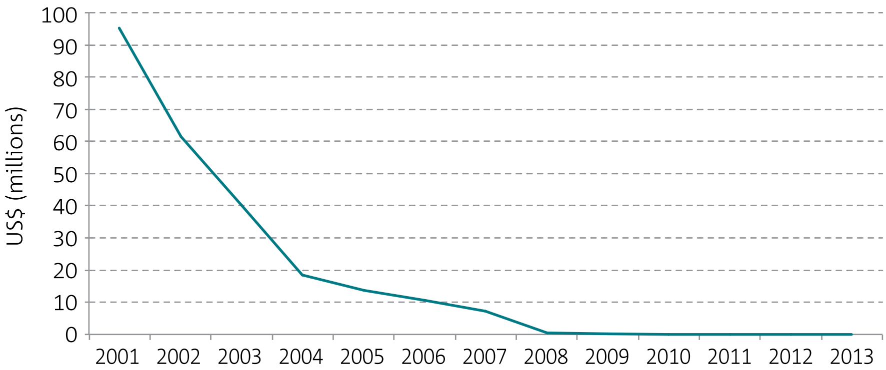
We have seen rapid progress in surveillance and diagnostics across the last two decades, particularly in the area of genetics. This includes a dramatic decrease in the cost of sequencing genes (see Figure 14). As well as fundamentally improving our understanding of ourselves and our own evolution, improvements in genetics facilitate the rapid detection of pests and diseases (e.g. through the detection of pathogen-specific proteins or pest-specific DNA) and improve our ability to respond (e.g. through rapid-response breeding of resistant varieties and resolving disputes related to market access).[228]

Furthermore, genetics may help to enhance taxonomy in the face of declining specialists. DNA barcoding, for example, involves reading a short DNA sequence from a genetic sample, recording this sequence in a public database, and then comparing it against all other samples to understand how closely related two organisms are. It provides a more objective analysis than just recording the results of a single study that classifies a particular specimen, and the data remains useful over time such as when species are reclassified or previous taxonomies are questioned.[230] DNA barcoding may prove to be extremely valuable as it reduces the cost of species identification while at the same time improving the quality and distribution of taxonomic information.[231]

Greater insights into genetics will have considerable impacts on future biosecurity approaches. For example, genetic research has the ability to improve our understanding of biological control. Genetic markers can be used to examine population origins and spread (for both target pests and the organisms introduced for biocontrol), or through the isolation of genes that are involved in the development,

FIGURE 14: SEQUENCING COST PER GENOME

Source: Wetterstrand, 2014[229]
Note: 2001 & 2002 represent data from September, 2003-13 represent data from October



reproduction and behaviour of organisms used for biocontrol.[232]

In addition, insights in genetics are leading to developments in the breeding of pest and disease resistant crops in order to prevent crop losses, such as breeding wheat that is resistant to one or more types of rust.[233] Resistant crops can also help to reduce the use of pesticides and associated environmental impacts. The use of genetic modification (GM) in the cotton industry has reduced the use of pesticides by 80 per cent when compared with conventional varieties, improving the profitability and environmental sustainability of Australia's cotton industry.[234] In Panama, GM has been used by an American company to grow salmon that reach market size in 18 months, rather than 30.[235]

While we may one day be able to breed a foot and mouth disease resistant cow, it is important to recognise that progress with GM, as with all technologies, will be subject to broader social understanding and acceptance. For example, a move by the Tasmanian Government to remain GM free has received mixed views with some highlighting lost market and productivity opportunities and others indicating that the position is valuable for branding of Tasmanian produce.[236]

Significant technological progress also continues to be made with relation to the size and capability of diagnostic devices. As devices become smaller and miniaturisation and processing ability increases (either on the device or in the cloud), diagnostics technologies have the potential to become handheld, smarter and capable of detecting a range of pests and diseases. These devices can also be used to understand environmental conditions and can be integrated with data from a broad range of sources.

While progress towards a 'lab-on-a-chip' is already being seen in healthcare,[237] advances in biosecurity solutions would create a step change in diagnostics for use in quarantine, pre- and post-movement inspection, and on-farm and backyard surveillance activities. One day this may remove the need for low-level diagnostic testing at highly advanced and secure facilities.

More broadly, there is even greater potential for these chips to act as surveillance and detection tools across global and local One Health initiatives that unify clinical, veterinary and environmental health research. The success of such initiatives will be important to combating emerging infectious diseases in people (70 per cent of which are zoonotic in nature).[238]

Addressing the barriers to technology and innovation

Of course, the opportunities for improving our biosecurity system through new or improved technologies are not limited to the four areas discussed above. There are endless ways that technology and innovation can help to prevent the entry, establishment and/or effects of pests and diseases. Through nanotechnology, Lifesaver Systems claims to have created the world's first portable water bottle that can, without chemicals, remove pathogens from water using filters with pore sizes of 15 nanometres, which is smaller than the Polio virus at 25 nanometres.[239] There could also be future opportunities to address biofouling via innovative types of coating technologies or by using additive manufacturing (3D printing) to print a structure that reduces the ability of pests to settle on the surfaces of a ship.

In the face of declining resources and investment, science and technology offer opportunities to create greater efficiencies in biosecurity while at the same time driving competitive advantage in primary industries. In addition, a world-leading position in biosecurity management may allow us to export our knowledge and services to other countries.

However, it is important to recognise that increased technological adoption is not without its own risks. For example, increased dependence on digital technology exposes industry and the nation to a new range of cyber security threats that are evolving in complexity and sophistication.[240] The challenge with technology adoption is in ensuring that it occurs alongside improvements in the levels of digital maturity in our society and processes. Equally important are the more traditional challenges related to information technology adoption such as funding, usability and integration that can lead to poor adoption and wasted investment.

The funding of technology systems has been widely discussed and was recognised in the *Beale Review*.[3] Given the scale of the challenges outlined in the megatrends, securing sufficient biosecurity funding in the future may require innovative models such as an insurance mechanism across industry or states, a funding approach that shares expenses across the value chain (from farmers through to distributors and retailers), or a philanthropic or crowd sourced funding model that leverages the community.

Other issues that can arise with major technology rollouts are usability and integration. These issues can often be attributed to a failure to recognise the skills and technological maturity (and internet connectivity) of those out in the field. A lack of long-term thinking can also result in the development of technologies that are independent and not easily (or cheaply) integrated with broader national surveillance efforts. When considering how technology can play a role in addressing future biosecurity challenges it is important to identify the risks and barriers that exist and develop strategies to address them, in order for technological innovation to deliver the efficiencies required.

Key Implications:

- With an ageing population and less young people entering agriculture, we are seeing a loss of long-time farmers and the tacit biosecurity knowledge they hold
- We are also seeing a decline in specialists in areas crucial to biosecurity management such as taxonomy, plant pathology and entomology
- There is a general sentiment that biosecurity investment is not keeping pace with the growing challenges we face
- A lack of biosecurity specialists and investment could limit our ability to prevent and respond to shocks
- Low cost sensors and automated systems create opportunities to better identify and respond to pests and diseases
- Improvements in data modelling and visualisation, combined with increased data availability, can improve long-term decision making and help us to better understand biosecurity risks across social, economic and environmental dimensions
- New communication tools, as well as behavioural and social science, can help to improve the flow of information and engage the wider community in biosecurity management, including citizen scientists
- We have seen rapid progress across surveillance and diagnostics in the area of genetics, enabling improved detection and understanding of pests and diseases, as well as opportunities to breed resistant species
- The development of diagnostic devices that are smaller, smarter and capable of detecting a range of pests and diseases could create a step change in quarantine and surveillance activities
- Issues such as poor design, a lack of funding and poor data integration could limit the potential for technological solutions to address current and future biosecurity challenges

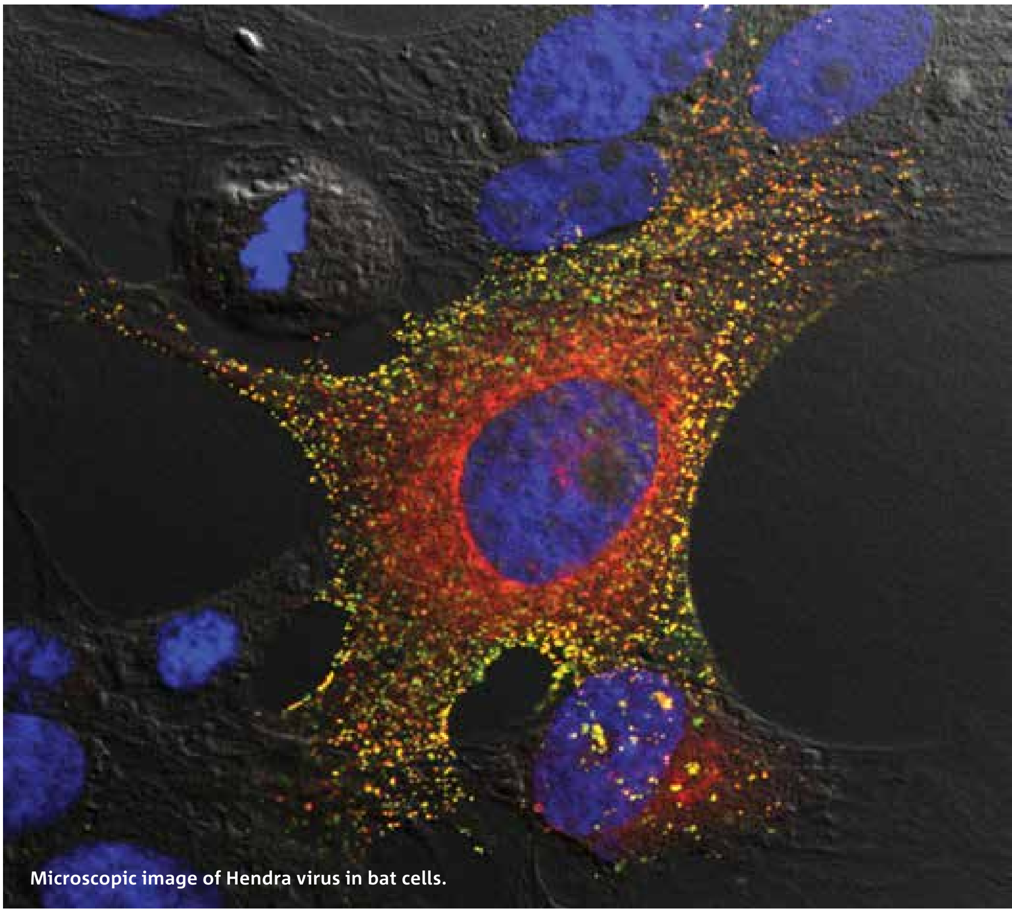
Megashocks

The megatrends discussed illustrate the growing complexity of Australia's, and indeed the world's, biosecurity landscape. The different ways in which these megatrends interact with one another over the coming 20-30 years could expose Australia to a greater level of biosecurity risk with the potential for future 'megashocks' to Australian industry, the environment or even our way of life.

Megashocks involve significant, relatively sudden and potentially high impact events, the timing of which is very hard to predict. Megashocks have major and often long-lasting consequences and they can dramatically change the foundational mechanisms by which an organisation, industry or society operates. Megashocks do not emerge without some warning signs, although unfortunately these warning signs are often not paid as much attention as they deserve. Megashocks are defined by numerous historical events of similar and/or related nature and typically have a high profile. It is just the timing, location and magnitude of the impact that is hard to foresee.

Numerous potential biosecurity megashocks can be identified across plant and animal industries, marine, environment and human health. This analysis has focused on a selection of two to three potential megashocks within each of these five categories. These megashocks have been chosen based on what the biosecurity community identified (through stakeholder interviews) as some of the most important threats we might face over the coming 20-30 years. They were also chosen because of the ability of the identified megatrends to alter the level of risk and/or impact posed by each of these threats.

Many of the megashocks are based on threats we are currently well aware of and, in some cases, somewhat prepared for. However, the interaction of the megatrends over the coming decades could create the conditions for these potential threats to turn into megashocks. When thinking 20-30 years into the future, it is also important to consider how the megatrends could lead to megashocks due to threats we may not yet be aware of or fully understand. The key trends that could interact to create the conditions for a megashock are outlined for each of the five categories.



Microscopic image of Hendra virus in bat cells.

Although these particular biosecurity megashocks may currently be hypothetical for Australia, throughout history there have been numerous biosecurity megashocks around the world. For example, the UK foot and mouth disease outbreak in 2001 and the 2002-2003 SARS epidemic had economic impacts of US$25-30 billion and US$30-50 billion, respectively.[241] While it can be argued that Australia has so far been spared from significant biosecurity megashocks, the megashocks in this report illustrate that we cannot use our relatively fortunate history as an excuse for complacency. It is also important to consider how well prepared we would be if Australia was hit with multiple megashocks at once and whether our biosecurity system could cope with such a situation.

When using megashocks as a tool to aid decision making it is important that all relevant levels of impact are considered. An incursion that decimates a relatively small primary industry (e.g. salmon) may not be considered as economically significant as an incursion that affects a much larger industry (e.g. wheat or beef) but it can be still be considered a megashock for that particular industry. In order to represent the breadth of threats that exist and the diversity of our primary industries, this report includes a selection of potential megashocks from both ends of the spectrum.

Furthermore, while some megashocks will be of economic significance due to the effects they have on our primary industries, others will have a greater impact across dimensions that are harder to put into dollar terms, such as biodiversity, recreation or human health. Therefore, this analysis covers a range of megashocks – from those with primarily economic impacts through to those with more widespread consequences. The megashocks illustrate why a number of threats are likely to be of growing concern for Australia in the future due to the potential effects of the megatrends.

Within each of the five categories, particular focus has been given to one megashock for which a future scenario for the year 2040 has been developed. The five key scenarios considered are:

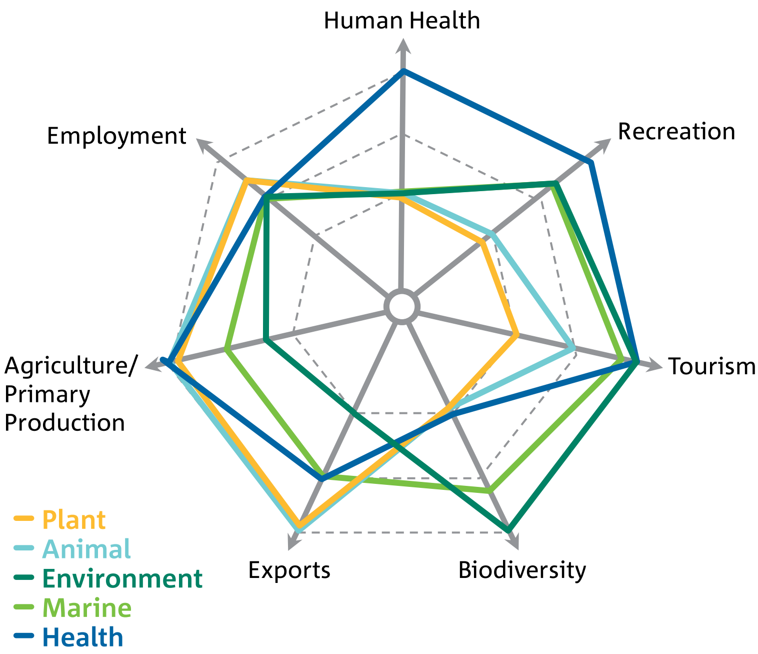
- **PLANT:** A nationwide incursion of a new exotic wheat stem rust race
- **ANIMAL:** A nationwide outbreak of a variant strain of foot and mouth disease
- **ENVIRONMENT:** A highly virulent rust spreads across multiple ecosystems
- **MARINE:** The successful establishment of black-striped mussel
- **HEALTH:** A nationwide outbreak of avian influenza

Each of the scenarios is based on a particular, plausible confluence of events, as determined by the interaction of the megatrends, which could lead to a 'worst case scenario' for Australia. Activities conducted at two full-day workshops with senior leaders from Australia's biosecurity community were used as inputs to the development of each of these scenarios. The relative impacts of each scenario are plotted against a number of environmental, economic and social dimensions (see Figure 15).

While this analysis is entirely qualitative, it gives an indication of the potential for widespread consequences for each of the megashock scenarios. It is important to keep in mind that while plausibility was a key consideration in the development of the scenarios, this analysis does not imply that one scenario is more or less likely than any other. In many ways, it is the decisions that we make in the short-term that will determine if and how these scenarios will play out in the long-run.

FIGURE 15: QUALITATIVE ASSESSMENT OF THE RELATIVE IMPACTS OF MEGASHOCK SCENARIOS

(Note: inner line represents low impacts, middle line represents moderate impacts, and outer line represents high impacts)



PLANT INDUSTRIES

Overview

The diverse nature of Australia's plant industries means that there are a large number of biosecurity threats, all with varying levels of potential impact. Certain plant biosecurity megashocks may affect just one part of the industry (e.g. an ineradicable outbreak of citrus greening impairing the citrus industry) while others could have an impact across multiple crops (e.g. a nationwide incursion of an exotic fruit fly that devastates a number of fruit and vegetable crops).

In 2012-13 Australia's plant industries (including broadacre crops, crops for hay, nurseries and cut flowers, fruit, vegetables and nuts) had a gross crop production value of more than $28 billion.[242] In addition, the gross value of logs harvested from Australia's plantations was estimated at $1.33 billion in 2011-12.[243] While there are a small number of large crops (e.g. wheat, barley and canola have a combined gross value of more than $11 billion), the industry is made up of a large number of smaller crops (e.g. most fruit and vegetable crops have a gross value of less than $500 million).[242] This can lead to a heightened level of complication in relation to biosecurity as there is a need to understand the potential effects of a number of different pests and diseases on a vast range of plant species.

The absence of many pests and diseases found in other countries is a vital factor in the success of Australia's plant industries, as it helps in securing market access and maintaining lower production costs.[244] This is of particular significance for the plant industries that are predominantly export focused, such as the grains industry. Keeping the industries that predominantly supply the domestic market free from pests and diseases is also important, both from an economic perspective as well as to ensure food security. A shock to supply, even in one region, can be felt across the entire country. For example, when Queensland's banana crops were wiped out by Cyclone Yasi in 2011, banana prices around the country increased to more than $12 per kilogram.[245]

While it could be tempting for decision makers to focus just on the higher value crops, it should be recognised that the biosecurity of all plant crops is important in ensuring we have an ongoing supply of fresh produce. The loss of one or more of crops due to a megashock could lead to a greater reliance on imports, with implications for long-term food security.

Contributing Megatrends:

- **An Appetite for Change** – Agricultural intensification and homogenisation are creating single point sensitivities in our biosecurity system
- **The Urban Mindset** – Changing consumer demands (e.g. for organic produce) could create new challenges for pest and disease management
- **On the Move** – Greater global movement of people and goods (particularly imports of plant products) is creating new opportunities for pests and diseases to enter the country
- **A Diversity Dilemma?** – The loss of certain species (e.g. pollinators) could threaten the viability of a number of crops
- **The Efficiency Era** – Declining resources could limit our ability to prevent and respond to an incursion

The dreaded weed *Miconia calvescens*, also known as 'Purple Plague'.

Miconia underleaf © Forest & Kim Starr

While Australia has bred resistant wheat varieties for decades, it is believed that up to 60 PER CENT of our cultivated varieties will become moderately susceptible to susceptible should Ug99 establish.

Potential Megashocks

A nationwide incursion of a new race of an exotic wheat stem rust

Rusts are a major concern for a number of plant species in Australia and are an area of ongoing research due to the significant impacts they can have, particularly with regards to Australia's wheat industry, which had a gross value of $7.2 billion in 2012-13.[242] The most severe epidemic in the Australian wheat industry's history occurred through a wheat stem rust epidemic in south-eastern Australia in 1973, with an estimated $200 to $300 million in damage.[246] Although wheat stem rust has been under control for the last 30 years, Ug99 (a new lineage of the disease comprising several races) has overcome resistance in an estimated 80-90 per cent of global wheat varieties and can cause wheat yield losses of 70 per cent or more under the right conditions.[247] While Australia has bred resistant wheat varieties for decades, it is believed that up to 60 per cent of our cultivated varieties will become moderately susceptible to susceptible should Ug99 establish.[246]

Eradication or containment strategies would be extremely difficult due to disease mobility, with an ability to spread over large distances via the wind or through the movement of goods and people.[247] There is strong evidence that the 1969 introduction of a wheat stem rust in Australia could have occurred via wind borne dispersal from southern Africa and the 1979 introduction of wheat stripe rust in Australia likely occurred via a traveller from Europe.[248]

There has been a steady increase in the rate of exotic cereal rust incursions since 1925[246] and the rate of rust incursions may get worse as global trade increases, creating new pathways. In addition, agricultural expansion, intensification and changing agricultural practices (such as increased use of nitrogen fertiliser, irrigation and the concentration of production on fewer productive varieties) may create favourable environments for stem rust build-up. There are also concerns over the potential for a non-accidental release of wheat stem rust as an act of agroterrorism.[248]

While Ug99 is currently only found in countries within Africa and the Middle East, a potential future megashock to Australia's wheat industry could occur through a nationwide incursion of a new wheat stem rust – possibly even one more virulent than existing races of Ug99 – that impacts known cultivated varieties and has a broad host range (native grasses and pastures). Since discovery in Uganda in 1999, eight new races in the Ug99 lineage have been identified with different virulence patterns.[249]

Countering the impact of a wheat stem rust megashock would require significant surveillance and diagnostics capabilities and pre-breeding for germplasm resistance. Should Ug99 become established, there would also be a need for extensive communication across the grains industry, sufficient chemical stockpiles, as well as resources to ensure that seeds of resistant cultivars are available for sowing in the years after the outbreak.[246]

Outside of affecting global wheat supply and Australia's disease free status, a virulent exotic rust could also affect other Australian crops. For example, Ug99 has the potential to impact Australia's barley industry,[250] worth $2.1 billion in gross value in 2012-13,[242] although yield reductions would be significantly lower than those experienced in wheat.

The nationwide loss of pollination services from feral European honey bees

It is widely known that pollinators (e.g. birds, insects, bats) provide valuable services to industries and ecosystems, with pollination playing a role in 35 per cent of the world's crop production and approximately 80 per cent of all flowering plant species.[165] In Australia it is estimated that honey bees alone contribute $4-6 billion per year to the economy through pollination services[251] and a very high proportion of that benefit is provided by feral European honey bees.[169] A number of crops, such as almonds and avocados, are 100 per cent reliant on honey bees for pollination.[169] As such, the loss of feral European honey bees, through a parasite such as the varroa mite and the diseases it can transmit, is a potential megashock for Australia's plant industries. This loss would affect several fruit and vegetables, sunflower and certain nuts (e.g. almond and macadamia).[169] A study conducted in 2003 estimated that the loss of feral honey bees in Australia could result in short-term economic losses of $3.6 billion and the loss of more than 20,000 full-time-equivalent jobs.[252]

While the Asian honey bee has evolved to live with varroa unaffected, the varroa mite has shifted hosts from Asian to

European honey bees that have little resistance to the pest,[253] representing an important threat to Australia's pollination-dependent industries. Within three to four years, varroa infestations have resulted in the disappearance of 95-100 per cent of unmanaged or feral hives in Europe and the US.[254] Since discovery in New Zealand in 2000, varroa mites have caused major economic impacts including crop yield and export revenue losses.[255]

Given that 65 per cent of Australian crops are dependent on honey bees for pollination,[252] the varroa mite has been described as "the bee industry equivalent of foot and mouth disease for livestock."[256] The pollination services provided by the honey bee also expand beyond plant industries and play a role in wool, meat and dairy production (e.g. through the pollination of pastures such as lucerne and clover).[251]

An incursion also has the potential to affect honey production with a gross value of $90 million per year,[257] as well as the commercial pollination services industry. While managed hives can implement control options, there would be significant costs associated with such measures. These costs would likely be passed on to producers in the plant industries as they become more reliant on paid pollination services in the absence of feral colonies. Alternatively, some producers may switch to non-honey bee dependent crops, reshaping the landscape of Australia's agricultural output.[258] The higher cost of pollination could even see some farmers leave the land altogether[258] and the costs associated with managing hives could make many apiarists (beekeepers) unviable.[251]

Recent evidence of pesticide resistance in the mite has the potential to make a varroa mite infestation much worse.[259] Without sufficient resources and surveillance technologies, the greater movement of goods and people has the ability to increase the level of varroa mite risk for Australia.

As the varroa mite is an example of a pest that cuts across both the plant and animal industries, coordination and collaboration across the different industries is crucial in understanding and addressing this potential threat.

A nationwide incursion of an exotic fruit fly

There are more than 280 species of fruit fly that are endemic to Australia, with seven of these having substantial economic impact.[260] Worldwide, however, there are in excess of 4,000 species of fruit fly in the family Tephritidae, of which around 50 species are of economic importance.[261] Significant effort has been invested in helping to keep Australia's horticulture industries protected from the threat of fruit flies. This is important in enabling Australia to maintain market access through its valuable pest-free export status. It is also one of the most high profile pests in Australia, with a much wider public understanding of the issues associated with it compared to other pests due to long-running education campaigns.

Our level of preparedness against the risk of a new exotic fruit fly entering Australia could therefore currently be considered relatively high. However, in the future we may see a loss of capability in fruit fly management (due to declining resources, an ageing population etc.) coupled with increased international and domestic trade in fruit and vegetable products. If this is the case, we will need to consider the potential for a scenario in which a new type of fruit fly enters undetected and rapidly spreads before we are able to respond. This could lead to an industry megashock for horticulture in Australia, with more than $5 billion worth of crops susceptible to fruit fly.[262]

Furthermore, if consumer expectations relating to organic, pesticide-free produce continue to grow, farmers will face significant challenges with regards to minimising production losses while also meeting consumer demands. This potential megashock illustrates that even the biosecurity threats that we may currently be prepared to respond to could become an issue if we remain complacent in the face of changing local and global trends.

Bactrocera dorsalis.

2040 Exotic Wheat Stem Rust Scenario

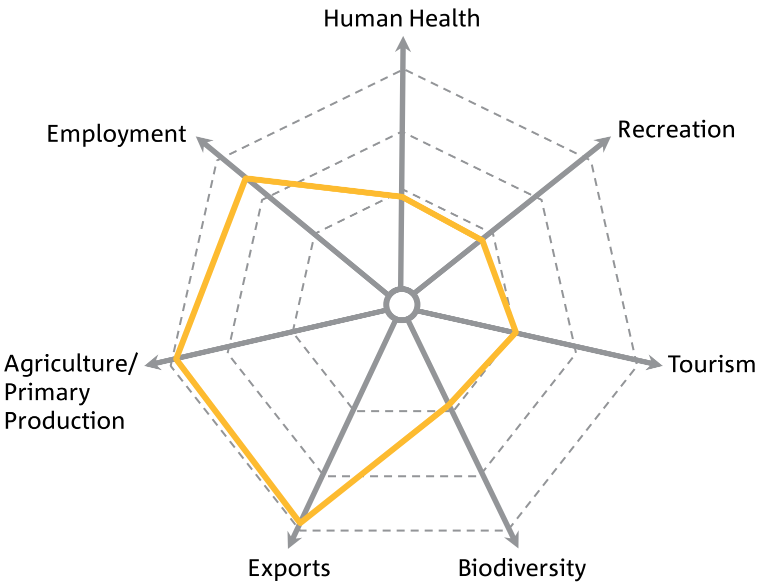
It's the year 2040 and a new, more virulent race of Ug99 has spread across Australia's major wheat producing regions

There are a number of factors that have led to this outbreak:

- With limited resources and no history of outbreaks in Australia, little investment has been made in recent decades in R&D relating to Ug99
- With a long-term decline in experienced farmers, biosecurity standards for wheat crops have begun to slip
- With a need to intensify and remain globally competitive, Australian farmers have focused more on growing higher yield crops, rather than disease resistant crops
- Homogenisation of crops has meant that all cultivars are susceptible
- The rust is believed to have entered via contaminated equipment or clothes via trade or a traveller
- Extreme weather events have helped to spread spores across the country
- The rust has high resistance to pesticides and a lack of availability of new chemicals (due to factors such as a lack of investment in research and a more complex regulatory environment) has left Australia without the necessary tools to respond quickly

The outbreak has had significant economic and social impacts:

- Australia loses access to a number of key markets and exports drop significantly for wheat and associated produce that could be contaminated (e.g. other cereals that pass through the same delivery chain)
- Australia's reputation as a 'disease free' wheat producer is tarnished
- The price of feed increases for Australia's livestock producers
- Australia's food security is seriously questioned
- There are widespread unemployment issues affecting those involved directly (e.g. farmers) or indirectly (e.g. transport) in the industry



ANIMAL INDUSTRIES

Overview

A very small number of animal species constitute the bulk of Australia's livestock industry. Including livestock products (milk, wool, eggs), the sector had a gross value of around $20 billion in 2012-13. Cattle (including dairy) accounted for 57 per cent, sheep (including wool) accounted for 23 per cent, poultry (including eggs) constituted 14 per cent and pigs accounted for just under 5 per cent of gross production value.[(242)]

Animal biosecurity threats can attract significant media and political attention, which is often followed by investment. For example, following the globally publicised outbreak of foot and mouth disease (FMD) in the UK in 2001, the Howard government's 2001-02 budget committed $596.4 million over five years "to provide additional resourcing and infrastructure to strengthen Australia's defence against the introduction of exotic pests and diseases, including foot and mouth disease."[(263)] Following this, in 2002 'Exercise Minotaur' involved more than 1,000 people from government agencies and industry bodies and tested our ability to deal with a hypothetical outbreak of FMD.[(264)]

While we may be relatively well prepared to deal with known pests and diseases, pests can spread to new areas, develop resistance to existing measures, or evolve and mutate creating new disease strains. If we are to truly gauge our level of preparedness we need to be asking important questions about the future such as "how would we respond if a highly virulent strain of FMD were to hit our shores for which no effective vaccine exists?" Managing the investment of resources in known biosecurity threats versus unknown threats will need to be a key consideration when developing animal biosecurity strategies that aim to protect the future of our livestock-related industries. In a globalised world this will be crucial in helping our animal industries to remain competitive through gaining and maintaining access to international markets.

Contributing Megatrends:

- **An Appetite for Change** – Agricultural expansion and intensification could heighten the spread and effects of a pest or disease outbreak
- **The Urban Mindset** – Growth in peri-urban production could heighten the threat and impact of a pest or disease outbreak if small-scale/hobby producers fail to engage with biosecurity issues
- **On the Move** – Greater global trade is creating new opportunities for pests and diseases to enter the country
- **A Diversity Dilemma?** – A warming climate is allowing the spread of pests, diseases and disease vectors into new areas
- **The Efficiency Era** – Declining resources could limit our ability to prevent and respond to a pest or disease outbreak

Potential Megashocks

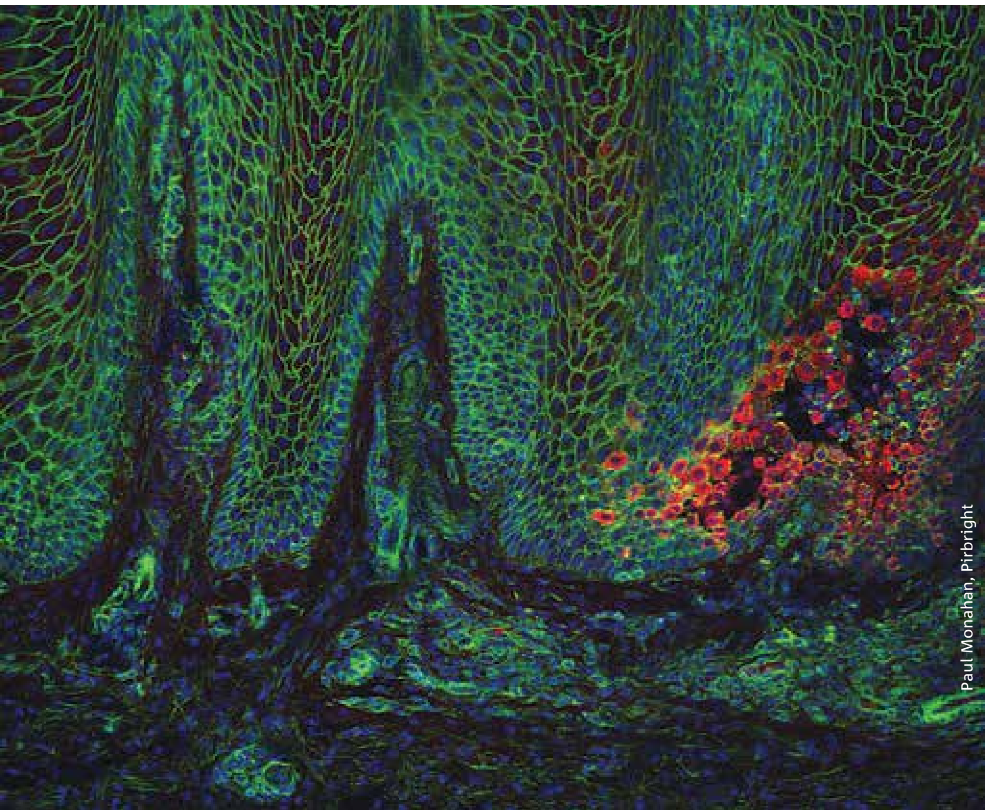
A nationwide outbreak of a variant strain of foot and mouth disease

FMD is a viral infection that affects cloven-hoofed animals such as cattle, pigs, sheep and goats. While not fatal to adult animals, it is considered to be one of the most infectious viral diseases.[265] It has a short incubation period and is easily transmitted, with the ability to infect entire herds within 48 hours.[266]

Infection can occur through inhalation and ingestion of excretions (breath, saliva, mucus, milk, semen and faeces) and direct contact with infected animals.[267] In addition, the virus can be carried in meat products (including frozen, chilled and freeze-dried foods), bones, untreated hides, as well as vehicles and equipment exposed to infected animals.[266] Although vaccines exist, constant mutation and recombination of viruses result in new variants that challenge the value of diagnostics and make vaccination an uncertain option.[265]

Due to the ease of transmission across livestock sectors, an outbreak of FMD results in trade bans to prevent the spread of infected animals or products to other countries free from FMD. This has significant impacts on the local country's agricultural reputation and its ability to trade internationally. Gaining a disease-free status after an outbreak (a process that could take months or years) requires rapid culling of infected and in-contact animals with a possibility of using vaccination to further prevent the spread of disease. This is then followed by an intense surveillance program to demonstrate freedom from infection. This process therefore has significant impacts on producers, both financially and emotionally.[268] The 2001 FMD outbreak in the United Kingdom is said to have caused more than US$12 billion in losses and to prevent the spread of the disease more than six million sheep and cattle were slaughtered.[269] As the impacts of FMD are largely trade related, FMD is sometimes called an economic disease.[265]

Foot and mouth disease on a cow tongue.



Given Australia's strong reliance on the beef industry, a large amount of research and analysis has been undertaken on currently known virus serotypes. In a 2013 study, the Australian Bureau of Agricultural Resource Economics and Sciences highlighted the potential economic impacts of an FMD outbreak. These include depressed domestic prices and the loss of exports, which account for around 60 per cent of livestock production.[268]

An FMD outbreak could lead to industry-wide revenue losses for livestock producers of around $6 billion for a small outbreak and $50 billion for a large multi-state outbreak over a ten year period. Additional costs related to disease control, such as labour, decontamination, slaughter, disposal and facilities, would be expected to range from $60 million to $373 million. Broader production and revenue losses for industries in the agricultural supply chain (e.g. transport, trade and feed) could total $11.5 billion over ten years.[268]

It is therefore important to consider the potential for a multi-state outbreak of FMD to create an economic megashock for the country. In the absence of ongoing increases in quarantine investment, growing trade can create more opportunities for the disease to enter the country. A combination of declining resources over time and a requirement to spread available resources across multiple states during an outbreak could also lead to a lower level of preparedness. Furthermore, if it is a new variant for which no effective vaccine exists, delays in producing a new vaccine and/or insufficient doses of vaccine could lead to higher and longer-term impacts than current estimates.

The effects of such an outbreak could also be made worse if Australia's beef industry continues to grow and intensify, without an adequate level of supporting investment in resources and diagnostic testing facilities. Growth in peri-urban production could

With a national sheep flock of 74.7 million and a gross value of more than $2.2 billion for livestock and more than $2.4 billion for wool in 2012-13, a widespread outbreak of **CLINICAL BLUETONGUE DISEASE** in Australia's major sheep producing regions could lead to an industry megashock with devastating impacts on our agriculture sector.

also heighten the threat and impact of an FMD outbreak if small-scale/hobby producers fail to engage with biosecurity issues. Furthermore, a decrease in investment in feral animal control programs could see wild populations (e.g. pigs and deer) increase beyond the already high numbers, which would help to facilitate the incubation and spread of the disease and may make eradication almost impossible.

A bluetongue outbreak in major sheep producing regions

An important consideration in the analysis of megashocks is the subtle influence climate change can have on the spread of infectious diseases and, in particular, the spread of vectors such as mosquitoes, midges and ticks that carry disease (e.g. arthropod-borne viruses). Bluetongue, a virus that primarily infects sheep but can also infect goats, deer and cattle, was first identified in northern Australia in 1975. Despite its long-term presence in Australia, bluetongue has not yet caused any clinical disease under natural conditions.[270]

As a result of milder winters and changes to rainfall patterns, the midge (the insect vector that carries the disease) has increased its range over the last two decades with the potential to spread to high sheep production areas.[271] The movement of the bluetongue virus due to climate change is not unheard of. It is believed that changes in the European climate have led to the northward movement of the main midge vector for the virus, allowing the virus to spread to Europe from Africa. Warmer temperatures have also allowed the virus to persist during winter and the transmission of the virus by indigenous midge species has allowed the virus to extend even further beyond the traditional vector's range.[272, 273]

The main issue bluetongue currently causes in Australia relates to market access. A number of markets, such as Israel and Turkey, will only accept sheep imports from regions known to be free from the virus. If the midges that currently carry the virus were to spread into the major sheep and cattle producing regions in New South Wales, Victoria, South Australia and Western Australia that are currently free from the disease, it could significantly affect Australia's position in live exports. Australia's sheep and cattle live exports were valued at more than $900 million in 2013.[274] If the virus was able to jump hosts to native midge species found in these regions, the disease could spread even further through a new insect vector.

Although bluetongue has not yet caused clinical disease in Australia, there are strains currently restricted to far north Australia that have been shown experimentally to cause severe disease and death in sheep, as highlighted in the 2014 Meat & Livestock Australia report *Detection of Bluetongue virus and vectors to enhance surveillance*.[275] Changing climate conditions and associated changes in vector distributions have the potential to lead to pathogenic strains of bluetongue moving south towards sheep populations. Extreme weather events also have the potential to bring new, more virulent strains of the disease from neighbouring countries into Australia.[275] If feral deer continue to invade our natural environment they could help to facilitate the spread of the disease into new areas. Agricultural expansion and intensification also have the potential to increase the spread and impact of an outbreak.

With a national sheep flock of 74.7 million[276] and a gross value of more than $2.2 billion for livestock and more than $2.4 billion for wool in 2012-13,[242] a widespread outbreak of clinical bluetongue disease in Australia's major sheep producing regions could lead to an industry megashock with devastating impacts on our agriculture sector.

2040 Foot and Mouth Disease Scenario

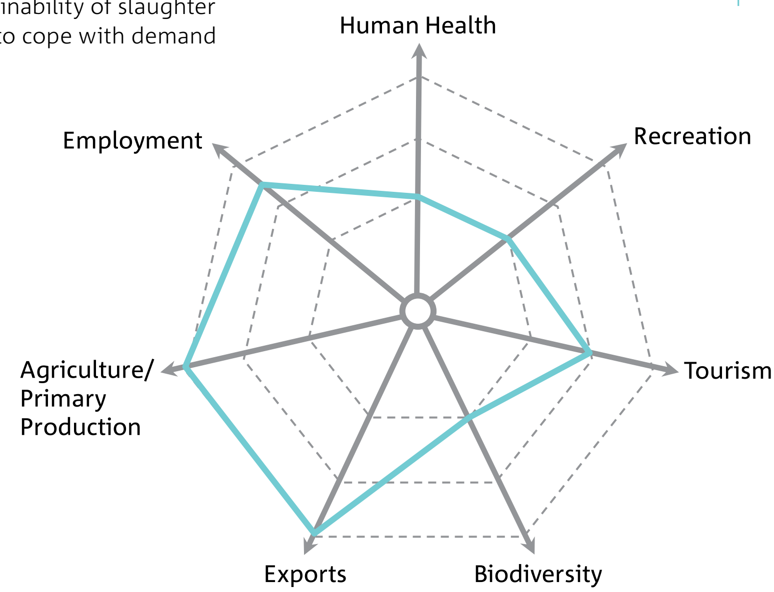
It's the year 2040 and a multi-state outbreak of a variant strain of the FMD virus has occurred, affecting the exports of all livestock products. There is no effective vaccine available to this particular virus at the time of the outbreak.

There are a number of factors that have led to this outbreak:

- Australia has become a major 'food bowl' for Asia and our beef, lamb and pork exports have increased dramatically, leading to significant intensification in our livestock industries
- The virus was introduced and went undetected for three months, due to a decade-long decline in investment in biosecurity control, surveillance and staff training
- A lack of farmer incentives to participate in on-farm surveillance has hindered detection and response and has also made it hard to identify the large number of sheep farms that have been affected, as clinical signs are difficult to detect in sheep
- It is believed that the increased number of hobby pig farmers could have created a pathway for the disease due to their close proximity to high density pig farms that are located near major feedlots
- There are insufficient numbers of veterinary staff to ensure control measures are implemented, leading to further spread of the disease

The outbreak has had significant economic and social impacts:

- Australia's beef, lamb, pork and wool industries lose market access in a number of regions and exports decrease significantly
- The local market experiences a surplus in meat and prices tumble
- Local consumers avoid red meat as they receive incorrect information via social media that FMD affects humans
- The lack of an efficient vaccine limits the options for control and leads to extended periods of movement restrictions
- There is a major animal ethics problem on numerous farms due to overcrowding as a result of movement restrictions and the inability of slaughter houses to cope with demand
- The inability to control the disease leads to trading partners losing confidence in governmental effectiveness and there are difficulties with regaining their confidence after the outbreak
- A large number of farms are closed, causing major regional community and social impacts
- After the disease is controlled, Australia is unable to regain access to some of its previous markets as they have been taken over by other producers, leading to long-term impacts
- The local market remains weak due to the distribution of false information about the risk of eating meat from vaccinated animals



ENVIRONMENT

Overview

Environmental megashocks are perhaps the most difficult to identify and understand. The threats are numerous (many of them unknown) and their potential impacts are often hard to quantify. Furthermore, even if there is a relatively sudden shock to the environment, the full effects are not likely to be realised for many years.

Environmental megashocks can have irreversible consequences as they can lead to the extinction of one or more species. Around 1,600 Australian species of plants and animals are classified as rare or endangered[149] and a megashock could devastate these already fragile ecological communities. Furthermore, many Australian species are not found elsewhere.[141] Of particular concern are keystone species that have a significant effect on their environment. The southern cassowary, for example, spreads the seeds of as many as 238 plant species in northern Queensland.[147]

In addition to assisting with the preservation of certain species, biosecurity can also help to secure the future of ecosystem services – the benefits obtained from ecosystems. These include food, freshwater, timber and wood products, carbon sequestration, pollination, climate regulation, protection from natural hazards, erosion control and pharmaceutical ingredients, as well as cultural benefits such as recreation and education. While difficult to measure, one study estimated the global economic value of ecosystem services at US$33 trillion.[277] In Australia, the national value-added economic contribution of the Great Barrier Reef was estimated at $5.7 billion in 2012.[278]

In deciding on the type of biosecurity future we want for Australia, important decisions will need to be made about how we manage the biosecurity of our natural environment and the level of investment that is appropriate.

Contributing Megatrends:

- **On the Move** – Greater global movement of people and goods is creating more opportunities for pests and diseases to enter the country
- **A Diversity Dilemma?** – Agricultural expansion, climate change and other biodiversity pressures are reducing the resilience of our environment to pests and diseases
- **The Efficiency Era** – Rising cost pressures and a push for efficiencies could lead to future disinvestment in environmental biosecurity management

Potential Megashocks

A highly virulent rust spreads across multiple ecosystems

The highly transportable nature of rusts makes them an ongoing biosecurity threat. For example, myrtle rust, a disease that affects trees and shrubs in the Myrtaceae family of plants (including species such as bottle brush, tea trees and eucalypts), was first detected in April 2010 on the NSW central coast. By December 2010, efforts to suppress and eradicate the disease were unsuccessful, resulting in a shift in effort from eradication to ongoing management.(279) The difficulty in eradicating myrtle rust is due to its poor detectability and the pace and ease with which its spores can spread. It has the ability to disperse over long distances through the wind or through the movement of infected or contaminated plants, animals, equipment, or even clothing.(280)

Myrtle rust deforms leaves, causes heavy defoliation of branches, and even leads to plant death in new growths.(281) Given the right conditions, myrtle rust can affect food sources for birds, flying foxes and other native mammals. Declines in foliage can also affect many Myrtaceae feeding insect communities, such as beetles and caterpillars, and decline in canopy growth can result in erosion, reduced water quality and weed invasion.(282)

It is yet to be seen whether the current strain of myrtle rust, once it has spread across Australia, will be considered a megashock. The difficulty in identifying environmental megashocks lies in the fact that they often play out over a number of decades – a time frame that can still be considered 'relatively sudden' when placed in the context of the history of ecosystems. Regardless of whether this strain of myrtle rust is looked back on as a megashock, this incursion illustrates our vulnerability to new rusts (or other plant pathogens) entering and establishing in our natural environment.

There is the ongoing possibility of a new strain of myrtle rust, much more virulent than the existing one, to enter the country unnoticed and cause widespread damage over an even shorter time frame. Such a megashock would have significant impacts on Australia's biodiversity and would threaten food sources of iconic species including the koala, which is linked to our global identity as well as tourism. In 1997 it was estimated that the koala contributed more than $1 billion to Australia's tourism industry – a figure that is likely to be even higher today.(283) There is also the potential for a widespread rust outbreak to lead to production losses for Australia's hardwood plantations.(284) Internationally, rust diseases have caused significant issues for the environment and/or plant industries in areas such as Central and South America, Jamaica and Hawaii.(282)

Australia's changing climate (e.g. the expectation of more extreme weather events), combined with the increasing movement of people and goods, can create improved conditions for a rust disease megashock scenario to occur. The incursion of myrtle rust in 2010 highlights the ease of spread, and the broader biodiversity loss discussed in *A Diversity Dilemma?* could help to further stress the natural environment.

Myrtle rust.

The government 'walks away' from environmental biosecurity

A potential megashock could be caused by the government 'walking away' from its environmental biosecurity efforts, despite existing international commitments (e.g. Convention on Biological Diversity).

Environmental biosecurity activities can be costly. For example, approximately $500,000 a year is spent trying to eradicate one woody weed species in Kakadu National Park.(143) While the costs of environmental biosecurity activities can be easy to understand, the benefits are often debated and largely unquantifiable in dollar terms, making it difficult to develop meaningful estimates for return on investment.

Where environmental biosecurity issues cross over with primary industries, however, the impacts are easier to quantify. Beyond environmental and social impacts, the cost of weeds to Australian agriculture is estimated at more than $4 billion per year.(143) From a global perspective, it has been reported that conserving fish stocks would cost between $800 million to $3 billion per year from 2013 to 2020 but there is the potential for global fisheries to be worth $50 billion per year.(285)

The challenge of understanding the benefits of environmental biosecurity is compounded by the sheer size of Australia's land mass as well as the range of ecosystems, pests and diseases that need to be managed from an environmental perspective. Given the long-term horizon of impacts, the responsibility for environmental biosecurity and associated funding is often left to governments. With rising biodiversity pressures, greater movement of people and goods, and declining resources, the biosecurity costs of eradication or management may one day increase to the point where the government declines to invest. If this does happen, the full effects across health, industry and the environment are hard to predict and could be irreversible.

2040 Exotic Myrtle Rust Scenario

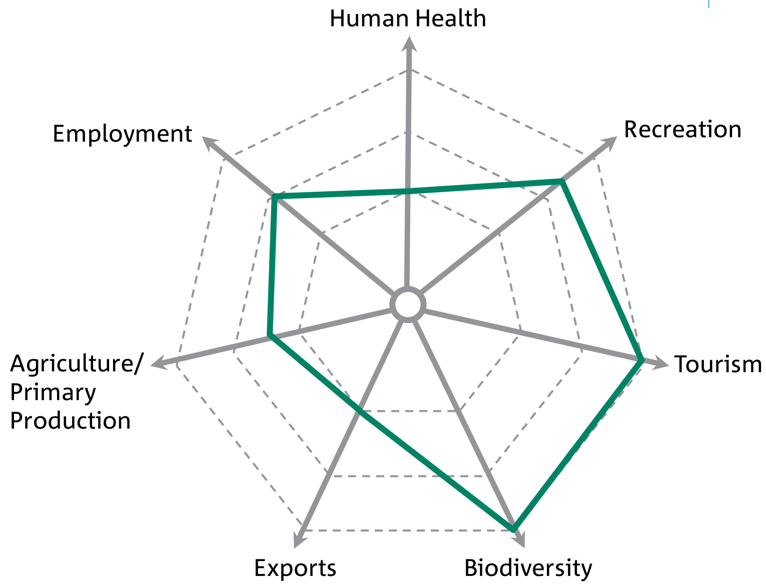
It's the year 2040 and a more virulent strain of myrtle rust has been found in Australia, causing widespread damage to ecosystems around the country.

There are a number of factors that have led to this outbreak:

- Growing biodiversity pressures (e.g. more bushfires relating to climate change, invasive species) have significantly reduced the resilience of the natural environment to compensate for the impacts of new diseases
- The rust is believed to have entered via contaminated equipment or clothes via trade or a traveller and it has hybridised with existing strains to become more virulent
- Extreme weather events as well as greater interstate plant trade and freight movements have helped to spread spores across the country
- Environmental biosecurity is not seen as a national priority and, as such, there is no contingency plan for emergency response to the incursion
- A lack of understanding about the impact of rusts on forests and Myrtaceae species, due to a lack of research in this area, has also limited our ability to respond

The outbreak has had significant economic, environmental and social impacts:

- Several Myrtaceae plant species become threatened and food plants of the koala and several other species are also affected, leading to these animals becoming critically endangered or extinct
- The event is publicised around the world, damaging our reputation as a travel destination with significant impacts on tourism (particularly the highly lucrative Chinese market)
- Forestry production suffers as the rust affects plantations
- The composition of species in native forests changes, affecting entire ecosystems and the services they provide
- There is public uproar as Australians question why more effort wasn't made to protect our natural environment



MARINE

Overview

Marine megashocks incorporate both shocks to industry (e.g. fisheries, aquaculture, and shipping and port operations) and the environment. As an island nation, Australia's oceans are important in facilitating trade, aquaculture and fisheries production, and tourism, as well as providing a source of recreation for local residents. Australia relies on sea transport for 99 per cent of our exports,[286] national fisheries and aquaculture production had a gross value of $2.3 billion in 2011-12,[37] and the Great Barrier Reef was associated with $5.7 billion in value in 2012.[278]

The CSIRO Biosecurity Flagship held a two-day marine biosecurity workshop in 2013 that brought together key stakeholders across industry, government and the science community. The workshop concluded that there are significant threats in marine biosecurity that are poorly recognised. There are two important reasons for this: comparatively little is known about biosecurity in marine environments, and risks are not necessarily recognised because they are not immediately visible (i.e. it seems to be a case of 'out of sight, out of mind'). However, with increased port development and global shipping, we need to better acknowledge and prepare for the risks that exist.[287]

The invasion of marine ecosystems by non-indigenous species continues to increase and the control and eradication of invasive marine species is both technically and financially difficult. Each year, more than 11,000 vessels from 600 overseas ports visit Australia's 65 major ports.[288] Globally, it is estimated that more than 3,000 organisms are transported in ballast water every day.[287] Of these, 494 species are known to be established in Australian waters, including 156 that are native, 129 that are non-native and 209 that are of unknown origin.[114] However, it is likely that as few as five to eight of these pests are of real concern.[287]

Understanding and responding to marine biosecurity risks is comparatively more complex than terrestrial biosecurity threats, making collaboration and technology even more important in finding solutions that can increase our level of preparedness.

Contributing Megatrends:

- **An Appetite for Change** – Expansion and intensification of aquaculture production could increase the potential impacts of a pest or disease outbreak
- **On the Move** – Greater international vessel movement will increase the opportunities for pests and diseases to enter our waters
- **A Diversity Dilemma?** – Warming ocean temperatures may see pests and diseases move into new areas
- **The Efficiency Era** – Declining resources could limit our ability to prevent and respond to a pest or disease outbreak

Potential Megashocks

The successful establishment of black-striped mussel

Invasive marine species can be difficult to eradicate and can cause severe consequences to aquaculture and fisheries operations, navigation, cooling water systems, public health and native biodiversity.[289] One invasive species that has attracted a lot of attention in recent years is the black-striped mussel, which was first recorded in Australia in 1999 across several Darwin marinas. Although the mussel is not known to have established since, the black-striped mussel has been listed as a Class 1 noxious species in all NSW waters and it is believed that an incursion could devastate a range of marine industries such as shellfish, fishing and tourism.[290]

The black-striped mussel can cause significant fouling on wharves and marinas, sea water systems (e.g. pumping stations and cooling systems) and marine farms (e.g. pearl oysters and aquaculture sites).[291] Fouling can also cause issues for shipping as it leads to a need for increased vessel maintenance, decreased fuel efficiency and blocked or damaged pipes. For example, hull fouling has the ability to increase drag causing greater fuel costs, and an infestation in engine cooling systems has the ability to cause overheating and damage.[290] While containment and eradication costs related to the 1999 black-striped mussel incursion were only $2.2 million,[290] they could have been significantly higher if the incursion had not been detected early. In the US it is believed that the invasive zebra and quagga mussels, close relatives to the black-striped mussel, led to costs in excess of US$5 billion between 1993 and 1999 due to cleaning and control exercises.[292] The prolific breeding and rapid growth of the mussel also has the ability to reduce native biodiversity, creating dense mats of mussels that can exclude other species.[290]

Black striped mussels.

While native to eastern Pacific waters from the Gulf of Mexico to Columbia,[291] the black-striped mussel can easily be transported via the hull of a commercial or recreational vessel, or as larvae in ballast water (although this is considered less likely due to their short larval stage).[290] The Darwin Harbour incursion of the black-striped mussel is believed to have been caused by biofouling on the hulls of yachts and it is suspected that the mussel was introduced to Hong Kong via a refugee boat.[293] The mussel has already invaded ports in a number of Indo-Pacific countries including India, Singapore, Taiwan, Japan, Hong Kong and possibly Fiji.[290]

With an ability to survive in a wide range of temperatures (5-40 degrees Celsius) and salinities (0-50 parts per thousand), the black-striped mussel has the potential to establish along the northern coastline from Fremantle in WA to Sydney in NSW, as well as in the warmer parts of the Spencer and St Vincent Gulfs in South Australia.[290] A changing climate, in particular warmer ocean temperatures, is allowing native and invasive species to move to new areas,[294] which may have the potential to alter the impacts of the mussel. Furthermore, experiments conducted on zebra mussels indicated that higher temperatures could enhance growth rates.[295]

There are a number of factors that could inhibit our ability to respond to a black-striped mussel incursion as effectively as we did in 1999, leading to a potential future megashock scenario. Increasing vessel numbers and movement continue to create new opportunities for the mussel to enter our waters and affect marine industries. For example, the detection of the mussel on Indonesian fishing boats apprehended in Western Australian waters highlights the potential risk to the region's pearling industry,[296] worth close to $100 million in 2011–12.[37]

While eradication in regions such as NSW is already considered extremely difficult and costly, if not impossible,[297] the challenge would be made worse if biosecurity resources and surveillance efforts decline. At the same time, a greater reliance on our ports could increase the economic impact of the pest. Given the extent of the spread of similar mussels in the US, it would be naive to think that the black-striped mussel poses no risk to our inshore ecosystems, although further research is required to quantify the levels of risk that exist.

An outbreak of infectious salmon anaemia

The value of the salmon industry to Australia's fisheries sector cannot be understated. Between 2001-02 and 2011-12 the value of farmed salmonids (mainly Atlantic salmon and a small portion of trout) grew by 211 per cent and production volumes increased by 171 per cent. The industry accounted for 49 per cent of the total value of Australian aquaculture production and 22 per cent of the total value of fisheries production in 2011-12.[37] Tasmania was responsible for around 99 per cent of salmonids production in 2011-12[37] and the industry is planning to double production in the region by 2030.[39] A disease outbreak in salmon (such as infectious salmon anaemia) across south-east Australia is therefore a potential megashock of concern for Australia's fisheries industry.

Infectious salmon anemia (ISA) is a viral disease exotic to Australia that has the potential to cause large-scale mortality in salmon populations and can spread through the transportation of infected young salmon or through contact with contaminated equipment.[298] Salmon disease outbreaks have occurred in Scotland, Norway and Canada with one of the most significant cases occurring in Chile where the 2007 discovery of ISA led to a drop in production from 386,000 tonnes in 2006 to 98,000 tonnes in 2010.[299] While the industry growth experienced in Australia has been supported by research and development related to disease control measures,[37] continued intensification of production may lead to larger volumes of fish kept in close proximity, increasing the ability of one infected fish to affect national production.

2040 Black-Striped Mussel Scenario

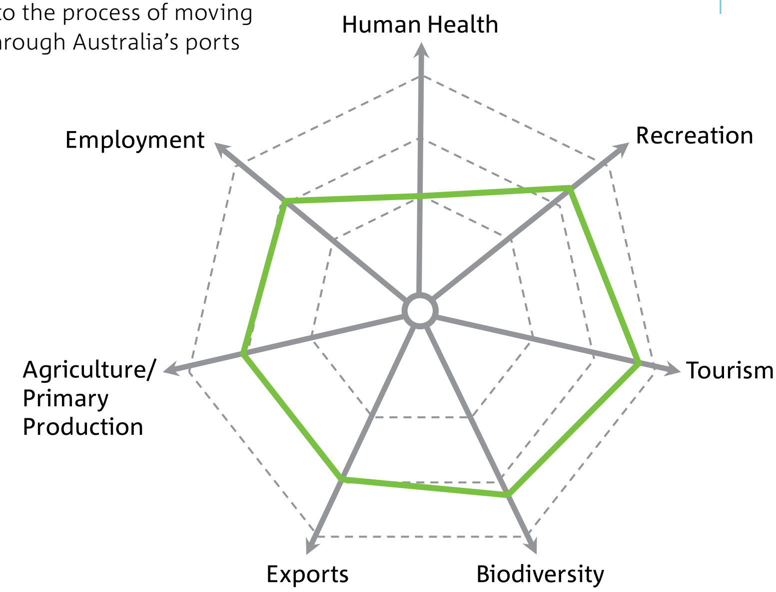
It's the year 2040 and the black-striped mussel has successfully established along Australia's coastline, disrupting port and shipping operations, aquaculture industries, and out-competing native species.

There are a number of factors that have led to this outbreak:

- Agricultural expansion in northern Australia has seen new port developments and increased shipping in the region
- Investment in biosecurity capacity and capabilities in the region hasn't kept up with this expansion
- Increased shipping has led to the black-striped mussel being introduced via biofouling and it goes undetected for a number of months due to a lack of surveillance

The outbreak has had significant economic, environmental and social impacts:

- Significant disruptions occur across Australia's ports due to significant fouling of vessels and infrastructure
- Relationships with trading partners are affected as a new layer of complexity (and cost) is added to the process of moving ships through Australia's ports
- Fouling on aquaculture equipment significantly increases costs for producers, leading to an increase in the price of some seafood products in Australia
- Coastal tourism and recreation are negatively affected as native coastal communities are smothered by monocultures of this exotic pest



HUMAN HEALTH

Overview

The megashocks met with the highest degree of concern are often those with the potential to have a widespread impact on human health. With a growing population and increased travel, future pandemics could have disastrous consequences. The World Health Organization (WHO) writes that "it would be extremely naïve and complacent to assume that there will not be another disease like AIDS, another Ebola, or another SARS, sooner or later."[300]

We have seen enormous improvements in medical research and the provision of health care around the world since the Spanish flu outbreak of 1918 that infected 25 per cent of the global population.[95] In spite of this progress, it is estimated that a similar global pandemic influenza today could affect the same proportion of people.[301] While in the event of a global pandemic such as this, most fatalities, sadly, are likely to be experienced in the developing world,[302] Australia cannot become complacent. Even if we were fully prepared to respond to a pandemic of this severity, we would still likely see around two million Australians become infected and around 25,000 deaths.[303]

With an ageing population and greater incidence of chronic disease, increasing pressure continues to be placed on Australia's health care system, which could limit our future responsiveness in the event of a disease outbreak. We cannot just think about our ability to respond to an infectious disease outbreak today. We need to ensure we are prepared for how the world will change in the coming 20-30 years and how the risk or impact of an infectious disease outbreak in Australia may change in response to this.

Contributing Megatrends:

- **An Appetite for Change** – If poorly managed, intensified agricultural production systems and agricultural expansion can increase the risk of a zoonotic disease outbreak
- **The Urban Mindset** – A growing population and urbanisation, particularly in developing countries, is increasing the potential risk for an emerging infectious disease outbreak. Urban encroachment and peri-urbanisation are also changing interactions between people, wildlife, agriculture and disease vectors, increasing the risk of diseases passing from animals to humans
- **On the Move** – Greater global travel increases the risk of any future disease outbreak quickly becoming a global pandemic. It can also help to facilitate the spread of antibiotic and antiviral resistant diseases
- **A Diversity Dilemma?** – Biodiversity loss can increase the risk and incidence of zoonotic diseases
- **The Efficiency Era** – Declining biosecurity resources may limit our ability to develop the vaccines, therapeutics and surveillance technologies required to limit the effects of emerging infectious diseases on the Australian population

Potential Megashocks

A nationwide zoonotic disease epidemic

Recent decades have seen a rise in emerging infectious diseases in humans, of which more than 70 per cent are zoonotic (diseases that can pass from animals to people). The WHO and emerging infectious disease experts generally agree that the next human pandemic is likely to be caused by an outbreak of a zoonotic disease, probably transmitted from wildlife.[304] The zoonoses of particular concern are those that have the potential to transmit from their animal reservoir into people and then spread through subsequent human-to-human transmission.

The SARS epidemic of 2003 is believed to have started after a SARS-like virus, which had remained dormant in bats for some time, was passed on to civet cats and a mutation occurred in the new host. Civet cats are consumed as food in some parts of Asia and the trade and consumption of these animals is thought to have led to human infection.[305] This disease then spread to more than two dozen countries through human-to-human transmission and resulted in 774 deaths.[306]

The H1N1 (swine flu) epidemic in 2009 was derived from several viruses circulating in pigs and quickly spread to 30 countries,[307] including Australia where nearly 200 deaths resulted from the pandemic.[308] While the H5N1 strain of avian influenza hasn't led to sustained transmission of the virus between people, there is concern that the virus could change and a strain could develop that is transmissible between people and to which we would have little or no immunity.[309]

More than 200 zoonoses have been described[310] and significant investment has been made in research and management of some of those known to pose significant risk. However, the next pandemic could be the result of a currently unknown zoonotic agent.[304]

Due to the risks associated with zoonotic diseases, the importance of the One Health concept in understanding and managing emerging infectious diseases has been widely acknowledged. One Health recognises that human, animal and ecosystem health are inextricably linked and multi-disciplinary collaboration is required to support new health strategies in this area.[238]

Based on existing trends, a national outbreak of a zoonotic disease is a potential human health megashock for Australia. So far, the impacts of these diseases on Australia have been well-managed, with the number of deaths caused by H1N1 far less than originally estimated.[311] However, increased global trade and travel are creating opportunities for emerging infectious diseases and their vectors (including antibiotic and antiviral resistant diseases) to more easily spread around the world.

Densely populated cities, particularly in countries with relatively low health standards, can act as pathogen incubators increasing the risk of an outbreak. Furthermore, urban encroachment and peri-urbanisation, as well as agricultural expansion, are creating changing interactions between people, livestock, wildlife and disease vectors that could help to facilitate an outbreak. An increase in the intensification of our agricultural production systems (without an appropriate increase in biosecurity efforts) could heighten the risk of zoonoses, as could continued biodiversity losses. At the same time, declining biosecurity resources could limit early detection of and rapid response to zoonotic disease threats and outbreaks.

A bioterrorist attack

In an increasingly globalised world, the potential for a bioterrorist attack based on an emerging infectious disease cannot be overlooked as another potential megashock. This is particularly important in light of declining biosecurity resources, which may limit our ability to develop vital vaccines, therapeutics and surveillance technologies and reduce our overall preparedness for such an attack. At a Harvard School of Public Health forum in 2012, panellists discussed how a different form of H5N1, one that could now pass from mammal to mammal, was created in laboratories to help prepare public health groups for a possible pandemic.

While such research was done with the best of intentions, questions were raised about potential unintended consequences that could arise, from bioterrorism to an accidental release to blanket secrecy that could stymie sharing of scientific information. David Franz, a former commander in the US Army Medical Research Institute of Infectious Diseases, said that while the powerful tools of infectious disease research and biotechnology have been almost universally used for good, "we can't ignore the small possibility that they might be used for harm either accidentally or even intentionally".[312]

A rapid spike in antimicrobial resistance

The overuse and misuse of antibiotics in medicine and agriculture is leading to the worldwide emergence of drug-resistant strains of bacteria.[29] Increased global travel is also helping to facilitate the spread of antibiotic-resistant infections.[99] A report from the WHO has shown that antibiotic resistance (when bacteria change and render antibiotics ineffective in treating human infections) is a major threat to public health. According to Dr Keiji Fukuda, WHO's Assistant Director-General for Health Security, "without urgent, coordinated action by many stakeholders, the world is headed for a post-antibiotic era, in which common infections and minor injuries which have been treatable for decades can once again kill".[313]

Resistance to antiviral medication is also a major concern. In 2005, two Vietnamese patients died from an infection of A(H5N1) influenza virus (avian influenza) with high-level resistance to oseltamivir (marketed as Tamiflu).[314] A rapid increase in the pace of antimicrobial resistance is therefore another potential human health megashock to be considered. Such a megashock could see us lose important tools for managing infectious disease with potentially catastrophic consequences.

2040 Avian Influenza Scenario

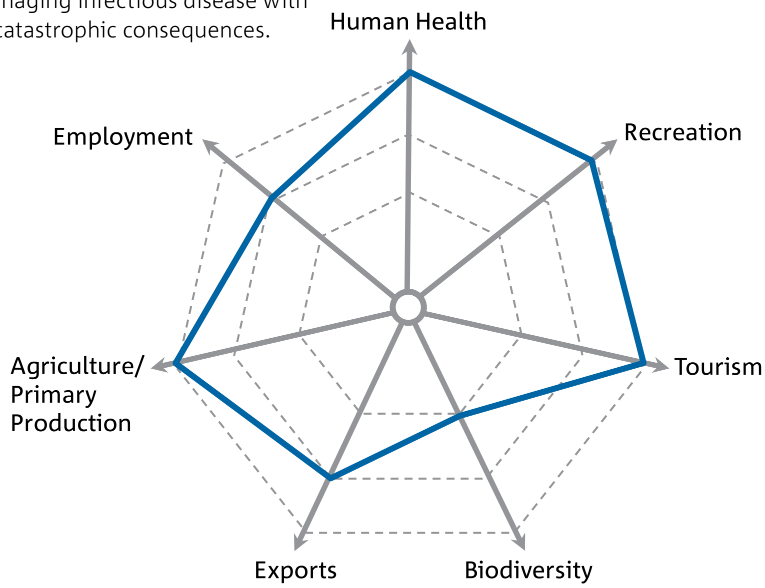
It's the year 2040 and a national outbreak of a new strain of avian influenza has occurred in Australia, significantly impairing poultry production, with widespread human infection.

There are a number of factors that have led to this outbreak:

- Demand for poultry products has continued to increase due to a growing global population
- Rising wealth in developing regions has led to a greater demand for free-range poultry products
- Australia has become a larger exporter of poultry products due to an increased commitment to free-range production
- Australian poultry farms have intensified in order to meet the growing local and global demand
- A new strain of avian influenza has evolved, transmitted from wild birds on free-range farms
- General response has been slow due to a multi-year decline in surveillance investment
- The virus is transmitted to poultry workers and has mutated to enable human-to-human transmission
- The strain is found to be resistant to existing antiviral treatments and there are no suitable vaccines available

The outbreak has had significant economic and social impacts:

- Australia's healthcare system is placed under significant strain with a lack of hospital beds
- Productivity drops significantly due to the level of workplace absenteeism
- Inbound tourist arrivals come to a halt, with significant economic impacts and job losses in hospitality and other areas related to tourism
- Sporting events (and other recreation events) are cancelled as they are seen as a high risk environment for disease spread
- Millions of poultry are culled around the country, creating a sudden drop in meat and egg production and the loss of jobs across the sector
- Australia loses its reputation as a preferred supplier of free-range poultry products
- Supermarkets struggle to keep the shelves stocked as people fill their pantries out of fear and a desire to avoid leaving the house
- Other types of meat are in short supply and meat and egg prices increase dramatically



The Way Forward

"... it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Lewis Carroll, Through the Looking-Glass (1871)

The megatrends illustrate the unparalleled change that is increasing the complexity of the biosecurity landscape and the decisions we will face. Unfortunately, the pace and scale of these changes (both globally and locally) are arguably so great that maintaining our envious biosecurity position is not a simple proposition. Analogous to the Lewis Carol quote (above), the changing environment will require us to significantly *improve* our biosecurity system just to maintain Australia's *current* level of preparedness.

The intersection of greater levels of urbanisation, increased movement of people and goods, the expansion and intensification of agriculture, and ongoing environmental pressures is creating more opportunities for the entry and spread of pests and diseases. At the same time, a loss of agricultural and biosecurity knowledge and resources could reduce our ability to respond to a biosecurity shock. With growing biosecurity challenges and declining resources, we appear to be setting ourselves up for the perfect storm. While technology and science offer significant opportunities to improve the situation, we need to act now to make the necessary decisions that will allow us to better control the biosecurity challenges we will face in the future.

Biosecurity as an enabler

Biosecurity is generally regarded as a means of insuring against potential pest and disease threats to avoid the associated negative consequences. In this way, our biosecurity efforts can help to protect the value of our primary industries, preserve our natural ecosystems, and protect the health of the population and societal wellbeing.

While biosecurity plays an important role in helping to insure against risk, it should also be thought of as an enabler. Our reputation as a relatively 'pest and disease free' nation helps to differentiate our produce in the global marketplace as well as facilitate export growth through market access opportunities. Biosecurity can also play an important role in enabling the sustainable agricultural expansion and intensification required to realise the growth opportunities that exist for our agricultural sector.

If we are able to build and maintain a reputation as a world-leader in biosecurity management while biosecurity becomes a growing concern around the world, we may see an opportunity to grow our exports of knowledge and services in this area. As biosecurity challenges increase, countries interested in improving their food safety standards may seek our help, which can provide long-term benefits to international relationships and reduce global biosecurity risks. Therefore, it is important to recognise that our biosecurity efforts don't just insure us against the threats that exist; they also create opportunities for growth and prosperity for the nation.

Moving towards common solutions

In order to remain prepared in the face of growing complexity, as well as capitalise on the opportunities that a world-class biosecurity regime presents, we need to improve our ability to identify shared and common solutions, maximising our resources and return on investment. This is important as the biosecurity successes and failures in one area or industry are intertwined with fate of the others. We need to understand the interrelationships within our biosecurity system and look beyond short-term solutions that provide certainty in a single field or industry. A short-term approach inevitably creates competition for scarce resources and funds rather than identifying the opportunities for longer-term, multi-industry, cross-disciplinary solutions that will deliver better results.

Developing common solutions will require improved clarity around roles, responsibilities, co-dependencies and funding across federal and state government, as well as industry and the general community. This will be important with regards to all stages of the biosecurity continuum (pre-border/border/post-border). As the biosecurity landscape incorporates a diverse group of stakeholders with different motives and needs, a move towards 'common solutions' does not mean the development of one-size-fits-all technology, science and policy solutions – our national challenges are far too complex for that. The shift is predominantly behavioural and one that requires greater consensus on the opportunities and challenges that exist, how these are changing as a result of local and global trends, and how this will influence the biosecurity threats we may face in the future. It also requires greater cross-pollination of experts and decision makers, and more organisations, agencies and industry groups that are able to cut across traditional silos and enable greater coordination and collaboration.

Developing a balanced biosecurity regime

It is clear that finding common solutions will involve coordination across government (both federal and state-level), industry and the science and research community. As the biosecurity landscape grows increasingly complex, a truly collaborative and integrated system will be necessary if the biosecurity efforts across these different groups are to be truly successful in managing risks and enabling opportunities for Australia. Only when these three stakeholder groups (and the many subgroups within them) work together will Australia be able to develop a balanced approach to biosecurity. This involves maximising science and technology opportunities for efficiency; creating a broader understanding of biosecurity risks, consequences, benefits and responsibilities through greater levels of education and engagement; and improving the biosecurity operating environment through appropriate levels of policy and governance.

One area alone cannot adequately address the challenges. For example, policy will increasingly rely on scientific and technological advances to facilitate more effective decision making and ensure efficiency in implementation. Similarly, greater levels of farmer communication and engagement will need to be supported by policy that incentivises and technology that facilitates the implementation of biosecurity standards. An approach that balances policy initiatives, science and technology investment, as well as education and communication will therefore be most effective in meeting our future biosecurity needs.

A balance also needs to be achieved between biosecurity prevention and response activities, which have differing timescales and pay-back periods.

- *Response* activities include pest or disease containment, control, eradication (where possible) and recovery. They require immediate investment and resources, and often have a visible economic, environmental or social case for action
- *Prevention* activities require long-term and ongoing investment to better understand and monitor potential pests or diseases. It is often harder to justify investment in this area as the benefits are not always easily visible

Importantly, this balanced approach will need to be achieved in light of budgetary constraints and competing national priorities, resulting in a complex array of questions and considerations regarding the future of biosecurity for Australia.

Key considerations to guide the future

Based on the findings from this report, the following table identifies some of the most important biosecurity considerations across the areas of policy, science and technology, and communication and engagement. In the table the term 'we' is used to refer to the collective biosecurity community (incorporating government, industry, and science and research). While not intended to be exhaustive, the table aims to spur discussion and highlight priorities as input to the development of any future biosecurity strategies.

With growing complexity and declining resources we seem to be on a path towards an uncertain biosecurity future. However, Australia's existing biosecurity system provides a strong foundation to anticipate and prepare for the future challenges illustrated throughout this document. The biosecurity community is in a position to work together to make the decisions and collectively take the actions required to put us on the necessary trajectory to address the known threats, anticipate the likely but unclear threats, and create new growth opportunities for our primary industries and our economy as a whole.

The table on the following pages outlines some of the most important considerations that provide a starting point for this process. Decisions will need to be made regarding which of these considerations to pursue further to ensure we protect and enhance our economy, our environment, and our health and wellbeing, through a commitment to securing Australia's biosecurity future.

1 Policy

PREVENTION ACTIVITIES

1.1. How do we secure sufficient funding for long-term biosecurity prevention activities without detracting from other national priorities? Are there opportunities for new funding models such as a national levy, broader industry responsibility for funding along the value chain (e.g. supermarkets), insurance and/or philanthropy?

1.2. How do we make sure prevention activities are proactive and well maintained given that success often breeds complacency? Put another way, how can we maintain investment without having to see a major crisis locally or overseas?

1.3. How do we ensure policy keeps up with changing biosecurity risks driven by changes in market demand? For example, have our policies and practices in poultry kept up with demand for free-range in a way that allows us to appropriately manage the risks involved? Are we well prepared to manage the risks created by the vertical integration of national food supplies?

1.4. What incentives could be created to increase farmer and industry participation in surveillance (onshore and offshore)? Is there an opportunity to incorporate biosecurity responsibilities in land tenure agreements or property registrations?

2 Science & Technology

PREVENTION ACTIVITIES

2.1. How can we best leverage smaller and smarter sensor technologies for monitoring – for example, to monitor for the presence of wild animals (e.g. ducks on free-range farms or feral animals) or to understand environmental conditions (e.g. climate) in order to better predict risk levels?

2.2. Are we fully exploring the potential opportunities that exist for a single monitoring system to detect multiple pests and diseases, rather than developing unique surveillance systems for each potential threat? Are we making the most of the current surveillance and monitoring systems that we have in place?

2.3. How can advancements in diagnostics be leveraged for early identification and understanding of future disease strains and pathogens? How can this be incorporated into long-term preventative strategies such as preventative breeding programs?

2.4. How can we develop and leverage a better understanding of the relationship between biodiversity and biosecurity?

2.5. How can trends related to citizen science be further embedded in national and industry biosecurity efforts? How can we ensure that citizen science data and analysis is scientifically valid and useful?

2.6. How can we develop a more integrated system for managing data that allows decision makers to more easily take a holistic view of biosecurity issues across the country?

2.7. How can we leverage scientific models and predictive analytics to improve decision making and certainty in response situations?

3 Communication/Engagement

PREVENTION ACTIVITIES

3.1. How can social and behavioural sciences be leveraged to improve general public perceptions and behaviours related to biosecurity? Importantly, what level of attitudinal and behavioural change is really appropriate - i.e. how do we ensure we aren't investing in campaigns that don't deliver the necessary benefits?

3.2. How can the Australian biosecurity community better engage and educate hobby farmers and amateur producers across the country?

3.3. How can social media and new online communication channels be maximised to cost-effectively communicate biosecurity values and drivers and create a long-term, two-way dialogue with a wide set of stakeholders, including the community?

RESPONSE ACTIVITIES

1.5. How do we ensure that our response considers all areas of potential impact, such as the potential environmental impact of an industry megashock?

1.6. How do we ensure measured responses to threats? In particular, how do we ensure that improvements in surveillance don't lead to an unnecessary level of response? On the other hand, how do we avoid underestimating seemingly small threats that have long-term implications?

1.7. What policies are required to ensure that Australia has the skills and capabilities to respond to national threats in the context of our ageing workforce and declining resources in biosecurity?

1.8. How do we ensure that resource and funding agreements are in place such that bureaucracy and governance challenges do not stifle our responsiveness? How can we ensure we have the 'fighting funds' required to respond immediately, in the case that the lines of responsibility aren't initially clear?

1.9. How do we ensure that jurisdictions are working together as effectively as possible to allow for a nationally coordinated approach when responding to biosecurity threats?

RESPONSE ACTIVITIES

2.8. How can traceability and surveillance be maximised to increase the speed at which we can regain a disease free status?

2.9. How can technology be used to improve collaboration and knowledge sharing between industry, government and the research community during response situations?

2.10. How might autonomous systems and advances in robotics be applied to improve the effectiveness of our biosecurity response?

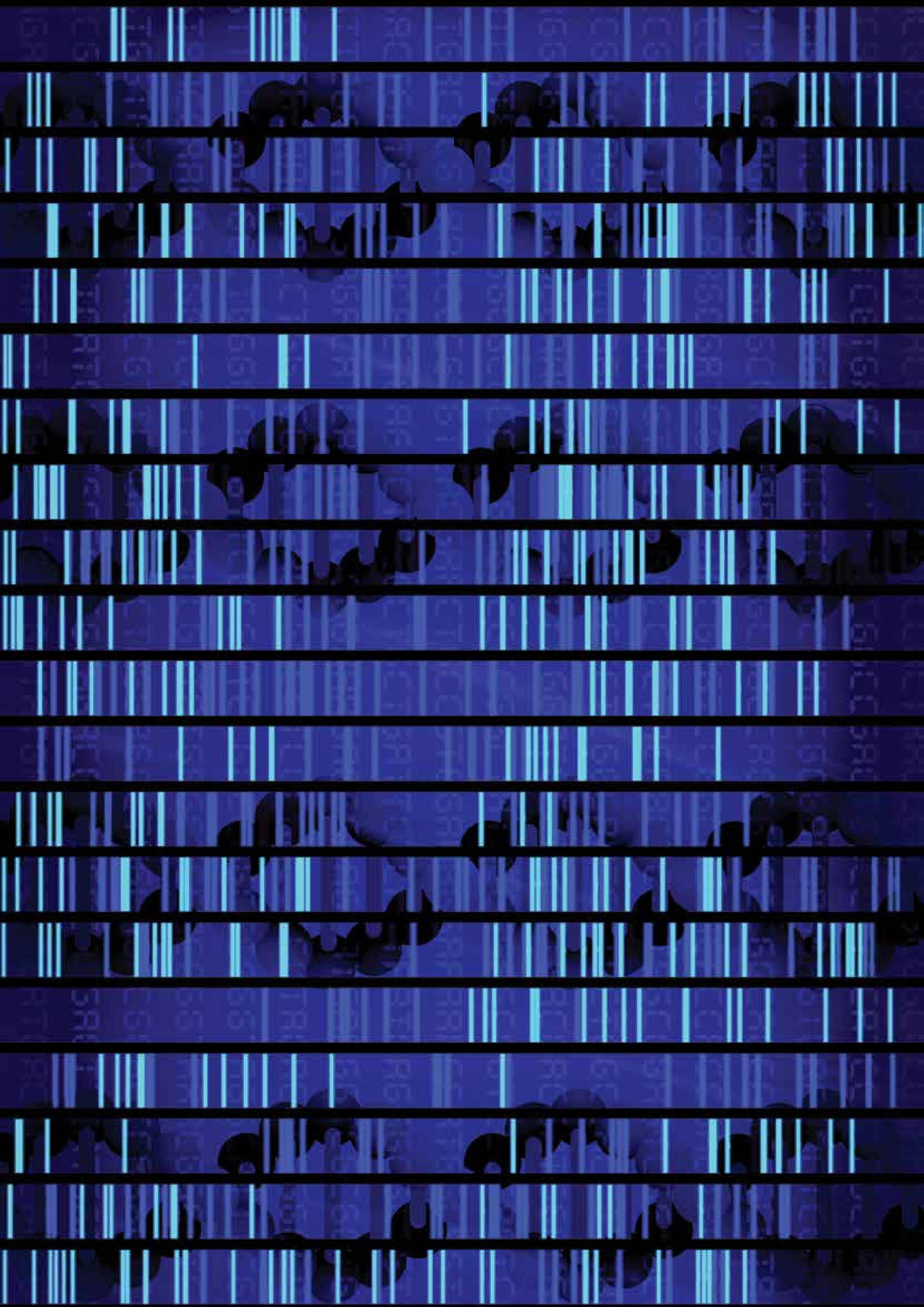
2.11. How can we use technology to improve on-farm or on-site real-time diagnostic testing in order to reduce the need for sample collection followed by high cost laboratory-based diagnostics and dramatically improve our speed of response?

RESPONSE ACTIVITIES

3.4. How can we ensure that online communication channels are not hijacked by misinformation or one-sided information during a biosecurity crisis?

3.5. Given the complexity of the national biosecurity landscape, how can education and communication ensure that public overreaction/panic is avoided during megashock events?

3.6. How can we use communication to bring together the disparate biosecurity community in order to facilitate a faster and more effective response? How can we ensure that we quickly mobilise all relevant industries, hobby farmers and even the general public, if and when it is required?



Partners

CSIRO Biosecurity Flagship

The CSIRO Biosecurity Flagship assembles strong multi-disciplinary research teams, spanning the critical areas of environment, animal and human health, to tackle the major national and international biosecurity challenges critical for Australia's ongoing agricultural sustainability and environmental and human health. We work with government and industry to assist in bringing scale and connectivity to help Australia prevent, prepare for and respond to the spread and impacts of pests, weeds and diseases and are achieving this by working across the biosecurity continuum – investigating risks offshore, at the border, as well as monitoring what is happening in our own backyard.

We explore new technologies to assist in improving Australia's surveillance and detection, sensitive diagnostics and response management, and we continue our science endeavours to pre-empt and respond to the next human pandemic.

Overall we aim for a biosecurity system that is pre-emptive, responsive, resilient, and based on cutting edge surveillance, informatics and new technologies.

CSIRO Futures

CSIRO Futures is the strategy and foresight advisory arm of Australia's national science agency. We work with government and industry clients to help them develop informed strategies to address significant opportunities and challenges brought about by long-term economic, environmental, social and technological trends. The services we provide focus on the role that science, technology and innovation can play in creating competitive advantage and driving economic sustainability.

Animal Health Australia

Animal Health Australia (AHA) manages national programs and projects that improves animal and associated human health, biosecurity, market access, livestock welfare, productivity and food safety and quality.

We play a key role in maximising the effectiveness of partnerships and consultative mechanisms to ensure Australia's commitment to the broad implementation of effective biosecurity.

Our work helps underpin local and international confidence in Australia's animal health systems – thereby safeguarding access to domestic and international markets.

AHA is also responsible for managing the internationally recognised Emergency Animal Disease Response Agreement (EADRA) framework. The EADRA deed is acknowledged as a world-first response model that brings animal industries and Australian governments together in cooperative partnerships that enable us to prepare for and respond to exotic diseases.

We have 32 members spread across five categories: the Australian Government, state and territory governments, industry, service providers and associate Members. Our livestock membership covers the spectrum of Australia's livestock industries.

The Invasive Animals CRC

The Invasive Animals CRC is one of the world's largest integrated pest animal research and management collaborations. It is a 27 member partnership to develop new knowledge, products, strategies and services that deliver more strategic and efficient pest animal control. The Invasive Animals CRC collaboration involves:

- a powerful mix of industry investors, research providers, commercial businesses and extension organisations that cover all key points on the value chain from R&D to adoption
- industry and government investors to ensure a strong and practical end-user focus
- deep research capability in a variety of key areas including ecology, biocontrol, environmental genomics, modelling, new toxin development, and community engagement
- key overseas research and commercial partners in New Zealand, US and the UK to facilitate knowledge and technology transfer, and build critical mass to tackle problems of shared concern
- commercial businesses to take new products to market and grow jobs.

The Plant Biosecurity Cooperative Research Centre

The Plant Biosecurity Cooperative Research Centre (PBCRC) was established in 2012 as an extension of the Cooperative Research Centre for National Plant Biosecurity, in recognition of the need to strengthen Australia's biosecurity shield and build the nation's plant biosecurity scientific capacity.

PBCRC has an extensive collaborative network of researchers and educators from 27 Australian and international participating organisations, representing industry, universities, and state and federal government. The involvement of PBCRC participants ensures maximum benefit and impact in the delivery of project outputs, development of new products and services, and capture of intellectual property.

With the involvement of end-users, PBCRC develops and deploys scientific knowledge, tools, resources and capacity to safeguard Australia, its plant industries and regional communities from the economic, environmental and social consequences of damaging invasive plant pests and diseases. The CRC program is an Australian Government Initiative that supports end-user driven research collaborations to address the major challenges facing Australia. Australia's network of CRCs operates across all sectors of the nation's economy and society.

CSIRO

AnimalHealth AUSTRALIA

Invasive Animals Cooperative Research Centre

CRC PLANT biosecurity

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