

INVASIVE PLANTS & ANIMALS COMMITTEE

National RD&E Priorities for Invasive Plants and Animals

2016-2020

By the Invasive Plants and Animals Research & Development Expert Group

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Summary

- Pest animals and weeds cause significant impacts to Australia’s economy, environment and community, with economic impacts alone costing Australia well over \$7 billion every year.
- Strategic direction of pest animal and weed RD&E in Australia is currently provided by a diverse range of government and industry committees, working groups and strategies. Improved coordination by government and industry through collaborative efforts is needed across these areas. The Invasive Plants and Animals RD&E Working Group was established to address this need.
- Industry driven approaches where relevant are essential, especially for established pests and weeds of national significance.
- The National Biosecurity Committee has proposed an approach to ‘modernise’ Australia’s approach to established pests and weeds, which sets out some guiding principles for investment. In particular, setting priorities involves consideration of:
 1. maximising return on investment using the biosecurity continuum, and
 2. national significance and the national interest test—to guide decisions on the form and extent of national intervention or management
- This paper outlines the strategic context for framing and identifying RD&E priorities for pest animals and weeds, summarises the key considerations and process to date, and identifies national industry and government RD&E priorities for invasive plants and animals.
- Twenty-two national RD&E priority areas for Invasive Plants and Animals are recommended for 2016-2020 within 4 programs:
 1. New approaches to detection, prevention and eradication
 2. Biocontrol
 3. New and sustainability of existing management options, and
 4. Socioeconomic drivers of adopting best practice

1. Introduction

Pest animals and weeds cause significant impacts to Australia's economy, environment and community, with economic impacts alone costing Australia over \$7 billion every year. Government, industry and the community all seek better solutions and greater coordinated effort, and a longer term approach is needed. This is essential in protecting Australia's food security and biodiversity assets. A recurring theme is the on-going need for improved coordination of research and innovation resources between Governments, universities, industry and the community.

The Invasive Plants and Animals Research and Development Expert Group was established by the Invasive Plants and Animals Committee (IPAC) to address this need. Specifically the group will facilitate the establishment of a collaborative national system undertaking high priority invasive plants and animals Research, Development and Engagement (RD&E) to reduce pest and weed establishment, spread and impacts. Importantly this group includes key industry (RDC), as well as government representatives to provide oversight for RD&E for government, industry and the community.

Specifically this working group will:

1. Develop a discussion document/s outlining the background, strategic direction, process and progress to date in identifying national industry, government and community RD&E priorities for invasive plants and animals.
2. Make recommendations to IPAC on mechanisms and preferred options to facilitate nationally coordinated and collaborative invasive plant and animal RD&E.
3. Identify key RD&E investment priorities for invasive plants and animals consistent with IGAB, biosecurity, environment and industry RD&E strategies.
4. Explore opportunities and mechanisms for joint government, industry, university and community partnerships to address these priorities.
5. Re-define objectives and activities as required.

This paper addresses these actions, by:

- outlining the strategic context (Committees and Working Groups - who set priorities and Strategies - that outline the priorities),
- summarising the process and progress to date, and
- identifying national industry and government RD&E priorities for invasive plants and animals.

2. Strategic context

Strategic direction of pest animal and weed RD&E in Australia is currently provided by a diverse range of government and industry committees, working groups (who set priorities) and strategies (that outline the agreed priorities and implementation approach).

2.1 Committees and Working Groups

National Biosecurity Committee

The National Biosecurity Committee (NBC), formally established under the Intergovernmental Agreement on Biosecurity (IGAB), is responsible for managing a national, strategic approach to biosecurity threats relating to plant and animal pests and diseases, marine and aquatic pests, and the impact of these on agricultural production, the environment, community well-being and social amenity.

The NBC is supported by four sectoral committees that provide policy, technical and scientific advice on matters affecting their sector, covering all pests and disease risks to the terrestrial and aquatic (inland water and marine) animals and plants, and the environment.

An overview of the committees, working groups and major strategies that guide Biosecurity RD&E is shown Figure 1.

A core objective of the committee is to promote cooperation, coordination, consistency, and synergies across and between Australian governments. This includes exploring measures to:

- coordinate biosecurity investment in the national interest
- better connect the biosecurity rationale to market access and trade
- engage, partner and communicate with relevant stakeholders, as required
- increase visibility and engagement with sectoral committees
- provide assurance that the system is working

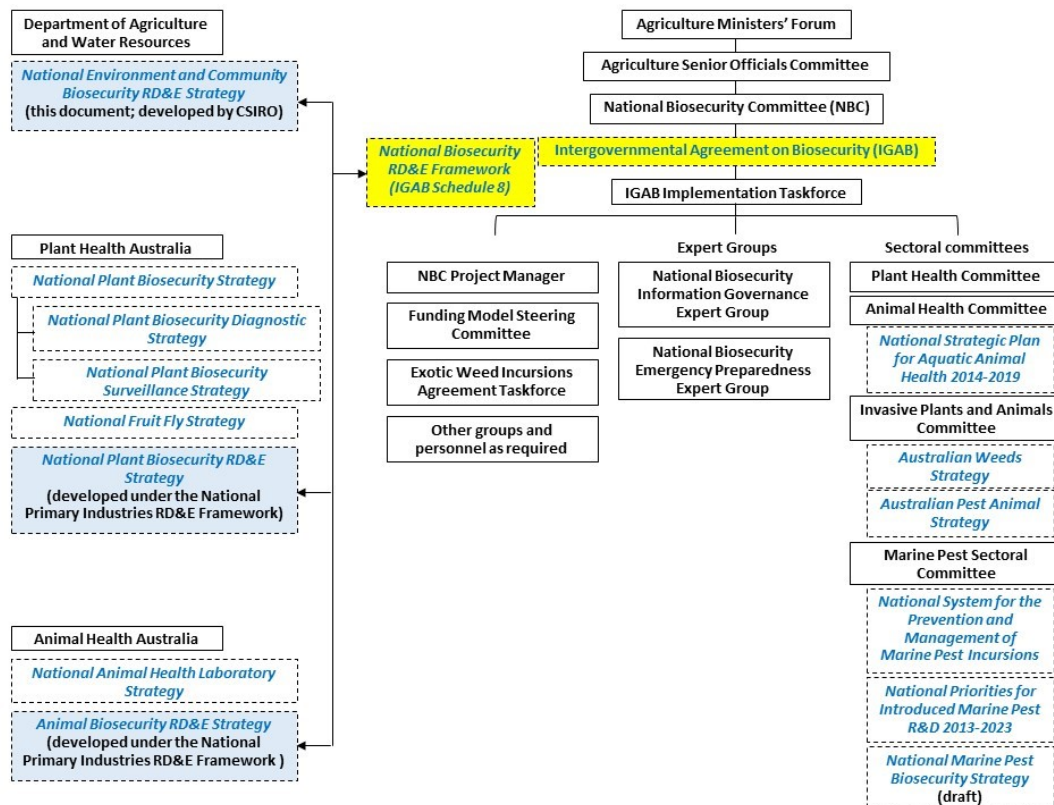


Figure 1. Schematic of Australia’s current national biosecurity system, including committees, working groups and major strategies that guide RD&E priorities for **pest animals and weeds**. (Adapted from CSIRO, Community & Environment Biosecurity RD&E Strategy).

Invasive Plants & Animals Committee

The Invasive Plants & Animals Committee is a sub-committee of NBC that ensures an integrated and effective national approach to the prevention and management of issues and problems associated with vertebrate pest animals, freshwater invertebrate pests and weeds by reporting to and advising the NBC on:

- National policy and planning solutions for vertebrate pest animals, freshwater invertebrate pests and weeds.
- Development of policies and monitoring of performance for national vertebrate pest animals, freshwater invertebrate pests and weed issues relating to implementation of the IGAB.
- Implementation, evaluation and review of the Australian Pest Animal Strategy (APAS) and Australian Weeds Strategy (AWS).
- Promotion and adoption of the principles of the APAS and AWS by key stakeholders (industry, the community, natural resource managers and government).
- Development, coordination and delivery of nationally consistent approaches for vertebrate pest animals, freshwater invertebrate pest and weed management in Australia.

Invasive Plants and Animals Research and Development Expert Group

The Invasive Plants and Animals Research and Development Expert Group is accountable to the Invasive Plants and Animals Committee (IPAC) and will provide regular updates on its activities to IPAC.

The role of this working group is to facilitate the establishment of a collaborative national system undertaking high priority invasive plants and animals RD&E to reduce pest and weed establishment, spread and impacts.

Red Meat Co-investment Committee

The Red Meat Co-investment Committee (RMCIC) had its origins in the combined Meat & Livestock Australia (MLA)–Departments of Primary Industries (DPIs) Co-investment Committee. The RMCIC was formed in 2005 to improve strategic alignment of production research, development and extension (RD&E) investments in the red meat industries.

Horticulture National RD&E Framework

This Framework sets out future Research Development & Industry Development (RD&E) commitment and investment, by Australia's State and Commonwealth agricultural agencies (largely the State DPIs and CSIRO) to/in the Australian horticultural industries. It has been compiled by these agencies and Horticulture Australia Limited (HAL).

The prevention and management of new exotic pests, diseases and weeds entering the country and interstate and international market entry issues is a key area affecting growth and profitability within the sector.

Grains Weed Research Advisory Committee (GWAC)

Formerly the National Integrated Weed Management Initiative Committee, this group provides advice and oversight on weed RD&E for the grains industry. The GWAC has set the following terms of reference.

- Define the strategic weed management issues impacting on the Australian grains industry.
- Identify gaps in the grains industry weed management R, D & E and make recommendations to GRDC.
- Create opportunities for networking between innovative technologies and traditional weed management R, D & E systems.
- Facilitating engagement across other research and development corporations (RDC's) for potential collaboration in weed management R, D & E.

Grains Pest Advisory Committee (GPAC)

The Grains Pest Advisory Committee (GPAC) delivers strategic information to GRDC on invertebrate pest management. The committee will facilitate communication and coordination between researchers, advisors, growers and industry representatives, with a

focus on sustainable, but practical solutions. GPAC will act as a think-tank and will be sufficiently resourced through the appointment of an Executive Officer at the University of Melbourne so that issues around resistance management, knowledge gaps and control opportunities are tackled in a rigorous manner rather than as a reaction to issues that arise within a particular season. GPAC will make recommendations about prioritising research as well as considering entomological training and capacity building

Australian Glyphosate Sustainability Working Group (AGSWG)

The Australian Glyphosate Sustainability Working Group (AGSWG) is a collaborative initiative aimed at promoting the sustainable use of glyphosate in Australian agriculture. This group provides an awareness role, promoting recent research and best practice management of herbicides.

2.2 Cross-sectoral Strategies

Pest animals and weed priorities are identified in many national government and industry RD&E strategies, agreements and plans. The major documents relevant for pests and weeds are marked with * below.

There are national RD&E strategies for:

- Animal Biosecurity*
- Animal Welfare*
- Beef*
- Biofuels & Bioenergy
- Climate Change
- Cotton
- Dairy
- Environment and Community Biosecurity*
- Fishing & Aquaculture*
- Food & Nutrition
- Forest & Wood Products
- Grains*
- Horticulture*
- New & Emerging Industries
- Plant Biosecurity*
- Pork
- Poultry
- Sheep Meat*
- Soils
- Sugarcane
- Threat Abatement Plans*
- Threatened Species Strategy*

- Water Use in Agriculture
- Wine
- Wool*

Intergovernmental Agreement on Biosecurity

The Intergovernmental Agreement on Biosecurity (IGAB), which came into effect in January 2012, is an agreement between the Commonwealth and all state and territory governments, with the exception of Tasmania. The IGAB aims to strengthen the working partnership between governments and to improve the national biosecurity system and minimise the impact of pests and disease on Australia’s economy, environment and the community. The IGAB Schedules identify priority areas for collaboration.

The first deliverable under the IGAB was the National Environmental Biosecurity Response Agreement (NEBRA). The NEBRA sets out emergency response arrangements, including cost-sharing arrangements, for responding to biosecurity incidents that primarily impact the environment and/or social amenity and where the response is for the public good. It includes marine pests and other incidents which are not covered under the Emergency Animal Disease Response Agreement or Emergency Plant Pest Response Deed. The Commonwealth and all states and territories are signatories to the NEBRA.

The National Biosecurity Committee (NBC) is the governing body tasked with identifying and implementing collaborative projects to meet the national priorities identified in the IGAB.

National Biosecurity RD&E Strategies

The National Biosecurity Committee has developed three primary strategies for guiding Australia’s investment in Research, Development and Extension:

- The National Animal Biosecurity RD&E Strategy 2013-2016
- The National Plant Biosecurity RD&E Strategy 2013-2016
- The National Environment and Community Biosecurity RD&E Strategy 2014-2017

RD&E priority areas identified across these three strategies can be grouped under four broad categories – Risk analysis and decision making; Detection, diagnosis and surveillance; Management methods and strategies; and Stakeholder engagement.

During the workshops and consultation program for the most recent of these (Environment and Community Biosecurity RD &E strategy) the seven priority areas most frequently selected as important by stakeholders across all sectors were:

1. Develop and apply risk analysis approaches to prioritise pests, weeds and diseases for management actions pre- and post-border, including ecological and socio-economic modelling of distribution, spread and impacts.

2. Characterise and prioritise pathways of pest, weed and disease movement, including between land uses and between jurisdictions.
3. Develop approaches to understand and quantify potential socio-economic and environmental direct and indirect beneficial and harmful impacts of pests, weeds and diseases, including cross-sectoral risks, and the cost effectiveness and benefits from policy and management options.
4. Refine or develop novel detection and surveillance techniques and best practice diagnostic procedures for pests, weeds and diseases established at low levels, including proof of absence (e.g. remote diagnostics, genetic identification techniques, automated approaches, social media).
5. Review and improve eradication and containment tools and strategies for national and regional use against priority pests, weeds and diseases.
6. Develop integrated management strategies for priority pests, weeds and diseases, including biological control.
7. Improve methods to increase public awareness of the impacts of pests, weeds and diseases, and influence behavioural change in response to biosecurity issues.

National Biosecurity Research and Development Capability Audit

The National Biosecurity Research and Development Capability Audit completed in July 2012 by the Intergovernmental Agreement on Biosecurity – Research, Development & Extension (RD&E) Working Group has identified:

- that state investment in pest animal and weeds RD&E is significantly lower than animal and plant biosecurity.
- an ageing population of research staff and low numbers of postgraduate and postdoctoral researchers. This highlighted the need for succession planning and capability building, including stable career paths to attract and retain capability,
- a need for adequate capability building and provision of long term career structures, and
- that disciplines were scattered across organisations highlighting the importance of collaboration and coordination of R&D activities between organisations

Australian Pest Animal Strategy

The Australian Pest Animal Strategy outlines 3 goals to protect Australia's biodiversity, agricultural assets and social values from the impacts of vertebrate pest animals:

- Goal 1: Provide leadership and coordination for the management of pest animals

- To develop the capacity and processes for effective delivery of pest animal management.
- To ensure nationally consistent pest animal management approaches are in place at all scales of management.
- To improve public awareness of pest animals, research coordination and its support for pest management at the national level, and adoption of best practice management methods.
- Goal 2: Prevent establishment of new pest animals
 - To prevent the introduction of new animals with pest potential.
 - To ensure early detection of, and rapid response to, new incursions of exotic animals.
 - To reduce the spread of pest animals to new areas within Australia.
- Goal 3: Manage the impacts of established pest animals
 - To identify established pest animals of national significance.
 - To identify and manage the impacts of pest animals on key assets.
 - To coordinate the management of established pest animals across Australia.

Australian Weed Strategy

The Australian Weeds Strategy outlines 3 goals to protect Australia's economic, environmental and social assets from the impacts of weeds:

- Goal 1: Prevent new weed problems
 - Prevent the introduction into Australia of new plant species with weed potential.
 - Ensure early detection of, and rapid action against, new weeds.
 - Reduce the spread of weeds to new areas within Australia.
 - Implement weed risk management practices to respond to climate change.
- Goal 2: Reduce the impact of existing priority weed problems
 - Identify and prioritise weeds and weed management problems and determine their causes.
 - Implement coordinated and cost-effective solutions for priority weeds and weed problems.
 - Develop approaches to managing weeds based on the protection of values and assets.
- Goal 3: Enhance Australia's capacity and commitment to solve weed problems
 - Raise awareness and motivation among Australians to strengthen their commitment to act on weed problems.
 - Build Australia's capacity to address weed problems and improve weed management.
 - Manage weeds within consistent policy, legislative and planning frameworks.
 - Monitor and evaluate the progress of Australia's weed management effort

Weeds of National Significance

Thirty two Weeds of National Significance (WoNS) have been agreed by Australian governments based on a nationally agreed assessment process that prioritised these weeds based on their invasiveness, potential for spread and environmental, social and economic impacts. Consideration was also given to their ability to be successfully managed. The WoNS were selected as they require coordination among all levels of government, organisations and individuals with weed management responsibilities. A list of 20 WoNS was endorsed in 1999 and a further 12 were added in 2012.

A strategic plan for each WoNS was developed, including RD&E priorities, to define responsibilities and identify strategies and actions to control the weed species. Coordination of these plans at a national level improves linkages between research and on-going control, and encourages commitment from a wide range of stakeholders. Some WoNS also have published best management practice guides.

There are three phases of national management for WoNS. In phases one and two, each WoNS had a Management Coordinator and a National Management Group/Steering Committee to oversee implementation of the goals and actions of the WoNS strategic plans and to develop and coordinate priority actions. In phase three, state and territory governments take responsibility for national coordination within their jurisdictions. From July 2013, the currently listed WoNS are in phase three. A national focus on WoNS continues through funding investments under the Agricultural Competitiveness White Paper and the Rural Research & Development for Profit Program and through the work of the Invasive Plants and Animals Committee and government agencies report to this Committee on progress against any remaining actions under the strategic plans.

Landowners and land managers at all levels are responsible for managing WoNS. State and territory governments are responsible for legislation, regulation and administration of weeds.

National Wild Dog Action Plan

This National Wild Dog Action Plan will guide the implementation of a nationally-agreed framework for a strategic and risk-based approach to wild dog management; emphasising humane, safe and effective management techniques and appropriate scales for mitigating the impacts of wild dogs. The NWDAP Goals are divided into four areas of work:

1. Effective Leadership and Governance - provide leadership and coordination for the management of wild dogs.
2. People - increase awareness, understanding and capacity building with regard to wild dog management.
3. Tools and methods - mitigate the negative impacts caused by wild dogs.
4. Monitoring, evaluation and reporting - monitor, evaluate and report to inform and continuously improve wild dog management.

The National Wild Dog Action Plan is an industry-driven initiative. It promotes and supports community-driven action for landscape scale management of wild dogs. Under the plan, stakeholders would work together to deliver effective, coordinated and humane wild dog management. The plan focuses on managing the effects of wild dogs on public and private assets.

The National Wild Dog Action Plan is consistent with the modern approach to manage established pests and diseases of national significance. The plan recognises:

- the importance of managing and minimising the negative impacts on assets at risk and, in the case of wild dogs, these are agricultural, social and environmental assets
- the responsibility for wild dog management should be shared between landholders, communities, industry and governments
- governments have a role to support collective industry and community-led action.
- governments have a role to work with other stakeholders to support research and innovation for more effective pest management where significant public benefits in doing so exist.

National Weed RD&E strategies

Over the past 10 years there have been two major weeds strategic reviews supporting national weeds RD&E investment programs;

- **Defeating the Weed Menace** – commissioned by Land and Water Australia (2005-2008)

Defeating the Weed Menace R&D component encompassed weed issues that are having an impact on extensive land systems and conservation areas across Australia, where the benefit is largely to the community as a whole. The component consisted of three priority themes:

- a. Reduce the rate of emergence of new weed problems:
 - i. Assess the risks of different sources and pathways of weed ingress into Australia;
 - ii. Explore the reasons for the persistence and emergence of sleeper weeds;
 - iii. Understand the drivers of, and develop approaches to reduce ecosystem invisibility;
 - iv. Develop robust target lists for incoming species and sleeper weeds;
 - v. Develop efficient methods for surveying and eradicating agreed priority emergent weeds (sleepers and new arrivals);
 - vi. Develop new approaches to help weed source sectors reduce their risk.
- b. Reduce the impact of existing weed problems of national priority:
 - i. Update the list of weeds of national significance and review progress on control of the existing WONS to date;
 - ii. Support the development of biological control for agreed national priority weeds;
 - iii. Develop new integrated management strategies that incorporate an understanding of weeds within landscape scale ecological processes.
- c. Support national frameworks and capacity for sustainable weed management and decision-making:

- i. Identify the social and institutional factors that drive or impede understanding of weed issues and implementation of solutions;
 - ii. Propose workable new policy instruments and institutional arrangements to reduce weed incursion and impact
- **National weeds and productivity research program R&D plan 2010-2025** – commissioned by Rural Industries Research and Development Corporation

This plan was prioritized under four objectives for RD&E investments: a) improve knowledge for effective risk management of weeds, b) reduce current and future impacts of weeds on Australia's productive systems and environments, c) support improved adoption of weed management approaches, and d) plan for future funding and institutional arrangements for national investment and management of weeds R&D. The key elements of the RD&E strategy were a) advance foundational knowledge, b) develop tools, methods and technologies, c) evaluate current social, economic and institutional influences, and d) test and translate existing resources and make them more accessible.

Threat Abatement Plans

Threat abatement plans provide for the research, management, and any other actions necessary to reduce the impact of a listed Key Threatening Process on native species and ecological communities. Implementing the plan should assist the long term survival in the wild of affected native species or ecological communities.

Threat abatement plans establish a national framework to guide and coordinate Australia's response to key threatening processes registered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Minister for the Environment, may decide whether to have a threat abatement plan for a threatening process in the list of key threatening processes established under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Approved threat abatement plans for pest animals and weeds include:

- Threat abatement plan for competition and land degradation by unmanaged goats - 2008
- Threat abatement plan for competition and land degradation by rabbits - 2008
- Threat abatement plan for predation by European red fox - 2008
- Threat abatement plan for predation by feral cats – 2015
- Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs - 2005

- Threat abatement plan for the biological effects, including lethal toxic ingestion, caused by cane toads - 2011
- Threat abatement plan to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100 000 hectares - 2009
- Threat abatement plan to reduce the impacts of tramp ants on biodiversity in Australia and its territories - 2006
- Threat abatement plan to reduce the impacts on northern Australia's biodiversity by the five listed grasses - 2012

2.3 Industry RD&E Strategies

The main national industry RD&E strategies relevant for pests and weeds are grains, beef, sheep meat and wool.

National Primary Industries Research, Development and Extension (RD&E) Framework

The Australian, State and Northern Territory Governments, rural R&D corporations, CSIRO, and universities have jointly developed the National Primary Industries Research, Development and Extension (RD&E) Framework to encourage greater collaboration and promote continuous improvement in the investment of RD&E resources nationally. Under the Framework, primary industries RD&E was to be more coordinated and collaborative, and national research capability better focused and used more efficiently and effectively to achieve the best outcome and uptake by primary industries.

Grains Industry National RD & E Strategy

The national strategy for the grains industry provides a mechanism for the industry to retain an effective and efficient RD&E capability. This will support the production sector to innovate and respond to the growing worldwide demand for grain, despite pressures on government budgets and human resources.

After wide consultation, including with Grains Producers Australia (GPA) and the private sector, the strategy represents a single view of the grains industry and provides a high-level roadmap for RD&E, marketing and policy investments across the value chain.

Subsequent development of the strategy has been the responsibility of an implementation committee. The 16-member committee has custodianship of the planning and implementation process into the future built on annual investment plans elements of which focus on weeds and vertebrate pests.

National Beef Production RD&E Strategy

The National Beef Production RD&E Strategy was developed at the request of the Primary Industries Ministerial Council (PIMC). In developing the Strategy, MLA and Qld DEEDI have worked with all the other organisations represented on the Red Meat Co-investment Committee (RMCIC) to develop:

- ten Priority Industry Outcomes, incorporating the regional and national needs of industry
- seven strategic imperatives that align with Australian Government, state and territory governments RD&E priorities and those prescribed within the Meat Industry Strategic Plan (MISP) 2010–2105
- proposed RD&E programs and deliverables for further assessment and consideration by the RMCIC.

These priorities have been identified and developed in consultation with beef producers, industry RD&E consultative entities (the North and Southern Australia Beef Research Councils) and the Cattle Council of Australia (CCA):

National Sheepmeat Production RD&E Strategy

The National Sheepmeat Production Research, Development and Extension Strategy was developed at the request of the Australian Primary Industries Ministerial Council. In developing the Strategy, NSW DPI and MLA have worked with all the other organisations represented on the Red Meat Co-investment Committee (RMCIC) to develop:

- seven strategic imperatives that align with Australian Government, state and territory government priorities, and the RD&E priorities prescribed within the Meat Industry Strategic Plan 2010–2015
- proposed research, development and extension RD&E programs, and specific deliverables for further assessment and consideration by the RMCIC.

National Wool RD&E Strategy

The National Wool RD&E Strategy has been prepared at the request of the Primary Industries Ministerial Council, by the National Wool RD&E Working Group. The Wool RD&E Program Framework consists of three programs:

1. Wool production;
2. Wool supply chain management and;
3. Demand growth and wool industry resilience and growth.

These three program areas are necessary for the profitable and sustainable production of the world's best natural fibre into the future.

2.4 Industry pest and weed RD&E reviews

Prioritizations of Weeds for the Grazing Industries

A Review of Recent Weed Research and Management Relevant to Australian Livestock Industries and Proposals for future Investments

Meat and Livestock Australia commissioned this report in 2013 to prioritize research and development investments based on the impact of weeds to the grazing industries and the feasibility

of addressing the threats and impacts from those weeds. Data from 17 independent sources were used to identify 71 species that are already widespread and abundant (“prominent weeds”) and 18 that are still relatively restricted (“emerging weeds”). Literature on the economic costs of weeds to livestock industries were reviewed. Species were prioritized using a decision tree approach based on distribution and abundance, current and potential impacts and availability of effective control measures and prospects for improved management through cost-effective research, development and extension (RD&E). The review concluded that future RD&E on weeds of Australian livestock industries require fundamental studies of important aspects of basic biology of poorly understood species, development of systems approaches to addressing weed issues, promotion of measures and strategies that are currently available, development of cost-effective solutions for priority prominent and emerging weeds and studies to test and demonstrate the benefits of weed management at an enterprise level.

Prioritisation of weed species relevant to Australian livestock industries for biological control

Meat and Livestock Australia commissioned this report in 2013 to prioritize established weeds of the grazing industries for classical biological control as this is the only realistic option for managing many of the most serious weeds affecting livestock industries. An applied framework was developed to prioritise biocontrol efforts using new agents against 79 weed taxa considered priorities for RD&E, based on current and potential impacts of the weeds and feasibility and likelihood of success of biocontrol. Key investment areas for future actions to address biocontrol knowledge gaps for each weed were identified. Twenty-one weeds with the highest combined rankings for biocontrol prospects and current and/or potential impacts were shortlisted as priority taxa for future investment.

Impacts of Weeds on Australian Grain Production

The GRDC has commissioned this comprehensive industry study into the cost of weeds, including yield loss and the costs of weed management practices. With input from grain growers, agronomists, consultants, agribusiness data experts and weed researchers, the report, *Impact of weeds on Australian grain production: The cost of weeds to Australian grain growers and the adoption of weed management and tillage practices*, is the most comprehensive review to date and will help guide future decisions on cropping systems research, development and extension.

- The overall cost of weeds to Australian grain growers estimated to be \$3,300 million or \$146/ha in expenditure and losses.
- Yield losses due to weeds amounted to 2.76 million tonnes of grain
- Based on extent and cost, the most costly weeds nationally in terms of total yield loss remain ryegrass, wild radish and wild oats, with brome grass being the most notable major new weed
- Herbicide resistance was estimated to cost \$187 million in additional herbicide treatment costs, in addition to the costs of using extra integrated weed management practices.
- Weeds in fallows are estimated to be costing more than \$430 million through reduced crop yields, despite \$487 million being spent on fallow weed control through herbicide application and cultivation.
- Yield losses due to weed competition from residual in-crop weeds were valued at \$278 million

3. Considerations and Process to Identify RD&E Priorities for Pest Animals and Weeds

Setting National R&D priorities for pests and weeds involves consideration of:

- maximising return on investment using the incursion curve as an indicative guide (Figure 2),
- national significance/national interest test—to guide decisions on the form and extent of national intervention or management
- availability of cost-effective solutions that are both feasible and have a high likelihood of success
- roles and responsibilities for government and other stakeholders—to provide greater clarity for all stakeholders. (Source: Modernising Australia’s approach to managing established pests and diseases of national significance)

3.1 Maximising returns from investments

Governments must manage numerous activities across the biosecurity continuum and seek to maximise the return on investments of public funds. Industry and individual land managers will similarly seek to maximise their investments in biosecurity management. For any given biosecurity threat, the responsibility and the scale and nature of returns will vary from investor to investor, as will the appropriate activity for investment.

Activities to deal with pests and diseases encompass four broad categories: prevention, eradication, containment and asset-based protection.

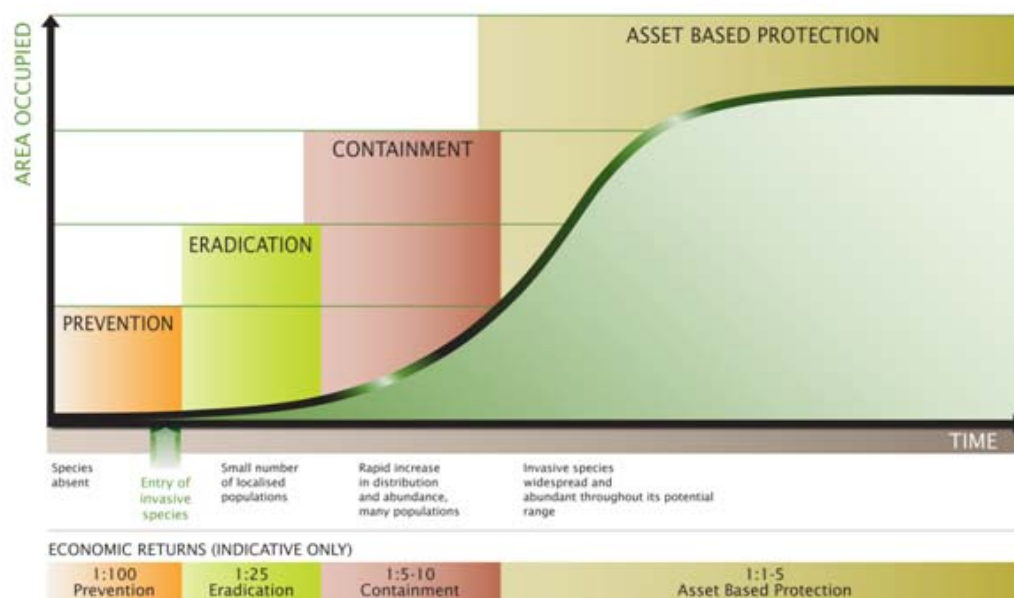


Figure 2 Schematic Invasion curve showing actions appropriate to each stage of a pest or weed incursion. The indicative economic returns do not also reflect chance of a successful outcome. The application benefits of the use of biological control on established pests and weeds is not included even though this has a BCR of >1:25 (Source: Dept of Economic Development, Jobs, Transport and Resources, Victoria)

Public benefit from protecting private assets is generally lower, particularly compared with other activities where government can play a role such as prevention or early detection of incursions. The benefits of managing an established pest or disease accrue predominantly to the owner of the land or the owner of the asset, so asset-based management may be the most cost-effective for an individual and/or as the basis for collective action by a government, community or industry where these are the landholder. While returns on investment generally decrease along the invasion curve there are exceptions. For example biological control where effective at reducing the widespread pests and weeds can have returns comparable with prevention or eradication.

3.2 National Significance and National Interest Tests

Where a net benefit in nationally coordinated management for a pest or disease deemed to be nationally significant exists, a national management plan or strategy should be prepared. The form and breadth of activities included in this management plan or strategy will depend on the specific circumstances.

National significance

The Intergovernmental Agreement on Biosecurity defines a pest or disease of national significance as ‘one that would be likely to have far reaching and/or national impacts’.

A pest or disease is nationally significant if it has a significant impact at a national level on:

- international market access and/or trade
- the economic health of the nation
- human health
- the natural environment and ecosystem services
- substantial damage to, or deterioration of infrastructure used by a significant proportion of people over an extensive area
- amenity of resources, such as public lands, and that has the potential to affect more than one state/territory; or
- Australian culture, cultural assets, practice or custom, or national image.

In assessing the impact of a pest or disease, the primary consideration should be the projected impact on any or all of the economic, environmental and social aspects of contemporary Australia at a national level.

National interest

Some pests or diseases may meet the test on impact for national significance, but the return on any projected intervention may not exceed the cost of implementing it. This may be because no practical management option exists or because the costs would exceed the benefits. In these cases no intervention or management would be justifiable.

A response to a nationally significant established pest or disease would be in the national interest if:

- the proposed management approach is technically feasible with a high likelihood of success, and
- there is a net economic, social or environmental benefit in taking action, and

- there is a clear benefit from, or requirement for nationally coordinated action or approach (e.g. because of costs or infrastructure requirements).

The national interest principle, as just described, is essentially a national interest test: is it in the national interest to intervene in a nationally coordinated way?

3.3 Process

The process and activities undertaken in 2014/15 to identify national RD&E priorities for pest animals and weeds has included:

1. Feb 2014. Workshop to develop the National Environment and Community Biosecurity RD&E Strategy with industry representatives
2. April 2014. Draft National Environment and Community Biosecurity RD&E Strategy
3. May 2014. National Wild Dog Action Plan Released
4. Sep 2014. AWC Weeds RD&E Working Group paper on priorities and delivery models presented at 19th Australasian Weeds Conference
5. Oct 2014. Pest Animal Innovation Strategy Issues Paper circulated for comment.
6. Oct 2014. National pest animal RD&E survey conducted and reported on priority RD&E areas for pest animals
7. Oct 2014. Special symposium and workshop. Future directions for Pest Animal RD&E, Orange
8. Nov – Dec 2014. IACRC Participant Committee consideration and endorsement of Centre for Invasive Species Solutions (CISS) business case
9. Dec 2014. Biosecurity R&D Capability Audit in Australia reported on pest and weed capacity and gaps
10. Dec 2014. Future RD&E directions for pest animals scoped with IACRC theme groups and partners
 - a. Mar 2014, Mar 2015, Sept 2015 – New Incursions
 - b. May 2014, Mar 2015 – Rabbit
 - c. June 2014, Mar 2015 – Pest fish
 - d. Oct 2012 (Trophic Responses Expert Workshop, Syd), Sept 2014, Feb 2015, Mar 2015 – Wild dogs – National Wild Dog Action Plan
 - e. Dec 2014, Mar 2015 – Community engagement
 - f. 2014, Mar 2015 – Commercial Products
11. Jan 2015. Establishment of the IPAC RD&E Working Group with industry representatives
12. Jan 2015. Australian Cropping R&D Gap Analysis NIWMI
13. Feb 2015. National Wild Dog Action Plan Stakeholders Consultative Group, Wild Dog R&D Working Group, Wild Dog Research Gap Analysis
14. March 2015. Whole of IACRC Review, Canberra
15. April 2015. Wild Dog Research Gap Analysis, Wild Dog Stakeholders Consultative Group, Research and Development Working Group, National Wild Dog Action Plan
16. April 2015. Inland water priorities reviewed by IPAC's Freshwater Fish Experts Group
17. April 2015. National Feral Cat Workshop, Canberra
18. May 2015. Consultations on the CISS Prospectus
19. June 2015. National MLA weed biological project commenced (Rural R&D for profit).
20. July 2015. Release of Agricultural Competitiveness White Paper.
21. July 2015. Threatened Species Summit, Melbourne and Threatened Species Strategy Released.
22. Sept 2015. IPAC Incursions Working Group Workshop, Melb to identify priorities for pest animal incursions.
23. Nov 2015. IPAC RD&E Working Group face-to-face and higher level 'Program Area' priorities formulated.

24. Nov – July 2016. National weeds R&D strategies reviewed to include detailed priorities for weeds (Weed Alert list, WoNs - strategies and IPAC WoNs Expert Group, Weed Categorisation project - ABARES, Exotic Weed Incursions Agreement Taskforce, RIRDC, Defeating the Weeds Menace, the NECBRDES etc.)
25. July—Oct 2016. Detailed priorities collated, gaps identified and grouped into higher level priority areas, with a description context provided by the IPAC RDE Working Group.
26. Oct 2016. Draft paper prepared for IPAC

4. National RD&E Priorities for Invasive Plants & Animals 2016-2020

The identification of national government and industry RD&E priorities for pest animals and weeds is complex, with many committees, working groups and strategies in place to guide this process. The Invasive Plants and Animals Research and Development Expert Group has comprehensively reviewed existing priorities, identified gaps and added additional new detailed priorities for invasive plants and animals and grouped these into 22 key national priority areas within 4 programs (Table 1). Review of these priorities is recommended every 3-5 years.

1. New approaches to detection, prevention and eradication

Early detection and prevention technologies, increased adoption of risk approaches, community surveillance systems and increased awareness of emerging invasive species are a high priority for future work. There also remain large gaps in the development and implementation of science based pre-border species and pathway risk assessment and prioritisation analysis (McGeoch et al. 2016)¹ and incursion response strategies for invasive species. For pest animals, birds and reptiles remain a high priority and further work is needed to quantify risks and the feasibility of eradicating these species to guide practical strategies to prevent their establishment or further spread. Greater involvement of the community and industry is needed to prevent and detect new invasive species. Invasive species detection and delimitation is the major challenge to successful eradications. Careful consideration of the feasibility of achieving eradications and associated costs and resources is a high priority (Blood et al. 2016)². For weeds, seed bank longevity can add significant time and cost. Eradications can be highly labour intensive and often result in multi-million dollar programs. Investment in technologies such as camera traps, remote sensing, unmanned aerial vehicles and environmental DNA detection is required to provide alternative or complementary options. There is an increased need for standardisation for use of these technologies, and improved statistical frameworks are needed to ensure that the likelihood of detection is taken into account when assessing risk and developing surveillance and response plans.

2. Biocontrol

Biocontrol is a well-justified case for government and industry investment, offering significant public good benefits accruing over time (e.g. average benefit : cost ratio of 23:1 for weeds , Page and Lacey

¹ Melodie A. McGeoch, M.A., Genovesi, P., Bellingham, P.J., Costello, M.J., McGrannachan, C. and Sheppard, A.W. (2016) 'Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion' (Biological Invasions 18:299–314)

² Blood, K., James, R. and Panetta, F.D. (2016). 'Looking for weeds: assess the risk guide. A guide for assessing the risk for weeds at the early stage of invasion on public land in Victoria' (Department of Environment, Land, Water and Planning, Victoria. URL: <http://www.depi.vic.gov.au/environmentand-wildlife/weeds-and-pests/early-invaders>)

2006³). There has been a continuing investment in rabbit and carp biocontrol and a recent increase in Commonwealth and State investment in weed biocontrol, with two national Rural R&D for profit programs in place. Research is constrained by an often long lead time to delivery and the need for specialist skills and facilities. There is already a strong international network for collaboration and efficiencies to be gained in working on groups of related weeds concurrently. National biocontrol networks are in place for rabbits and carp and re-building for weeds in Australia, with further work needed to explore sustainable funding models. There are currently three main quarantine facilities for weed biocontrol, in Brisbane, Canberra and Melbourne, with an additional new modular low cost, high through-put facility to be opened soon in Orange NSW. Ideally, there would be at least ten weeds being subject to biocontrol research in Australia at any one time, servicing high impact weed species of grazing, cropping, natural and aquatic systems.

Gene drives offers an attractive, albeit high risk solution, with considerations on learnings from other areas (e.g. mosquitos, human health), and considerations of community acceptance and feasibility for invasive species a high priority.

For weeds, a decision support tool for policy makers (Hennecke et al. 2013⁴) and industries and communities (van Klinken et al. 2016⁵) have been developed to aid prioritisation of weed targets for biocontrol research, with further development planned within current national Rural R&D for profit projects. A detailed prioritisation framework was subsequently developed and applied to weeds of livestock industries (Morin et al. 2013⁶), with many of the priority weeds also being WoNS and/or environmental weeds. Extension through state-based redistribution networks brings in community ownership and is fundamental to hasten establishment, spread and impacts of effective biocontrol agents.

3. New and sustainability of existing management options

Research is needed to both improve the use of existing established options and to develop new innovative management alternatives. For example, herbicides are a fundamental tool for weed management, yet their effective, long-term use is at risk due to issues of widespread herbicide resistance, low adoption of recommended practices, application cost, market failure for new minor uses, off-label usage and off-target risks.

³ Page, A.R. and Lacey, K.L. (2006). 'Economic impact assessment of Australian weed biological control'. Technical Series, No. 10, pp. 150. (CRC for Australian Weed Management)

⁴ Hennecke, B., Arrowsmith, L. and ten Have, J. (2013). 'Prioritising targets for biological control of weeds – a decision support tool for policy makers'. (Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra).

⁵ van Klinken, R.D., Morin, L., Sheppard, A.W. and Raghu, S. (2016) 'Experts know more than just facts: eliciting functional understanding to help prioritise weed biological control targets. (Biological Invasions 18:2853–2870)

⁶ Morin, L., Heard, T., Scott, J., Sheppard, A., Dhileepan, K., Osunkoya, O. and van Klinken, R. (2013). 'Prioritisation of weed species relevant to Australian livestock industries for biological control'. (Meat & Livestock Australia Limited, North Sydney).

Integrated and landscape management approaches remain a priority for agriculture (cropping systems and extensive grazing), the environment and community. There is a need to move from control effectiveness or tools alone to a greater understanding of landscape systems approaches, appropriate scale, species interactions, bio-economics, and how and when these tools and strategies are implemented. When should Government, industry, landholders invest to achieve maximum long-term reductions in impact? What are broader long term implications of control of pests and weeds on other species, for ecosystems, landscapes and production systems?

For weeds in cropping, key RD&E areas for traditional areas includes extending utility and access to herbicide modes of action, improved pre-emergent strategies in minimum tillage farming systems, increasing herbicide tolerant and competitive crop and pasture options, and accelerating new herbicides from overseas. However step change is also coming through development of robotics platforms incorporating non-chemical control options for weed management as part of the rapidly advancing digital agricultural engineering for whole of farm system management. In grazing systems greater effort is needed to develop and promote decision tools that inform the on-farm profitability of integrated approaches, including better use of herbicides and integrated control. A similar need remains for natural ecosystems, where managers are faced with multi-species invasions and very limited operating budgets. Here, new and existing, broad-scale invasive species and native vegetation management techniques need to be cost-effectively combined. A key to this area is dealing with 'causes' and not just 'symptoms'. For all systems, direct involvement of land managers in research and at demonstration sites is fundamental to reality check and foster broader adoption of new integrated environmentally and socially responsible approaches.

4. Socioeconomic drivers of adopting best practice

Invasive species management is primarily driven by people's knowledge, behaviours and actions. Knowledge doesn't equal behaviour. Further work is needed to understand barriers to and drivers of adoption of best practice. Government policy and regulation intervention through compliance and incentive programs seeks to motivate land holders, but has had limited or unknown long term benefit. In addition, government investment in invasive species management through control programs or one-on-one officer interaction with individual land holders is in serious decline. Alternative, community and industry-led models of cooperative action need to evolve as the social norm. Socioeconomic factors that foster widespread land manager adoption of existing and new R&D need to be factored into all research programs, rather than just the traditional extension reliance on the factsheet, website and field day model. Likewise, presenting invasive species information in the context of a production system is important – a decision on managing invasive species is in direct competition with other on-farm resourcing needs and need to be integrated into a systems approach. A 'communities of practice' approach, bringing together land holders across multiple land uses, scientists, local authorities, socioeconomic researchers, and advisers (e.g. financial, agronomic) may yield longer-term outcomes around an agreed invasive species problem of mutual concern. However, the coordination effort needs to be balanced with an appropriate compliance approach, for example through district invasive species officers. The cost effectiveness of these approaches need to be considered.

Table 1. National Priority Areas for Invasive Plants & Animals Research Development and Extension 2016-2020

IGAB Priority & Schedule	Priority Areas	Context/ Description
1. New approaches to detection, prevention and eradication		
2,4,8	1.1 Community surveillance systems	<p>Post border surveillance by the community can be highly effective for the early detection of newly arrived invasive species, which is vital if they are to be eradicated. Further work is needed to ensure biosecurity agencies are able to capture this information in a timely manner.</p> <p>This priority focuses on the development of reporting systems for community and industry that are fit for purpose, efficient and effective. This includes capturing observations in the wild, in captivity/cultivation and in spread pathways. It also includes surveillance of online market places and community sites. Systems need effective linkage to taxonomists and government agencies to guide decisions about appropriate surveillance and response. A world class pest animal and weed detection and monitoring system is required to enable effective community understanding, passive and active community detection and surveillance, and timely reporting to reporting to biosecurity organisations responsible for pest incursions. This system will need to enable accurate species identification and precise documentation of incursion location to maximise reliability of initial report and enable effective decisions about local biosecurity responses. Existing community pest animal surveillance platforms (such as FeralScan) should be extended (if appropriate) to incursion community surveillance.</p> <p>This priority is differentiated from other surveillance tools (1.2) as it is more specifically focussed on the development of community surveillance systems that complement current biosecurity agency reporting.</p>
2,4,5,8	1.2 Development and implementation of surveillance tools	<p>This includes surveillance tools, modelling and analysis techniques and technology to allow the rapid early detection of new invasive species. The development and application of this technology can also significantly improve the management of widespread pests and weeds.</p> <p>The development and implementation of surveillance tools will assist in identifying priority species and pathways, establishing and improving routine practices, and facilitating collaboration and sharing of information. These are underpinned by protocols and</p>

		<p>techniques for prioritising species, pathways and activities; passive surveillance procedures and networks, improved information management and analysis methods, the implementation of new technologies (e.g. eDNA, camera traps); and sharing of resources and information across jurisdictions.</p> <p>Examples of improved surveillance tools for widespread pests and weeds include:</p> <ul style="list-style-type: none"> • Drones and improvement of existing aerial survey methods, • More effective use of camera traps, and • eDNA technology and other biosensors
1	1.3 Establishing proof of freedom for eradication targets	<p>A critical point of an eradication program occurs when the species has apparently disappeared. If the wrong actions are taken at this stage and undetected individuals remain, many of the benefits that have accrued from the eradication program may be lost and the species re-established. It is vital to understanding the type and level of monitoring required to have confidence that eradication has been achieved. There is a need to establish standards guided by statistical frameworks for proof of freedom that build on risk management and detection and monitoring systems. The standards will be based on analyses of risk, including analyses of the duration of apparent freedom, delimitation, level of surveillance effort, and the reliability of detecting the pest animal.</p>
1,2,4,6,8	1.4 Improved eradication and containment standards & strategies	<p>While Australasian research is world leading on the effectiveness of weed eradication and vertebrate eradications on Islands, this needs to be translated into cost-effective implementation plans with science-based decision points. Standards and strategies for early detection, eradication and containment to enhance Australia's ability to respond quickly and effectively to incursions. This is enhanced through national coordination of responses and biosecurity plans, and integration of passive and active surveillance and prevention procedures. Coordination includes enhanced training and preparation through response exercises, the identification of risk pathways, and the development and implementation of risk analysis and prioritisation.</p>
1	1.5 Pre-border - analysis of future pest and weed risks	<p>The most effective outcome for biosecurity investment is the prevention of new pest incursions. To help prevent new incursions, national science-based systems and standards for the prediction of future risks need to be put in place to ensure that 'high risk' species – those that could readily establish in the wild – are not imported into Australia, and so high risk pathways are effectively managed.</p> <p>It is not feasible to eradicate all weeds or pest animals or to prevent all incursions. Enhanced analyses of future pest and weed risks is required to identify, coordinate and prioritise investments in systems to prevent new incursions to protect the environment, agricultural production and public health and safety.</p>

4,8	1.6 Rapid diagnostics and taxonomy	More effective surveillance and diagnostic services are required for the successful management of pest and weed incursions. Enhanced collaboration, identifying key gaps, building and maintaining expertise, accessing industry expertise, training and improved information systems are identified as high priorities. Information and expertise on diagnostic capability needs to be readily accessible for potential animal and weed incursions. This includes expertise and capability in taxonomy, eDNA, molecular phylogenetics, bioinformation management, and other cutting-edge technologies (e.g., genes, populations, species, higher taxa, communities and ecosystems). Only through building automated bioinformatics capability and readily accessible genome banks for invasive species can rapid diagnostics become a reality.
2,4,8	1.7 Molecular tools - eDNA, next generation biosensor approaches	There are significant advancements in next generation and molecular approaches that have direct implications for the early detection of new pests and weeds. Environmental DNA (eDNA), the DNA that an organism leaves behind in the ecosystem, requires further development as an early detection tool for invasive species, including pest fish. Cheap biosensor technology that are increasingly sensitive to specific diagnostic chemicals from organisms of biosecurity significance are also becoming more readily available to guard against incursion through regulated pathways. There is significant potential for the collection of large amounts of information and improved information management and statistical frameworks are also needed to capture, analyse and interpret this data and to guide response planning. This technology is also highly relevant to improved management of widespread species.
2. Biocontrol		This includes all approaches where biological processes are used for the management of established pests and weeds. It therefore includes classical biological control (import and release of new biocontrol agents from overseas which may or may not be manipulated to increase their effectiveness), augmentative biological control (use of biological agents for short-term suppression e.g. commercial biocontrol or biopesticides), conservation biological control (enhancing the diversity of the environment to natural augment natural enemy loads), sterile feral technologies (release of modified individuals of the target to suppress wild target populations), fertility control (which includes vaccines and other agents that reduce feral animal fertility) and other genetic based approaches being considered (e.g. gene-drives).
2,5,8	2.1 Biocontrol – Classical	Host-specific natural enemies, generally from the country of origin of the target alien pest or weed, are identified, and one or more are risk assessed, imported and released to control the target, based on clear evidence of specificity and expected capacity to control the target. Following release it is expected that the biological control agent (micro or macro-organism) will establish permanently from relatively small released founder populations, and that these

		populations will independently and rapidly reproduce and spread ⁷ . Redistribution of such biological control agents across the target range in the recipient environment or modifying that environment to improve agent fitness are also regularly used to assist in augmenting time to target population suppression.
2,5,8	2.2 Biocontrol - Genetic approaches.	This includes and growing range of blue sky gene-technology based solutions including Sterile-feral approaches around sex ratio manipulating constructs that alter target population reproductive success but also target other population fitness characteristics or susceptibility to cheaper control options. These can be introduced through both inundative approaches of novel genotypes for introgression through mendelian inheritance or single introductions spread through gene-drive technologies. Research includes risks analysis, public licence to operate and regulatory research necessary for the adoption of proposed technologies.
2,5,8	2.3 Biocontrol - In vitro breeding and selection of new agents	This includes ways of sustaining existing classical viral biocontrol agents for feral animal biocontrol using traditional and genetic approaches for maintaining and increasing agent virulence through a pipeline of new agent genotypes to ensure control is sustained in the long term in the face of host resistance development
2,4,8	2.4 Fertility control of vertebrate pests	Use of vaccines and other approaches to slow fertility in pest vertebrates for management of closed pest populations. Includes research on delivery mechanisms and cost effectiveness studies of this approach.
3. New & sustainability of existing management options		
4,5,6,8	3.1 Climate change and invasive species	Understanding how a changing climate will alter the impact of established invasive species – through factors such as altered ranges, emergence of ‘sleeper’ species, and greater or lesser impact – will clearly be important in fore sighting future invasive species risks and impacts.
4,5,6,8	3.2 Development and implementation of new non-biological control tools and approaches	New or improved tools that can improve the control of pest animals and weeds. For pest animals this may include; use of technology for traps such as linked alerts, tools for managing pest birds in grain, improvements to forecasting rodent plagues, implementation of landscape-scale fencing systems, optimisation of aerial baiting rates, the use of livestock guardian animals, and application of molecular tools (outlined in Priority 1.7). For weeds this may include; improved herbicide use patterns, amended harvest management approaches, research into alternatives to herbicides (e.g. eucalypt), and a new mode of action

⁷For general texts see Caltagirone L.E. (1981). Landmark examples in classical biological control. Annual Review of Entomology 26: 213-232. (1981) and Bellows T.S. and Fisher T.W. (1999). Handbook of Biological Control: Principles and Applications of Biological Control. Academic Press, San Diego.

		<p>for herbicides or new bioherbicides. The digitization of agricultural production systems also brings in robotics platforms with weed management capability for automated precision tillage or heat-based weed-kill technologies</p> <p>Included in this category is economic analysis of different tools to ensure that they are applied in a cost-beneficial manner.</p>
4,5,8	3.3 Humane vertebrate pest control	<p>There is an increasing need to demonstrate best practice animal welfare outcomes in vertebrate pest control activities. This provides an opportunity for updated standards and procedures to improve animal welfare for current and new management tools including:</p> <ul style="list-style-type: none"> • New vertebrate pesticides, including a rodenticide; • Optimising the interactions between the predators, prey, fire, grazing and current control tools; • New toxin delivery systems; and • Non-lethal controls for specific circumstances. <p>The development of codes of practice and standard operating procedures is essential to ensure acceptance of new vertebrate pest control techniques and to make sure the control is undertaken in the most humane and effective way possible.</p>
4,5,6,8	3.4 Improved standards & strategies for widespread species	<p>Management of widespread pests and weeds consumes considerable time and money. Improvements in the management approaches for these species through enhanced use of technology and more efficient assessment of current states and prediction of future states is needed to assist land managers. Examples of R&D priorities include:</p> <ul style="list-style-type: none"> • Estimating pest and weed impacts using life cycle assessment approaches • Improved and new aerial surveillance methods including drones • Demonstration sites for integrated landscape scale management • Field monitoring (e.g. mice) • Predictive monitoring for rodent plagues • Quantification of impacts and costs of control tools • Early alert systems (e.g. GPS linked) • Farming systems based approaches including multiple rotation and dual purpose cropping • Understanding impacts and management of invasive species in peri-urban environments
4,5,6,8	3.5 Impact of invasive species on market access.	<p>This includes the need for improved understanding of the impact of invasive species on market access and profitability of agricultural systems, and conflict species.</p>

4,5,8	3.6 Multi-species interactions and management	This includes an improved understanding of the interactions of pests and weeds and influence of combined management approaches. There is an increasing need to shift from species-specific control tools applied in isolation to the adoption of landscape systems approaches. This requires an understanding of the long term impact of multiple integrated control tools on a range of pest populations and weeds and the broader consequences of management to ecological and production systems (including trophic cascades and weed control by feral herbivores). A greater understanding of the appropriate management scale, optimisation and when and where to apply management approaches is also required.
4,5,8	3.7 Disease and epidemiology of invasive species.	Emerging infectious diseases cause significant impact on agricultural and natural systems and human health (OneHealth). These events are increasing significantly over time and are dominated by zoonoses (60% of EIDs, ⁸ Jones et al.2008).. A greater understanding of the role of pest animals and associated disease vectors and weeds as hosts for these diseases is required. This includes R&D into prevention of new diseases entering Australia or early intervention (e.g. rabies preparedness), the role of weeds in endemic and emerging plant diseases, as well as better understanding of how to manage spread between feral and domestic animals, and spread between species. The increasing peri-urban natural ecosystem overlap exacerbates these risks. An improved understanding of the prevalence and epidemiology of diseases in invasive species is a priority, and essential for adequate preparedness planning to manage these events. It is noted that wildlife health is only a concern for IPAC where an invasive species may be a vector for a wildlife pest or disease and it is not intended that IPAC duplicate the priorities and activities of Wildlife Health Australia.
4. Socioeconomic drivers of adopting best practice		
4,5,6,8	4.1 Ecological and socio-economic research and modelling for better decision making	This includes targeted research and improved modelling of pest and weed impacts on ecosystem services and the evaluation of management alternatives to guide decisions on the level of investment needed for both newly arrived and widespread species. Testing alternative valuation methods is identified as a priority to provide defensible estimates of impacts of invasive species on the economy, environment and community, and of the costs and benefits of competing investment options for their management. The consequences of invasive species outbreaks and sustained infestations on human psychological and wellbeing impacts are also

⁸Jones, K.E., Patel, N.G., Levy, M.A., Storeygard, A., Balk, D., Gittleman, J.L. & Daszak, P. (2008) Global trends in emerging infectious diseases. *Nature*, 451(7181), 990-93

		a critically under recognised impacts, particularly for indigenous and rural communities.
2,4,5,6,8	4.2 Coordinated community engagement for better invasive species outcomes	In addition to national, state and regional facilitators/coordinators, this includes extending and further tailoring existing toolkits (such as PestSmart Connect) or developing toolkit of strategies, systems and tools to increase community engagement in and coordination of invasive species management programs at an appropriate scale that optimises community ownership with effective outcomes. Priorities include: increased engagement and motivation of the urban and peri-urban community in understanding the impacts of pests and weeds, promotion of cross tenure community-led collective action, and developing better community of practice and community led and coordinated effective pest animal and weed management. Transdisciplinary approaches where stakeholders are included in project delivery from the get go maximises the likelihood that research outcomes will be end-user ready and quickly adopted.
2,4,5,6,8	4.3 Governance and institutional research to support better outcomes	This includes investigating alternative funding streams (e.g. offsets) and incentivising investment in best practice invasive species management, investigating risk based approaches to investment decisions, and options and policy instruments for overcoming regulatory and administrative hurdles.
2,4,8,6	4.4 Adoption of improved standards & strategies	This includes investigating the barriers to and drivers for adoption of best practice invasive species management at the local, regional, jurisdictional and national levels, and demonstrating methods to increase adoption. Understanding high risk behaviours, social psychology approaches and evidence of behavioural change leading to improved management outcomes are high priorities for future investment.