



Fighting plagues and predators

Australia's path towards a pest and weed-free future

November 2021



CENTRE FOR
INVASIVE SPECIES SOLUTIONS

CSIRO

CSIRO is Australia's national science agency and innovation catalyst, solving the greatest challenges through innovative science and technology. CSIRO collaborates with industry, government, academia and communities to turn science into solutions for food security and quality; clean energy and resources; health and wellbeing; resilient and valuable environments; innovative industries; and a secure Australia and region. Our science and technology innovations aim to drive the transformation of Australia's health and biosecurity sectors, improving prevention, detection and response to health and biosecurity threats.

Centre for Invasive Species Solutions

The Centre for Invasive Species Solutions (CISS) is a national collaborative research, innovation, and engagement organisation tackling the ongoing threat from invasive pests and weeds to our threatened species, agriculture and landscapes. We bring governments, industry, community, philanthropic and research partners together to create solutions-focussed, collaborative RD&E programs and innovation pipelines. Partners also invest through our Invasive Species Solutions Trust which is a deductible gift recipient charity.

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Acknowledgement

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

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Myrtle rust threatens many native trees
and shrubs. Photo by Louise Morin

1 Devastation on our doorstep

A disaster is unfolding in our backyards and on our doorsteps. It is in our cities, farms, forests, rivers, reefs, parks and playgrounds.

From feral cats to toxic toads, choking weeds, deadly fungi and armies of ants, Australia is in the grip of an unprecedented attack on our native wildlife, environment and way of life.

While invasive species are a major threat globally,¹ in Australia they have been the major cause of native animal and plant extinctions. Their damage to native species is worse than habitat destruction and climate change.²

Since European settlement, invasive species have contributed to the confirmed extinctions of 79 Australian species. More recently, invasive species have been the dominant driver in nearly all extinctions since the 1960s.³

Feral cats and red foxes have already killed off at least 25 native mammal species across central and southern Australia.⁴ Now, a new wave of mammal extinctions is looming across northern Australia, as intense fires and overgrazing by feral cattle, pigs and buffaloes remove shelter and make it easier for feral cats to hunt.⁵

The environmental, economic, cultural and health costs of invasive pests are multiplying.

Climate change is opening the door for the infamous cane toad⁶ and what were once regarded as tropical and subtropical weeds⁷ to stray into southern states. Carp⁸ and tilapia⁹ can set sail on flood waters, while mice, foxes and feral horses¹⁰ benefit from climate change in alpine areas.

Bushfires clear the way for feral cats to prey on pygmy possums, while fast-breeding rabbits, goats and deer are often the first to feast on new plant growth, reducing carbon storage and leaving native creatures without food or safe habitat.

The climate's new normal, which allows these invasive species to thrive, means we have no time to waste to save our native flora and fauna. Most of Australia's plant and animal species are found nowhere else on earth. Once they are gone, they are lost forever.

No time to waste

Plagues of pests are not a distant problem to worry about tomorrow. They are here now.

While current strategies have slowed some impacts, the challenge is for all Australians to work together to come up with new ways to stop the harm caused by invasive species.

More than 1,250 (eight in 10) of Australia's land-based threatened species are imperilled by invasive species. Much of the blame rests with 207 weed species, 57 invasive animals and three pathogens.¹¹

Seventy-three species of introduced vertebrates roam our continent, including 25 mammals, 20 birds, four reptiles, one amphibian and at least 23 freshwater fish,¹² but just three (rabbits, pigs, cats) and an endemic plant pathogen known as *Phytophthora cinnamomi*, threaten more than 800 threatened species.¹³ Australia is burdened with more than 2,700 weeds, making up about 12% of our flora, a higher proportion than in any other continent. About 20 new weed species have been establishing each year – or one new weed every 18 days.¹⁴ Weeds are transforming Australia's landscapes, displacing native plants, increasing fuel loads for bushfires and choking waterways.¹⁵

As more invasive species take hold and spread, the pest problem is growing; recent arrivals include myrtle rust,¹⁶ bird flu,¹⁷ white spot disease in prawns,¹⁸ ehrlichiosis disease in dogs,¹⁹ fall armyworm, Asian honeybees and several invasive ant species.

The financial cost is already enormous. Invasive species – predominantly weeds, cats, rabbits and fire ants – are conservatively estimated to have cost Australia \$390 billion over the past 60 years in impacts and control measures.²⁰ This cost will grow markedly if new pests, weeds and diseases are able to invade Australia.

Attack of the alien invaders: new pests and diseases could cost Australia's farmers billions

- African swine fever is on Australia's doorstep. An Australian outbreak could be spread by feral pigs, threatening the **\$5.2 billion** pork industry.²¹ A five-year outbreak could cost **\$2 billion**.²²
- Foot and mouth disease, which can be spread by feral animals, could cost Australia's livestock industries **\$16 billion** in the first year of an outbreak²³ and up to **\$50 billion** over 10 years.²⁴
- *Xylella fastidiosa*, a bacterial disease, could cost the Australian wine industry between **\$2.2 and \$7.9 billion** over 50 years.²⁵

Taking up the fight

This report offers a roadmap to a pest and weed-proof Australia. It shows that everyone has a role to play.

By working together, and investing in innovative technology and management approaches, we can ensure Australia's extraordinary, irreplaceable native animals and plants can survive for future generations to treasure.



Mouse plagues cause major damage to crops in Australia.
Photo by Grant Singleton

2 The worst of a bad bunch

Hundreds of invasive plants, animals and pathogens plague Australia but some are much more damaging than others.

Pest animals

European rabbits

- Infest two-thirds of Australia.
- Are the single biggest menace to threatened native species.²⁶
- Cost on average \$216 million a year in lost farm productivity.²⁷

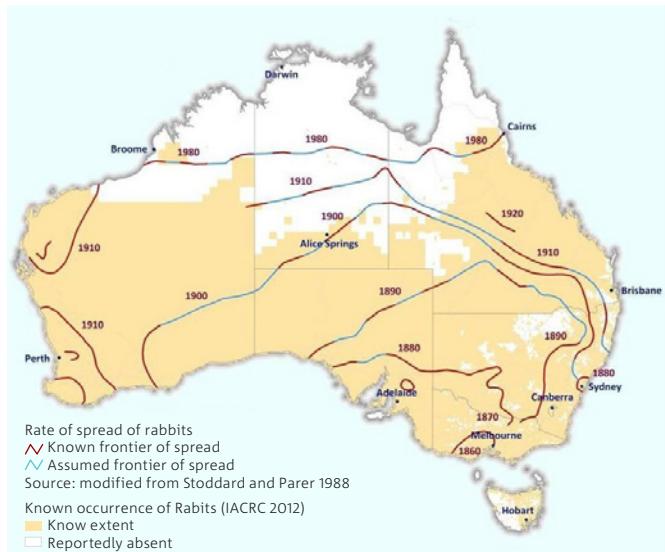


Figure 1: Rate of spread of wild rabbits since their introduction in 1857–60 to their current known distribution

Source: Invasive Animals CRC, Stodart and Parer.²⁸

Feral cats

- Number from 2.1 million to 6.3 million depending on environmental conditions.²⁹
- Kill more than 456 million native mammals,³⁰ 272 million birds,³¹ 92 million frogs³² and 446 million reptiles³³ each year.
- Have contributed to the extinction of 27 native species³⁴ and threaten the survival of 124 more.³⁵

Feral pigs

- Number up to 23.5 million and inhabit 45% of Australia.³⁶
- Cost up to \$106 million per year in crop damage and control measures.³⁷
- Destroy up to 90% of turtle nests in some areas.³⁸



Female cane toads can lay up to 35,000 eggs at a time.
Photo by Ruchira Somaweera

Cane toads

- Have invaded more than one million square kms in Australia and are advancing up to 60km a year in Western Australia.³⁹
- Can lay up to 35,000 eggs at a time.⁴⁰
- Are fatally toxic to many native predators, including northern quolls and goannas.⁴¹

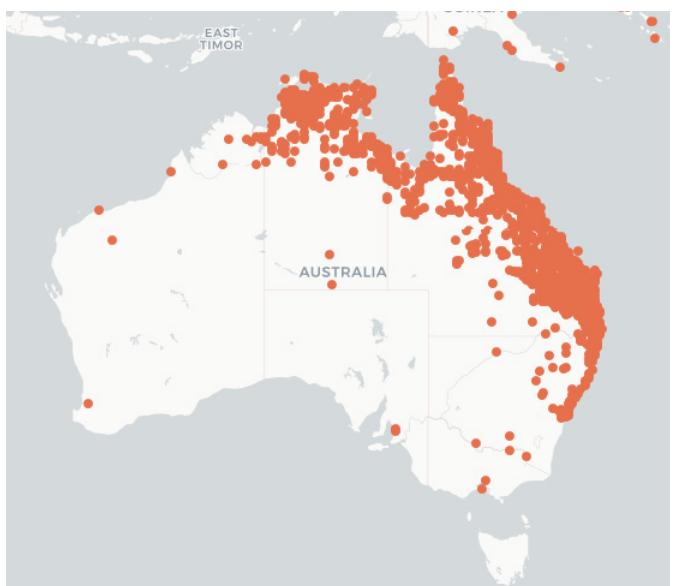


Figure 2: Current known distribution of cane toads (map does not reflect naturalised distribution of cane toads)
Source: Atlas of Living Australia.⁴²



About 200 million carp are present in our waterways in an average season. Photo by CSIRO

European carp

- Are found in all states and territories except the Northern Territory and are a major threat in the Murray–Darling Basin.⁴³
- Number about 200 million in an average season.⁴⁴
- Compete for food with native fish, damage aquatic habitats, reduce water quality, and undermine recreational fishing.⁴⁵

Red imported fire ants

- Are one of the worst invasive species in Australia,⁴⁷ forming super colonies with extremely high ant densities that can take over vast areas.⁴⁸
- Are the focus of eradication in one of Australia's most expensive single species management program.⁴⁹
- Prey on and compete with native animals, inflict painful and potentially fatal stings on people, wildlife, pets and livestock,⁵⁰ and have costly impacts on agriculture and horticulture.⁵¹



Red fire ants inflict painful and potentially fatal stings on people, wildlife, pets and livestock. Photo Shutterstock

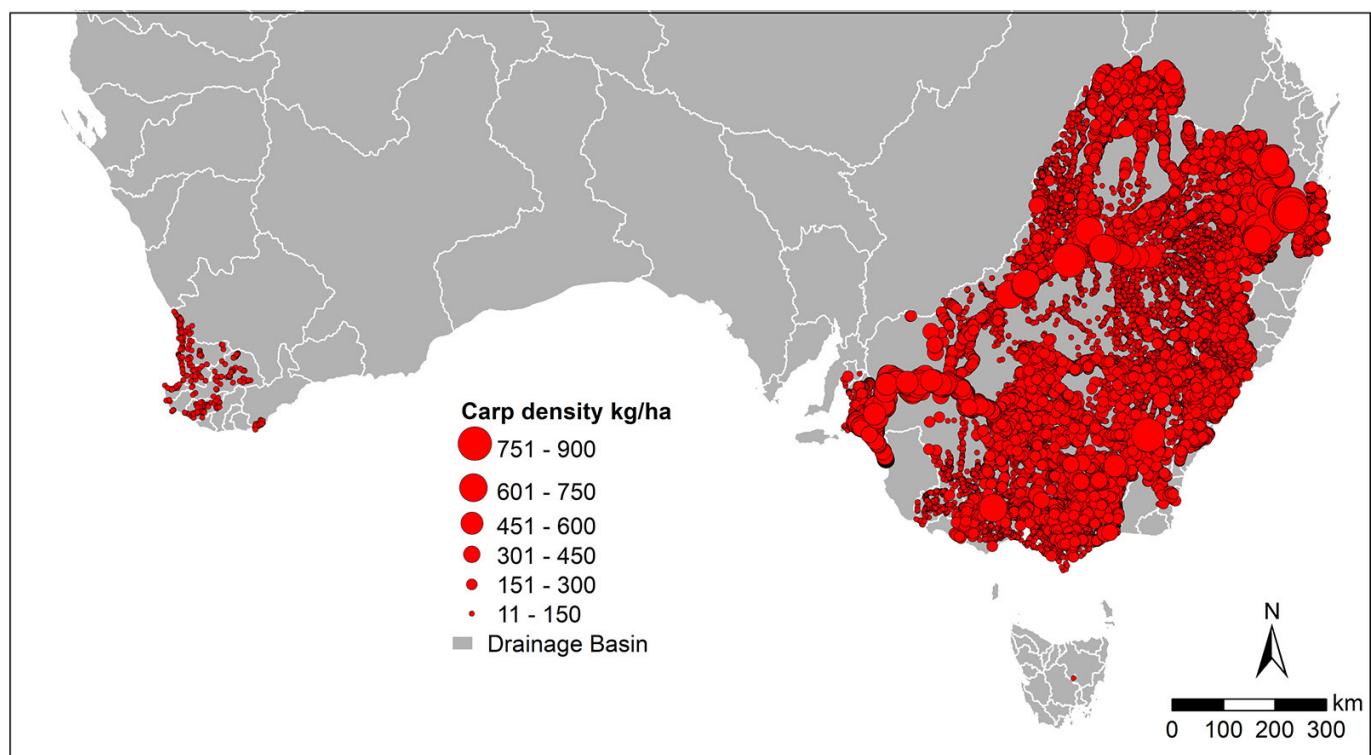


Figure 3: Location and density of carp in Australia

Source: Biological Conservation⁴⁶

Weeds

Lantana

- Has invaded more than four million hectares since 1841.⁵²
- Is a serious threat to World Heritage-listed areas, including the Wet Tropics of northern Queensland, Fraser Island and the Greater Blue Mountains.⁵³
- Costs graziers more than \$100 million a year in lost production.⁵⁴

Blackberry

- Infests nearly nine million hectares of land in Australia.⁵⁵
- Forms impenetrable prickly thickets and smothers native shrub and ground vegetation, provides shelter for rabbits and foxes, and increases fire threats.⁵⁶
- Costs around \$100 million a year in lost agricultural production as well as control measures.⁵⁷

Buffel and gamba grasses

- Are large African grasses introduced for cattle that are spreading rapidly across northern and central Australia.^{58,59}
- Fuel intense fires – gamba grass fires are up to eight times more intense than native grass fires.⁶⁰

Prickly acacia

- Occurs in Queensland, New South Wales, Western Australia and the Northern Territory, and has the potential to infest 50 million hectares.⁶¹
- Forms dense thickets, transforming grasslands into thorny shrublands and facilitates erosion.⁶²
- Costs the grazing industry more than \$9 million each year.⁶³



Blackberry provides fuel for bush fires and shelter for rabbits and foxes. Warren River, Western Australia. Photo by Bruce Webber

Pathogens

Myrtle rust

- Is a South American fungal disease that has spread rapidly in eastern Australia since first detected in 2010.⁶⁴
- Infects almost 400 species in Australia's iconic Myrtaceae family (including gum trees, paperbarks and lillipillies).⁶⁵
- Has already caused serious to catastrophic declines in at least 16 species, including the now critically endangered native guava, brush turpentine and velvet myrtle.⁶⁶

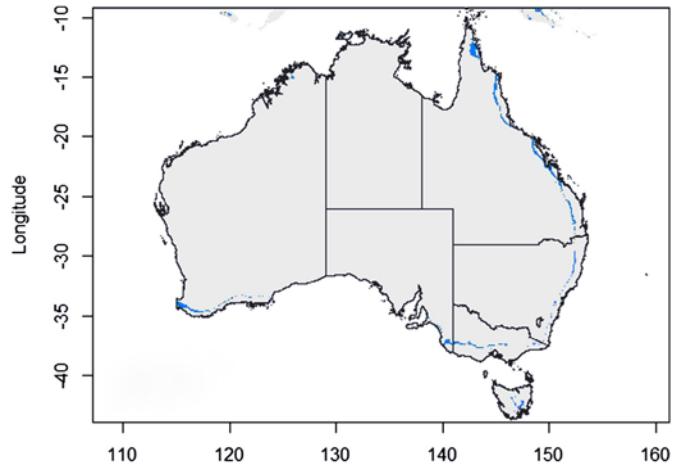


Figure 4: Potential distribution of myrtle rust across native forest in Australia

Source: adapted from Biological Conservation.⁶⁷

Chytrid fungus⁶⁸

- Is a fungal skin pathogen that has wiped out 90 amphibian species globally and threatens hundreds more.⁶⁹
- Arrived in Australia probably in the 1970s and is now widespread.⁷⁰
- Has been considered to have caused the extinction of five Australian frog species,⁷¹ the decline of another 43 frog species⁷² and is the primary cause of expected future declines and extinctions.⁷³

3 The size of the problem

The death toll

Invasive species continue to be the main driver of extinctions in Australia and its offshore islands.⁷⁴

At least 100 unique native species have become extinct since European settlement, with more than three quarters due wholly or partly to invasive species. Pathogens have also been a major cause of extinctions.⁷⁵

The tragically long list of extinctions caused primarily by invasive species include:

- 29 mammals
- 5 frogs
- 4 birds
- 3 lizards*
- 2 plants
- 1 invertebrate
- 1 fish*

* 2 lizards and the fish are alive in captivity

Dozens more species are at high risk of extinction in the next 20 years, including mammals, birds and reptiles threatened by cats and foxes, frogs by chytrid fungus, fish by invasive fish, and plants by pathogens and feral herbivores.⁷⁶

By the numbers

- **66% of weed species** were deliberately imported as garden plants.⁷⁷
- **75% of invasive fish** were imported as aquarium fish.⁷⁸
- Up to **six million** feral goats are grazing the nation.⁷⁹
- **20 million** land crabs have been displaced by yellow crazy ants on Christmas Island.⁸⁰
- **Phytophthora dieback** has affected plants across more than a million hectares⁸¹ in Western Australia alone.
- Australia has the **world's largest feral camel population**.⁸²

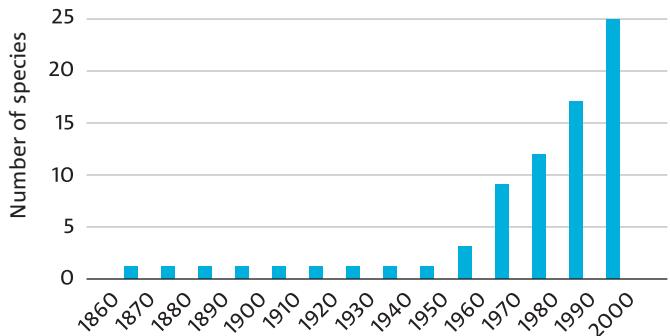


Figure 5: Cumulative increase in alien ornamental fish species in Australia

Source: CSIRO⁸³



Managing hooved animals such as feral camels to protect native wildlife habitats and farm infrastructure has proven cost effective. Photo by Bruce Webber



Impacts of climate change can be seen in the Pilbara region where Mexican poppies now grow freely. Photo by Bruce Webber

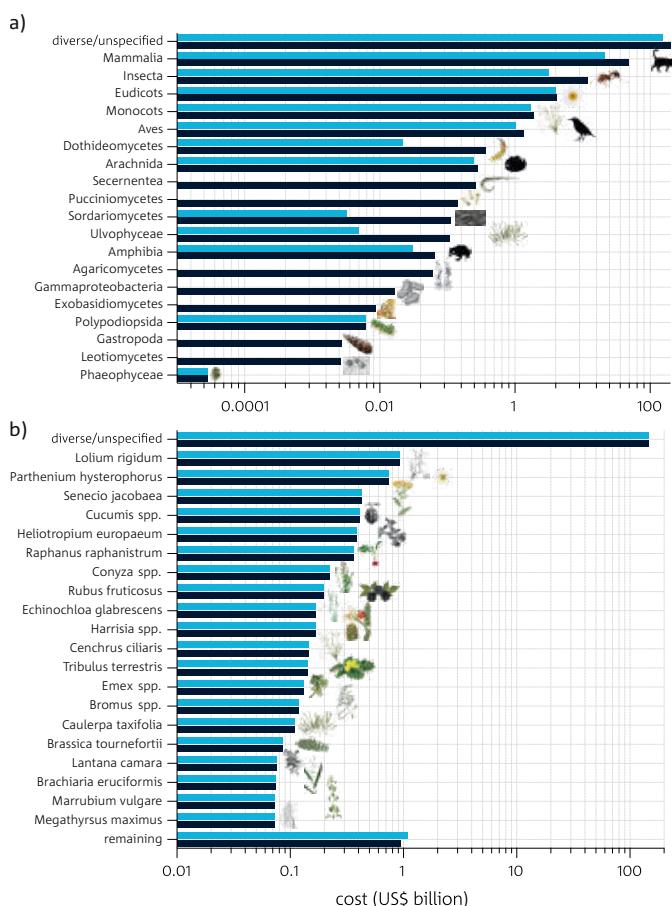


Figure 6: Economic cost of invasive species in Australia. Key: Sum of all (black) and highly reliable-only (blue) costs according to a) taxonomic class, b) by plant species, c) by mammal species, d) by insect species. Species are generally ordered by highly reliable costs, but, in some cases where there were no highly reliable costs for a particular category, the category was placed in the order suggested by total costs. Source: adapted from NeoBiota.⁹¹

The bottom dollar on costs

On top of the devastating environmental toll, invasive species impose an enormous financial cost on all Australians.

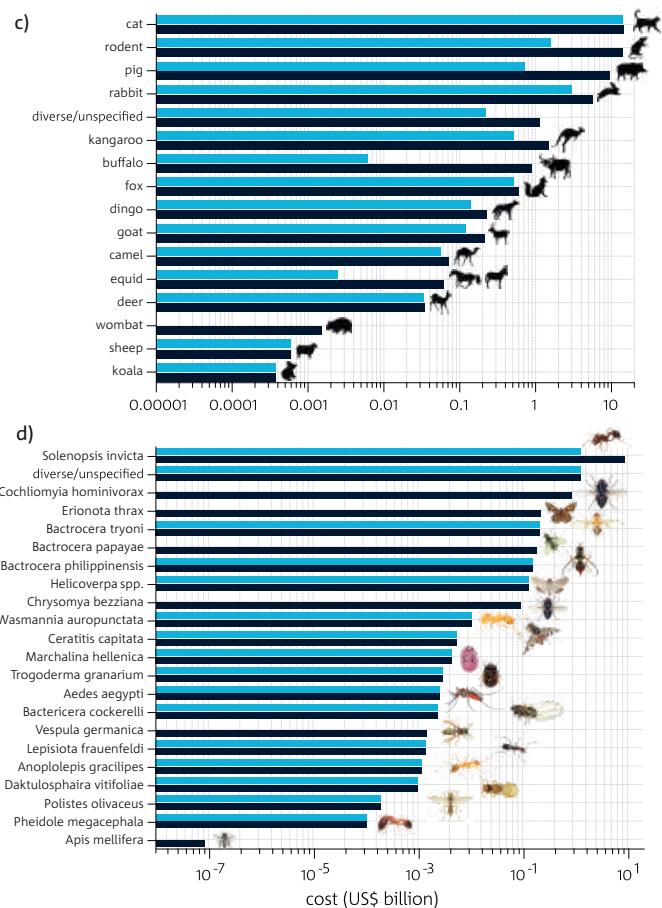
From 1960 to 2017, invasive species cost Australia at least \$390 billion.

The current annual cost is conservatively estimated to be around \$25 billion and it has increased up to six-fold every decade.⁸⁴

Weeds cost agriculture at least \$5 billion a year.⁸⁵

Costs of control

- Grain growers spend more than **\$2.5 billion** a year on weed control.⁸⁶
- Australia is spending more than **\$50 million** a year eradicating four invasive ant species from the nation and yellow crazy ants from the Wet Tropics.^{87,88}
- Public authorities spend about **\$300 million** a year controlling weeds.⁸⁹
- The most expensive individual pests to control are cats, rabbits and fire ants⁹⁰ (see Figure 6).





Stinking passionflower smothers native plants at Fitzroy River. Photo by Bruce Webber

4 The pressure points

The most effective and low-cost solution for managing invasive species is *prevention*, although this is not always possible.

Australia's biosecurity system to stop pests and diseases from entering, establishing and spreading in Australia is under increasing pressure – due to escalating trade, climate change, extreme events and other changes.^{92,93}

The urgency to safeguard our borders is being driven by several issues.

Global trade

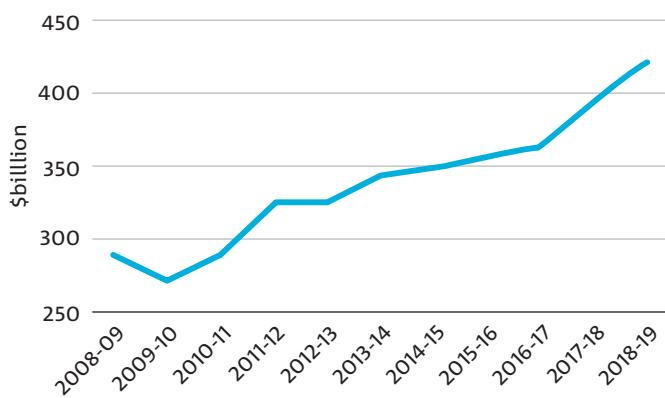


Figure 7: Australia's growing imports increase biosecurity risks
Source: DFAT.⁹⁴

The global marketplace is a superhighway for invasive pests.

Every year, thousands of shipping containers imported into Australia are contaminated in some way, especially with soil or plant material.⁹⁵ Invasive insects and diseases arrive on plants, produce and timber. Freighters carry marine organisms in their ballast or on dirty hulls. Hitchhiker pests include the brown marmorated stink bug, tiny but devastating Khapra beetle and Asian gypsy moth.

International and domestic air cargo also brings in unwanted arrivals through perishable plants and increased online retailing.⁹⁶ A bunch of flowers can hide ants, beetles, mites and pathogens ready to run rampant in a new country.

Illegal trade in exotic pets is growing with numerous prohibited wildlife available to buy online. Species such as the North American red-eared slider turtle threaten native aquatic animals in Australian waterways.^{97,98}

CASE STUDY

The Khapra beetle is the number one exotic pest threat to Australia's grain industry. It contaminates stored grain, making it unfit for human or animal consumption.

Beetles have been detected on a range of cargo entering Australia in shipping containers.⁹⁹ This includes infested refrigerator packaging found by an eagle-eyed citizen in 2020 who reported it to biosecurity authorities enabling a quick response to control the situation.¹⁰⁰

A Khapra beetle outbreak could cost Australia \$15 billion over 20 years.¹⁰¹

Climate change

"Climate change will increase the risk of invasion by alien organisms including pests, weeds and diseases."

– Intergovernmental Panel on Climate Change¹⁰²

Climate change is already making Australia's invasive species problem more urgent and unpredictable.¹⁰³ While invasive species are flourishing in warmer, cooler, wetter or drier surroundings, some native species struggle to adapt to shifting weather patterns.

More extreme weather events make our ecosystems more vulnerable to pests and diseases,¹⁰⁴ while impacted native species are resilient to droughts, they are not to rapid climate change.

Cane toads¹⁰⁵, feral horses and buffel grass are just some of the invasive species now on the march. Our native plants and animals are ill-prepared to compete for water, food and shelter.

In northern Australia, a combination of rising sea level and water buffalo threatens to destroy freshwater floodplain wetlands and paperbark swamps that are a mecca for waterbirds. By digging swim channels, water buffalo allow seawater to intrude into wetlands, turning them saline and allowing salt-tolerant weeds to invade.¹⁰⁶

From flood to fire

Extreme events such as fires, droughts, cyclones and floods, exacerbated by climate change, create opportunities for invasive animals and weeds to spread and dominate the landscape.¹⁰⁷

Floods can transport invasive species far and wide – they accelerated the spread of carp throughout the Murray–Darling Basin¹⁰⁸ and enabled athel pine¹⁰⁹ to establish along 600km of the Finke River in central Australia.

Around the country, bushfires often burn hotter when they are fuelled by introduced grasses.¹¹⁰ After the fires, feral herbivores can easily move in to stop regeneration.¹¹¹

CASE STUDY

Among the greatest threats to Australian wildlife are intensifying fire regimes and feral cat predation. These threats are combined after severe bushfires.

Often travelling long distances (up to 30km), cats target recently burnt areas for intensive hunting. An influx of cats can decimate the survivors of fire.¹¹²

Burnt areas offer easy hunting. Studies in the Kimberley recorded cats making a kill on 70% of their prey in open environments compared to only 17% in areas with dense grass or complex rocks.¹¹³

Fires create opportunities for invasive animals and weeds to spread. Photo by Bruce Webber





Buffel grass thrives along a train line in the Pilbara region. Photo by Bruce Webber

Travel and tourism

Invasive species are the ultimate backpackers, travelling across the world by hitching a ride in any way they can. They arrive on clothes or baggage, as gifts or souvenirs and in the treads of our shoes. They are also deliberately and illegally imported.

As Australia's nature tourism and outdoor recreation sectors grow, it is important to shore up national biosecurity measures to keep pests out and limit the potential damage to our vulnerable and iconic natural ecosystems.¹¹⁴

Urbanisation

Expanding cities are radically changing how humans interact with the environment. Urbanisation is putting pressure on the natural environment and, for many years, scientists have been warning of the growing risks from zoonotic diseases (infections spread from animals to humans) such as COVID-19.¹¹⁵ Urbanisation also brings new pest and disease risks, like new weeds,¹¹⁶ nearer to important areas for agriculture and conservation.¹¹⁷

5 Two futures

Australians have fought to keep unwanted plant and animal arrivals under control since the arrival of the First Fleet on our shores in 1788. Australia's first Quarantine Act more than 100 years ago was one of the first pieces of quarantine legislation in the world. To date, keeping out unwanted arrivals has depended on effective border security and, while we have not completely shut the gate, we are beginning to turn the tide.

Eradicating or containing pests is difficult but Australia has long-term programs underway to tackle the spread of high impact weeds, plant diseases and fire ants.

Australia is a world leader in biological control. Success stories include the control of prickly pear, a cactus which once infested 240,000 square kms of Queensland and New South Wales but has been at insignificant levels for the past 80 years.¹¹⁸

The highest weed biocontrol success rate has been against aquatic weeds.

The rabbit biological control program has also been highly successful, leading to far fewer rabbit numbers and impacts since the first biocontrol agent was released in 1950.¹¹⁹

These programs show that coordinated action is crucial if Australia is to strive towards removing invasive species as the number one threat to our unique biodiversity.

2050 will look vastly different than it does today if we take a 'business as usual' approach to fighting invasive species.

In some areas feral pigs destroy up to 90% of turtle nests. Photo by Brian Ross





Cabomba weed is so thick it makes recreational activities such as swimming, fishing and canoeing difficult and dangerous.
Photo by CSIRO

This is Australia's sliding doors moment – a tale of two very different futures rests in our control.

If we do nothing now, the future in 2050 will most probably look like this:

- Increased interceptions of threats at and inside our borders.
- More frequent pest and weed incursions.
- More human, plant and animal disease outbreaks and disease vectors.
- Established pests and weeds will worsen.
- Increased environmental, economic, social impacts.¹²⁰
- More native species extinctions and degraded landscapes.
- Eroding of social licence to prevent and control pests and diseases.
- Damage to Australia's reputation and success as an exporter of high-quality, safe food products.

But if we apply a strategic and innovation-centred approach to our invasive species issue, the future looks much brighter:

- Effective management of invasion pathways (trade and tourism).
- Flattening the curve of incursions and quickly detecting and containing likely impacts.
- Improved decision-making supporting effective eradication and disease outbreak response campaigns.
- Innovation-led cost-effective solutions incorporating automation and artificial intelligence to speed up decision-making across the pre-border to post-border biosecurity continuum.
- Strategic investment in potential new technologies supporting next generation biological control.
- Effective national-to-local community networks for response and management programs.
- Building ecosystem-based management to increase resilience of wildlife and landscapes to a rapidly changing climate.
- Increased humaneness in control options.
- Reduced non-target impacts on plants, animals and insects.
- National reputation for safe and quality exports.

Choosing our 2050

On farm



IF WE ACT

- New and improved biocontrols developed to limit or eliminate established pests and weeds.
- Drones and automated sensor networks used to protect farms from invasive animals such as wild dogs and feral pigs.
- Protect Australia's reputation for safe and quality exports.



IF WE DON'T

- Mice, rabbits and foxes continue to plague our farmers.
- Current detection methods abandoned due to ineffectiveness.
- Damage to Australia's reputation as an exporter of quality, safe food products.

Kitchen



IF WE ACT

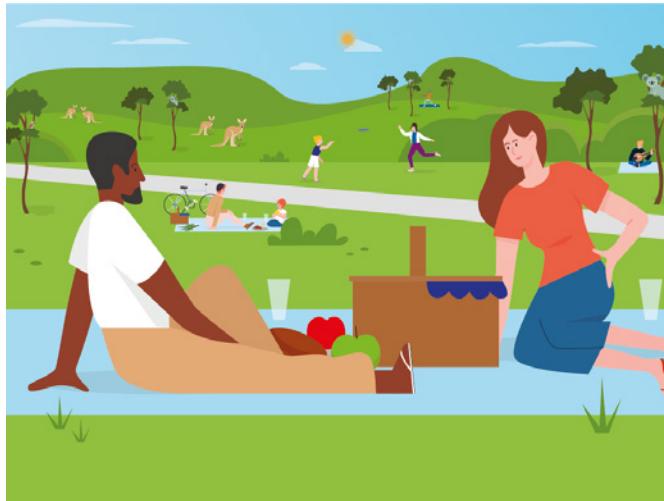
- European honeybees are protected and continue crop pollination which helps maintain our ecosystem.
- Supply of fresh produce remains available and the cost stable.



IF WE DON'T

- Pollination-reliant crops – including food – are adversely affected.
- Cost of fresh fruit, vegetables, bread and wine will increase.
- Supply issues will limit access to farm grown produce.

Outdoor recreation



IF WE ACT

- Maintain a quality outdoor lifestyle.
- Protect Australia's natural environment and native species.
- Protect our unique native wildlife.



IF WE DON'T

- Invasive ants spoil simple pleasures like picnics.
- Insect-borne diseases become a greater threat to our health.
- New diseases impact native species and invasive weeds degrade forests and landscapes.

Travel and trade



IF WE ACT

- Airport controls include foot baths for shoes and 3D X-rays for baggage to detect 'stowaways'.
- Ports have automated 24/7 surveillance and electronic sensors.
- Biosecure shipping containers become industry standard.



IF WE DON'T

- Detection and prevention systems struggle to keep up with illegally imported or invasive hitchhiker plants and animals.
- Lack of upgraded and standardised domestic biosecurity systems makes it difficult to prevent threats.
- Biosecurity systems abandoned due to ineffectiveness.



North Australian Indigenous Land and Sea Management Alliance staff assisting Indigenous rangers with invasive pest management on Cape York. Photo by Seth Seden

6 Indigenous people and invasive pests

Aboriginal and Torres Strait Islander people are Australia's greatest land custodians and are deeply concerned about and affected by invasive species, which have devastating impact on the natural ecosystems that have sustained livelihoods for millennia.¹²¹

Most Australian plants and animals are an intrinsic part of Indigenous communities' spiritual connection to Country.¹²²

Indigenous people draw on a complex mix of traditional laws, historical experience and ecological knowledge to respond to the presence and impacts of introduced animals on their lands.¹²³ With a long history of adapting to environmental and social change, Indigenous communities respond to landscape changes through holistic management practices.¹²⁴ For example, Indigenous groups in Arnhem Land and Kakadu National Park view the feral water buffalo and pigs as an important modern food source which has been integrated into their culture and identity over generations.¹²⁵

The management of invasive pests must respect the need for prior and informed consent in recognising and acknowledging the deep connection that exists between the local people and their contemporary socio-ecological environment.¹²⁶

Indigenous Australians contribute cultural heritage, unique understanding and knowledge of the management of invasive species on Country. Indigenous land managers are best placed to lead management programs on their lands supported by research organisations and assisting technologies. This co-development model that supports Indigenous led management practices through collaborative partnerships that share knowledge and experience is the best approach.



IF WE ACT

- Abundance of native species and plenty of bush tucker.
- Pristine wetlands and vibrant sacred wildlife refuges.
- Increase in environmental tourism.
- Maintain Indigenous cultural sites.

IF WE DON'T

- Wetlands become a pig quagmire and wildlife refuges devoid of life.
- Loss of cultural heritage and degradation of cultural sites.
- Indigenous and environmental tours cancelled, nothing to see.

7 The future of pest control

Australia is a world leader in developing pest and weed solutions, such as biocontrol agents and baits. We now need to take advantage of new genetic and digital technologies to create solutions for the 21st century that can find and manage invasive species more cheaply, easily and quickly. These new technologies have the potential to be game changers in how we tackle pests and weeds in the future.

Internet of things digital sensing platforms

By combining aerial imagery or real-time satellite technology with sensors that rapidly and autonomously detect pests, weeds and diseases and the damage they cause. Remote farm surveillance systems can also quickly monitor and report airborne pests and diseases.

Wireless sensor networks, often in remote terrains, are providing cost-effective solutions to tracking. By combining camera trap images with real-time alerts, land managers are now able to detect the presence of pest animals in real-time, enabling quick and focussed actions to control them.

Farmers use intelligent farm robot to detect weeds.
Photo Shutterstock





Quickly and accurately identifying fish and harmful pathogens in international ornamental fish consignments is being transformed by environmental DNA detection technology. Photo by CISS

Detect, track and trace

Many new diagnostic and track and trace tools are under development. A number have already been rolled out to detect COVID-19 viral fragments in wastewater and to track mutations and trace movement of the virus through the human population. These tools are being applied to biological invasions along with detection of images, sound and odour through increasingly automated detection systems.

We are diagnosing genetic fingerprints of invaders, from environmental DNA (eDNA) using hair, traces found in water, soil and even vacuum cleaner dust to identify invasive species. Detailed whole of genome sequencing and analysis allows the tracking and tracing of invasive species and diseases in real-time, as they arrive and spread in Australia. This technology will become an invaluable tool to help stop outbreaks.

CASE STUDY

Handheld devices that quickly sequence environmental DNA (eDNA) can provide an early warning system for many invasive species. These devices reduce DNA scans from days to about an hour, sending data to the cloud for speedy analysis. They also detect multiple invasive species, allowing a quick response.¹²⁷

Genetic control technologies

Genetic technology has great potential to help stop new invaders.¹²⁸ Genetic biocontrol options, such as causing all offspring in invasive populations to be only one sex, could dramatically change the fight to control widespread pests such as carp, cane toads, rodents, rabbits and potentially feral cats. “Daughterless carp” was the first¹²⁹, but advances in gene technology promise quicker, easier, more cost-effective ways to control pests at large scales.¹³⁰

Artificial intelligence (AI) and machine learning

Researchers are creating a range of automated devices which see, think and act to target specific pests and weeds. They include a high-speed camera to spot roadside weeds, a robot that identifies and physically removes weeds on farms, a smart phone app that detects fall armyworm damage on crops, and AI technology that protects sea turtle nests from feral pigs in north Queensland.

Data collected from sensors, drones, satellites and citizen scientists, when analysed with machine learning algorithms, will help to transform invasive species management.



Drones can monitor crops and identify invasive species.
Photo Shutterstock

Drones

Aerial and underwater drones are a safe, cheap way to tackle invasive species in remote and inaccessible locations. They can cover large areas with an array of cameras and sensors, collect specimens, target invasive species with pesticides¹³¹ and drop targeted bait.

On the Great Barrier Reef, the Rangerbot is used to detect Crown of Thorns starfish infestations with 99% accuracy. The drone then fires an injection to kill the starfish without damaging any coral.



CASE STUDY

Invasive species threatening wildlife in Kakadu National Park are being controlled through a combination of Artificial Intelligence, modern science and traditional knowledge.¹³²

Under the direction of Indigenous rangers, drones are being used to record video images across remote wetlands. The images are then computer-analysed to locate invasive species such as para grass, water buffalo and feral pigs.

The applications measure the biodiversity benefits of the management action, for example, the numbers of nesting magpie geese and the impacts of para grass control.

The information is made available to rangers in real time to help them decide the best way to control the pest, protect the environment and the inroads being made.

Satellites

Low-orbit satellites will provide broadband access across remote Australia allowing more effective monitoring and surveillance of established pests which can be used to support management decision-making in real time.

Small, low-cost nanosatellite constellations are a cost-effective and efficient alternative to drones and satellites for collecting remote-sensing data.¹³³



2001 nanosat Kinéis low earth orbit satellite is used to help rangers track feral buffalo and cattle in northern Australia.
Image ©HEMERIA

Biosensors

Highly sophisticated nano-biosensors could play a major role in efficiently monitoring large areas or ports of entry to Australia. Nano-biosensors can also detect fungal, viral and bacterial pathogens in crops and animals and could be adapted to invasive species.

For example, e-nose devices, which mimic a dog's nose, are used to detect hazardous microbes on crops, plant diseases and wood rot caused by pathogenic fungi. Portable e-nose devices will increasingly be used for invasive species detection.

Citizen science tools

Smart phones have made it possible for everyone in the community to help track invasive species.¹³⁴

In Australia, FeralScan (feralscan.org.au) is a free website and phone app that can be used to record pest animal activity, evidence of pests, pest damage and control actions. FeralScan contains more than 260,000 records of pest animals, entered by thousands of landholders, community groups, professional pest controllers and biosecurity organisations across Australia, to help them cooperatively manage pest animals in their region.

People power

From the suburban backyard to the science lab, Australians play important roles in pest prevention and control. By supporting education and public awareness campaigns, we can mobilise 25 million people to help manage our current pests and protect Australia from future threats.

Establishing a national, coordinated community surveillance network would bolster efforts to quickly find and eradicate invasive species before they get a foothold.

Technology has made it possible for everyone to get involved, allowing creation of a huge knowledge database. By harnessing our collective knowledge, Australia can overcome the growing environmental and economic damage being wrought by pests, weeds and diseases.

CASE STUDY

Australia's first real-time weed identification app will help farmers and community groups act earlier on invasive weeds. The smart phone app WeedScan will help people identify and report weeds and learn the best way to manage them.¹³⁵



We can protect Australia's ecosystems if we act now.

8 Conclusion: where to from here?

Australia's size, relatively small population, large numbers of pests and weeds already here, and the pressure from new invaders, mean smart decisions and interventions are needed now to make sure resources are invested where they are most effective.

The huge historical and likely future losses to our threatened species and ecosystems, particularly under climate change, demand urgent action. We need to think big on how we can help turn around our extinction rate of over four native species lost every decade and help protect agriculture from pests and weeds with game changing technologies.

We need to target and detect new pests before they enter Australia, eradicate unwelcome arrivals where possible and contain them where it is not. We need to better manage high-impact established invaders at landscape scale and protect environmentally sensitive and high-value sites.

CASE STUDY

In Western Australia's Pilbara region, where small native mammals are disappearing at an alarming rate, the most cost-effective recommended strategies have been:

- Managing feral hooved animals such as feral pigs, donkeys, camels and cattle.
- Creating predator-proof sanctuaries.
- Feral cat management.¹³⁶

As well as saving native species and protecting ecosystems, these methods create jobs and improve carbon sequestration, soil health, water quality and resilience to climate change.

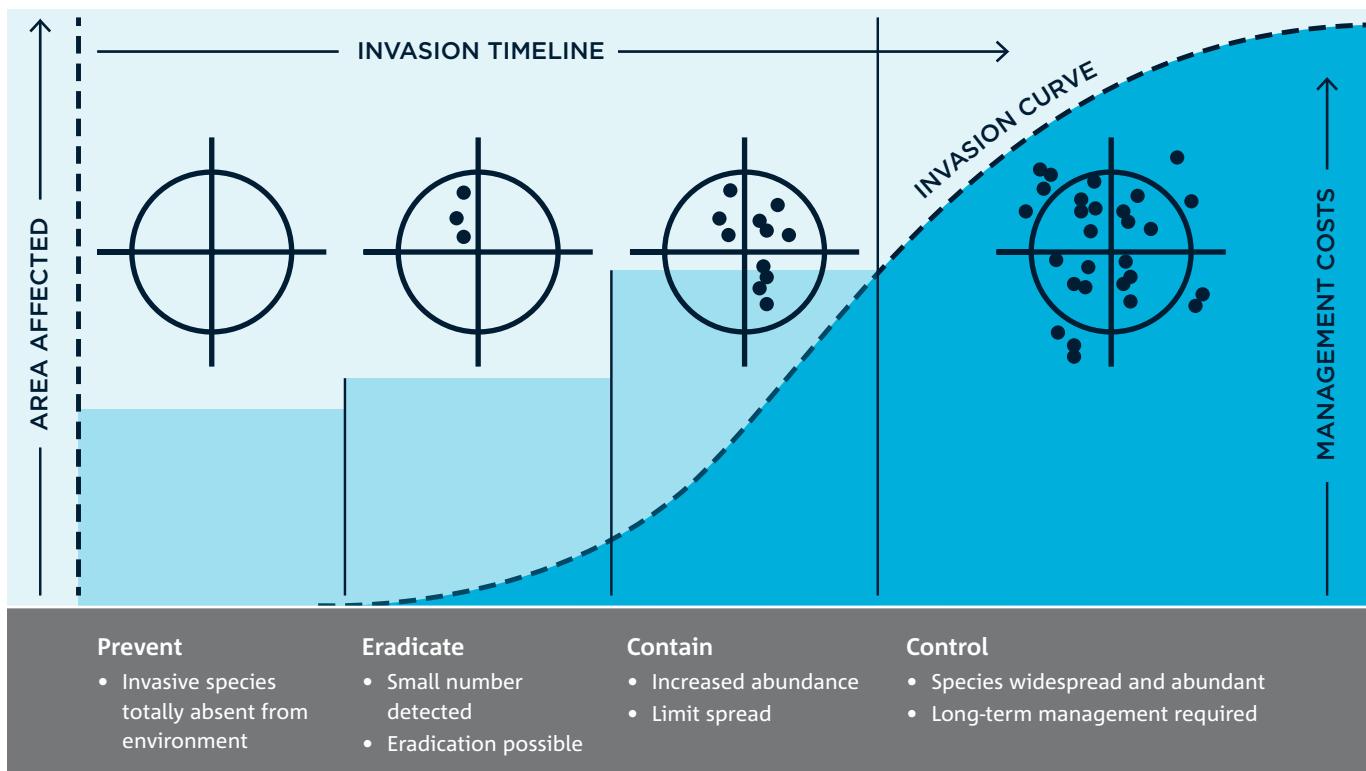


Figure 8: The invasion curve shows the stages of invasive pest and weed management

Source: Adapted from Generalised invasion curve for pests, weeds and diseases showing actions appropriate at each stage and return on investment. Source: Department of Environment and Primary Industries, Victoria.

The way forward

Australia is a world leader in managing biosecurity risks but there is still an urgent need to transform our methods to get ahead of our growing invasive species pressures.

Emerging technologies offer incredible opportunities for detecting, eradicating and preventing invasive species without wasting resources or harming our natural environment.

Already, innovation is happening through artificial intelligence, big data analytics, genomic and genetic technology, remote sensing and remote learning.

But Australia should invest in and exploit these new technologies to understand their full potential and how to manage any risks.

To better harness emerging technologies, Australia could revitalise its biosecurity research and innovation system and create innovation pipelines.

If we continue to invest in long term, strategic research and development that can fast-track novel biosecurity technologies, we will create new ways to prevent, eradicate, contain and control invasive pests.

Targeted investment can greatly reduce the costs of traditionally expensive human-led surveillance systems.

The Australian and state governments could consider matching New Zealand's leading Predator Free 2050 Strategy, focussed on the complete removal of their top feral predators in the next 30 years. Transformational genetic biocontrol technology makes this a possibility for several of our major vertebrate pests.

With commitment from the highest levels of government, corporate and philanthropic partners, and the broader community, we can protect the natural resources and ecosystems that underpin Australia's economy, environment and our wellbeing.

European rabbits infest two-thirds of Australia.
Photo by Rick Nash and CISS



Taking action now

Everyone has a role to play and there are simple steps you can take to help protect our environment and our industries as we move towards a pest free future. Be aware of your surroundings and if you spot a biosecurity risk in your community, report it.

Report a pest or disease concern to the Department of Agriculture.

Travel safely

Don't bring restricted items into the country or your state or territory. Follow the rules, don't be sorry and declare all items when returning home from overseas or interstate.

Be a responsible pet owner

Pets make fabulous companions but both cats and dogs are responsible for native animal population declines. Walk dogs on leads, keep cats indoors and never dump unwanted pets. Register your animals and keep them out of wildlife areas. Keep your pets healthy and free of disease.

Grow natives in the garden

Find out the best plants to grow and when to plant them. Consider native species rather than introduced plants. Remove any weeds that grow in your backyard and dispose of green waste properly. Check your plants for signs of disease and be on the lookout for weeds that pose a biosecurity risk to Australia.

Report pest species

Report pest animal locations through the FeralScan app. Download it from the app store or visit the website.

Protect farm animals

Always be on the lookout for symptoms of diseases that could impact your stock and animals on nearby farms.

Keep a healthy hive

If you keep bees, keep your hive healthy. Make sure you know how to identify pests and diseases. Register your hive and comply with state and territory rules.



Join a group actively working to prevent or reduce the impact of invasive weeds and pests. Photo by Ecohort Pty Ltd

Get involved

Find an organisation that is actively working to prevent or reduce the impact of invasive weeds and pests. Volunteer some time or make a donation.

Visit these sites for more information

- biosecurity.gov.au
- [CSIRO.au](http://csiro.au)
- invasives.com.au
- feralscan.org.au
- gardeningresponsibly.org.au
- growmeinstead.com.au
- pestsmart.org.au
- weeds.org.au

Listen to the Centre for Invasive Species Solutions 11 episode podcast series '**Towards A Feral Free Future**' or search in your favourite podcast search engine.

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