CENTRE FOR
INVASIVE SPECIES SOLUTIONS

ONE STEP AHEAD

ON THE FRONT FOOT OF INCURSIONS

COLLABORATION | INNOVATION | IMPACT | INVASIVES.COM.AU

These projects were funded by:

Australian Government
Department of Agriculture, Fisheries and Forestry

Program and Project Partners

Arthur Rylah Institute for environmental research

CSIRO

Manaaki Whenua Landcare Research

UNIVERSITY OF CANBERRA

THE UNIVERSITY of ADELAIDE

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

NSW GOVERNMENT

VICTORIA State Government

Government of South Australia

Cover image: Red-eared slider turtle. Source: Pablo Garcia-Diaz.

Corn snake, Lithgow. Source: NSW Department of Primary Industries.

Incursions of invasive pests need to be detected early for there to be any chance of cost-effective containment and eradication. With the diverse array of exotic species of concern and many possible introduction pathways, there is a pressing need for the Centre for Invasive Species Solutions to develop cost-efficient surveillance tools and put these into the hands of agency staff, industry and community groups across Australia. This has been a major focus area for the Centre.

Pests and diseases already introduced to Australia threaten the existence of some of our unique flora and fauna, and have contributed to Australia's unenviable rate of species extinction.[1] Many introduced invasive animals, weeds and pathogens have proliferated and spread across the country, destroying or threatening our native species and ecosystems.[1]

The challenges of preventing further incursions and establishment only increase with greater trade and travel.[1]

1 Inspector-General of Biosecurity 2019, *Pest and disease interceptions and incursions in Australia*, Department of Agriculture and Water Resources, Canberra, April. CC BY 4.0. pg.40

SO, WHAT KEEPS US UP AT NIGHT?

In November 2020 the National Priority List of Exotic Environmental Pests, Weeds and Diseases was released to strengthen environmental biosecurity and develop a national approach to address biosecurity risks to Australia's environment. The list contains 168 exotic species of significant environmental and social amenity risk to Australia, including the Asian black-spined toad, the Red-eared slider turtle and Corn snakes.

The **Asian black-spined toad** are frequently intercepted as stowaways and illegally imported pets. The Asian black-spined toad was intercepted 75 times from 2003 to 2010 (at least 79 animals) and 25 times from 2009 to 2012. Similar to the cane toad, they secrete poison from a gland on their back that is likely to harm native reptiles, birds and mammals that prey on the toad. Australia's climate and habitat are well suited to the Asian black-spined toad (ABST), as it prefers lowland habitats such as disturbed forests, forest margins, riparian areas and human-dominated agricultural and urban areas[2] — which represents a high percentage of Australia's coastal landmass. They also compete with native frog and amphibian species for food and habitat. The Asian black-spined toad is a prolific breeder — a single female is able to produce up to 40,000 eggs at a time.

The **red-eared slider turtle** is one of the world's most invasive species. They compete with native turtles for food as well as nesting and basking sites. They breed rapidly, with up to five clutches of eggs per year with anywhere up to 23 eggs per clutch. They have been illegally smuggled into Australia. They are sold through the illegal pet trade: for example, 90 were found being kept illegally in one backyard in Sydney in 2000.[3] Red-eared slider turtles have been either deliberately released by, or escaped from, people who have illegally bought them, and now several populations are established in Australia. Ongoing monitoring and eradication programs are minimising these populations. They can live in a wide range of freshwater habitats, including urban waterways, and tolerate brackish water. They are able to survive cold winters by hibernating.

Corn snakes are illegal to keep in Australia as they have a very high potential to become invasive pests. In Victoria alone, authorities detect three to four corn snakes every year.[4] They are well suited to Australian conditions, and can tolerate a wide variety of climates and habitats. Due to the illegal pet trade they have been detected in all states of Australia where they either escaped from, or were deliberately released by, the people who held them. Corn snakes are non-venomous constrictors so are likely to have a significant impact on native small mammals, lizards and birds. If they became established, it is unlikely that Australia could eradicate them.

Weeds are estimated to cost Australia nearly $5 billion on average every year. To date, we know of about 5,900 known weedy plants introduced to Australia but yet to naturalise. However, around 20 weeds naturalise every year – one every 18 days!

Invasive ant incursions: From 2001 to 2018, red imported fire ants entered Australia at least 16 times – six of these were not immediately detected,[5] and a further two incursions occurred in 2019 and 2021. Australia currently has seven national eradication programs responding to incursions of browsing ant (NT, Qld and WA), African black sugar ant (WA), electric ant (Qld), and red imported fire ant (Qld and WA).[5,6] Australia's governments are now spending almost $60 million a year managing and eradicating exotic ants. The risk of further incursions is high, with 29 border inceptions of exotic invasive ants between 2012 and 2017.[1]

From July 2007 to August 2016, the Emergency Plant Pest Response Program recorded 607 plant pest incidents – particularly through pest notifications (38.4%), incursions (37.7%) and weed notifications (22.9%).[1] **Pathogens** accounted for most incursions (66%) and included more than 300 different species.[5] **Invertebrates** accounted for 26%, and weeds for 23%.[5] From 2010 to 2016, departmental officers made 18 **animal disease** interceptions, including 15 in imported dogs.

---

2 Van Dijk PP, Iskandar D, Lau MWN, Huiqing G, Baorong G, Kuangyang L, Wenhao C, Zhigang Y, Chan B, Dutta S. 2004. Duttaphrynus melanostictus.e.T54707A86445591. http://www.iucnredlist.org/details/54707/0.

3 https://www.smh.com.au/politics/nsw/one-of-the-world-s-worst-invasive-species-is-threatening-our-turtle-population-20210228-p576in.html

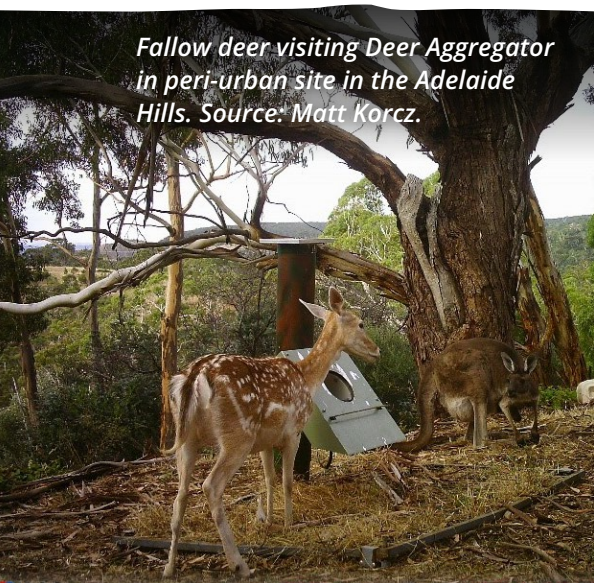
4 https://agriculture.vic.gov.au/biosecurity/pest-animals/priority-pest-animals/eastern-corn-snake

5 Inspector-General of Biosecurity 2019, *Environmental biosecurity risk management in Australia*, Department of Agriculture and Water Resources, Canberra, March. CC BY 4.0.

6 https://www.outbreak.gov.au/

WHAT WE'RE UP TO

The Centre and its predecessor, the Invasive Animals CRC, joined the fight to beat the introduction of exotics to Australia 17 years ago, along with other agencies and research organisations around Australia.



Fallow deer visiting Deer Aggregator in peri-urban site in the Adelaide Hills. Source: Matt Korcz.

A Platyfish investigation on the North Coast of NSW. Source: NSW Department of Primary Industries.

Red imported fire ants. Source: National Fire Ant Eradication Program, Queensland Department of Agriculture and Fisheries.

Feral cat trapped on Kangaroo Island. Source: Centre for Invasive Species Solutions.

Prickly pear (Opuntia spp.). Source: Centre for Invasive Species Solutions.

We **detect, survey and respond to invasive species invasions** by establishing national collaborations to develop new and better tools, systems and strategies.

Deer control research, in northern tablelands, NSW. Source: Centre for Invasive Species Solutions.

Real time eDNA tools can improve early detection and our response for high-risk pest animals

COMPLETED

An Asian black-spined toad, Cloverdale. Source: Department of Primary Industries and Regional Development, Western Australia.

CONTACT

Professor Dianne Gleeson, the University of Canberra.
dianne.gleeson@canberra.edu.au

Rapidly detecting and identifying high-risk invasive animals at the point of entry or in the field is essential to prevent new incursions and to enable a rapid response for successful eradication.

Detecting and monitoring species using environmental DNA (eDNA) is recognised as a powerful tool because of its greater sensitivity for less effort, and fewer negative affects compared to traditional survey methods.

With eDNA now firmly established as a highly effective method for species detection, we are now working on further refining it for routine use in biosecurity applications by:

- developing rapid eDNA detection tools using real-time technology for *in situ* application
- developing new eDNA tests for at least two high-risk invasive species and applying the tests to field operations
- validating a multi-species eDNA detection framework to enable all species to be detected from a sample or location
- developing eDNA capability within end-user organisations through targeted training and provide readily available eDNA services for ongoing surveillance.

The research team has been working with Asian black-spined toads and red-eared slider turtles as the starting point for refining our detection techniques. Several countries now use these techniques to detect the toads.

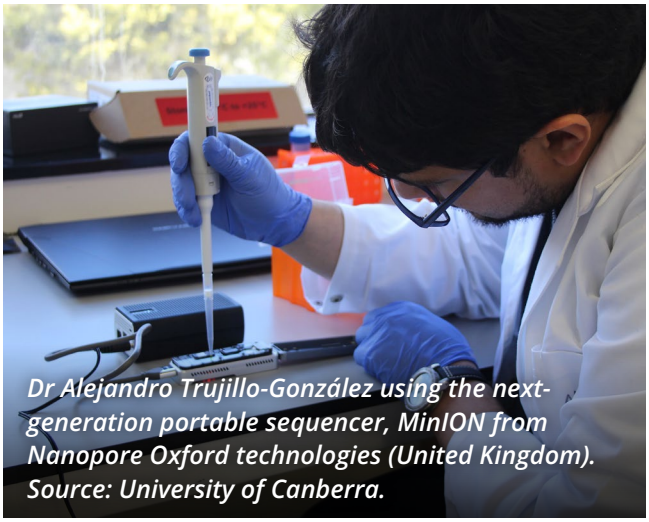
Other projects we have undertaken using eDNA include:

Biosecurity molecular screening using eDNA technology in ornamental fish

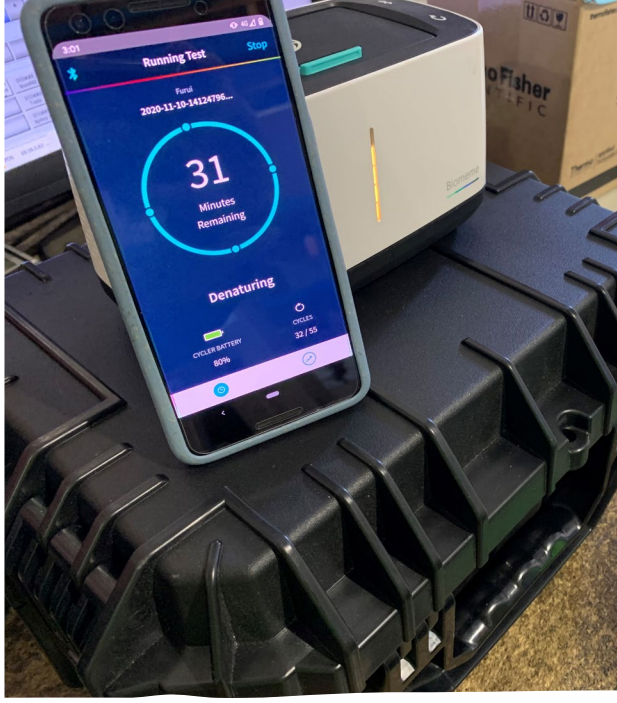
This project focuses on how we can quickly and easily detect biosecurity threats using the international ornamental fish trade as a case study. The ornamental fish trade is an ideal system for multi-species detection technology using eDNA, as the DNA from both the fish present and any potential pathogens are contained within a relatively small amount of water.

The project aims to:

- develop standard protocols for collecting samples and preparing eDNA
- construct reference databases for potential target species and for various taxonomic levels to identify novel species
- trial a real-time DNA sequencing platform – the Oxford Nanopore MinION device
- provide a bioinformatic pipeline to support analysis and interpretation of the results as they occur in real time.



Dr Alejandro Trujillo-González using the next-generation portable sequencer, MinION from Nanopore Oxford technologies (United Kingdom). Source: University of Canberra.



Field-based rapid detection of khapra beetle using real-time PCR

We used portable real-time PCR technology to detect khapra beetle eDNA during biosecurity responses in Canberra, ACT. We collected dust samples using vacuum cleaners and tested for khapra beetle eDNA using portable technologies. This research showed that insect pest DNA could be collected and extracted from dust samples and that timely detections could be done by biosecurity officers in the field.

Dr Alejandro Trujillo-González using the Franklin™ qPCR thermocycler from Biomeme (United States). Source: Alejandro Trujillo-González.

Rapidly screening shipping containers for khapra beetle using eDNA and real-time PCR

We used real-time PCR technology to detect eDNA/RNA as a rapid and effective method for screening shipping containers of khapra beetle. eDNA detection provided information on historical presence of khapra beetle within shipping containers, while eRNA provided information on the active presence of khapra beetle infestation.

Detection data from the trial was supplied to the Department of Agriculture, Fisheries and Forestry to help them determine the interception rates for khapra beetle via the sea-cargo pathway. This was essential to help the Australian Government to develop effective response measures against the increased biosecurity threat posed by khapra beetle. Samples collected during this trial are now being used to inform DAFF on the presence of brown marmorated sting bug, spongy moths and electric ants.

COMPLETED

Sophisticated digital surveillance may be our best tool to monitor illegal trade in vertebrate pests

CONTACT

Associate Professor Phill Cassey, the University of Adelaide.
phill.cassey@adelaide.edu.au

The growth and commercialisation of the open-source internet has greatly modified the environment in which pet markets and illegal wildlife traders can operate.

Given the complex and cryptic nature of these online networks, the development of advanced web intelligence techniques is core to successfully disentangle the trade. As online trade platforms and networks grow, so too does the inadvertent risk of new vertebrate incursions and introductions because of intentional or unintentional release.

We are working with the University of Adelaide to extract and tease apart the great amount of relevant online information that is available. We do this with sophisticated techniques and analytical approaches, to assist biosecurity agencies and decision-makers to take early preventive action to protect the environment and our economic activities such as agriculture.

Our project has developed novel approaches to understand the nature of exotic pet keeping, illegal vertebrate trade in Australia, and invasive species incursions.

The aims of the project are to develop efficient surveillance and identification tools for:

- enforcing compliance of keeping and trade in alien animal and plant species
- early warning of new alien vertebrate incursions
- identifying the origins of seized specimens from illegal keeping and at-large incursions.

Owning a non-native reptile, such as this ball python, is illegal in Australia. Source: Adam Toomes.

COMPLETED

Innovative tools to monitor illegal trade in plants

CONTACT

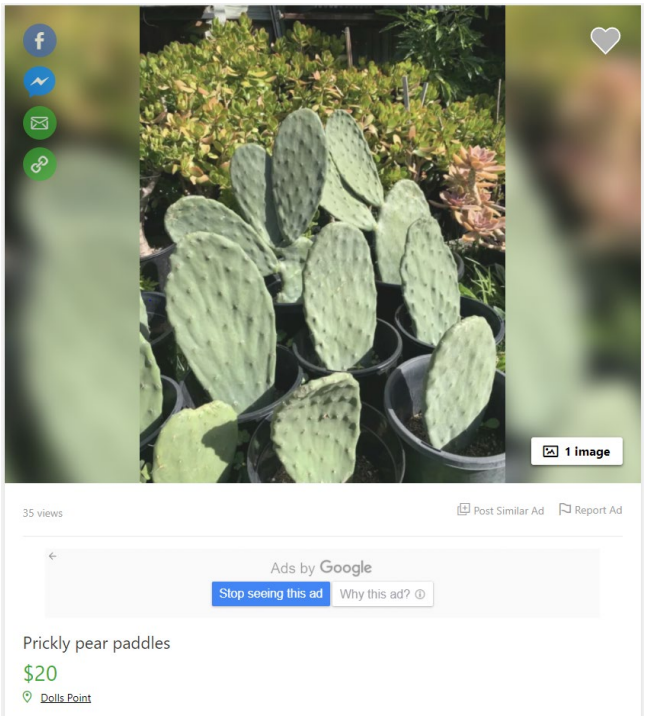
Associate Professor Phill Cassey, the University of Adelaide.
phill.cassey@adelaide.edu.au

We need innovative solutions to manage the biosecurity risk and prevent new weed incursions from the e-commerce trade of high-risk invasive species and declared pests.

These platforms can provide a significant pathway for the introduction of weeds and pest animals into new areas — which cause major biosecurity risks to human health, food security, agricultural health and biodiversity loss.

We are addressing this risk by:

- working with the University of Adelaide to develop a new surveillance system that monitors illegal plant trade on e-commerce websites
- creating baseline data on the quantity and diversity of illegal plants sold online in Australia
- developing minimum standards to guide web 'scraping' of sites engaged in illicit trade (including the dark web)
- providing a user-friendly interface for Australian Government and state and territory officials to handle and analyse the surveillance data.



An example of prickly pear being sold online. Source: Jacob Maher.

COMPLETED

Automated detection: triggering smarter, faster, better responses to incursions

CONTACT

Dr Susan Campbell,
Department of Primary Industries and Regional Development, Western Australia.
Susan.Campbell@dpird.wa.gov.au

The project aims to integrate the remote acoustic surveillance, detection and reporting with West Australia's starling control program. Source: Peter Tremain.

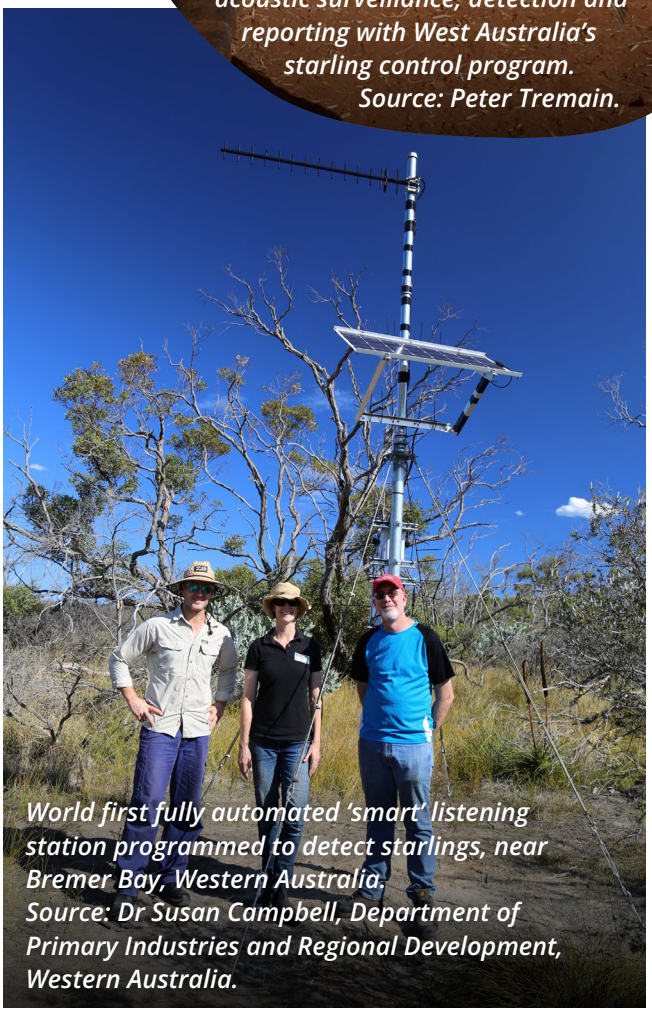
Passive acoustic surveillance (PAS) technology has the potential to help prevent establishment of high-risk invasive species that we can identify by their sound. Detecting invasive species early leads to more feasible and cost-effective control and potential eradication.

PAS could provide a solution for repeated, long-term, continuous monitoring — potentially over large spatial scales in a variety of habitats, generating data that can be curated and permanently stored for collaborative multi-disciplinary use in much the same way as traditional museum specimens.

To overcome difficulties associated with managing and analysing excessively large volumes of data, researchers have developed algorithms specific to certain species to automate detection of a wide variety of mammals, birds, amphibians and invertebrates (summarised in Aide et al 2013).

The project aims to:

- develop and demonstrate a cost-effective, remote acoustic surveillance, detection and reporting solution that uses WA's starling control program as an initial case-study
- develop and demonstrate how we can use the remote acoustic detection solution for other high-priority invasive pest animals
- communicate our results and promote people taking up the technology.



World first fully automated 'smart' listening station programmed to detect starlings, near Bremer Bay, Western Australia. Source: Dr Susan Campbell, Department of Primary Industries and Regional Development, Western Australia.

COMPLETED

Automated thermal imagery analysis could solve common problems of traditional surveying

CONTACT

Dr Stuart Dawson, Department of Primary Industries and Regional Development, Western Australia. Stuart.Dawson@dpird.wa.gov.au or
Peter Adams, Department of Primary Industries and Regional Development, Western Australia. Peter.Adams@dpird.wa.gov.au

Achieving successful pest species management requires integrating appropriate management techniques and also effective monitoring. Commonly deployed monitoring techniques (e.g. aerial surveys and camera traps), can be labour intensive, require substantial investment in equipment and personnel, carry safety risks, and rely on indices rather than enumeration.

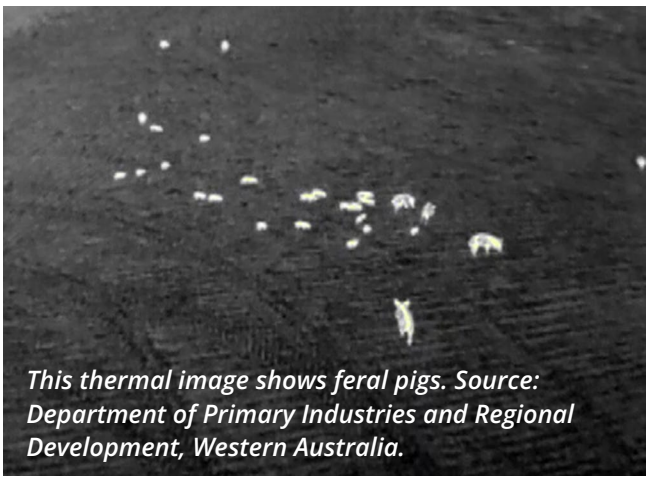
Applying thermal sensors for ecological and wildlife monitoring is a rapidly growing area of investigation. Thermal sensors have the potential to address common issues associated with traditional survey techniques such as visual acuity and observer fatigue, especially when attempting to detect cryptic targets or surveying large areas.

However, video surveys (thermal or otherwise) generate hours of footage that requires time-consuming and laborious analysis.

Automated computer software systems that detect and identify target animals from thermal imagery have the potential to quickly and accurately analyse large imagery datasets. This project will develop automated models for analysing thermal imagery that incorporate artificial intelligence and deep machine learning to improve low-cost and time-efficient processing. This work will provide a central analysis platform compatible for low-, medium- and high-resolution thermal imagery that is equally accessible to all stakeholders and end users.

The project aims to:

- demonstrate combined computer vision and geolocation software for detecting target objects from thermal imagery
- develop a deep machine learning model for fully autonomous thermal imagery analysis that can support monitoring multiple pest-animal species at a landscape level
- demonstrate how automated thermal imagery analysis can help manage multiple pest-animal species
- communicate our outcomes and promote people taking up the technology.



This thermal image shows feral pigs. Source: Department of Primary Industries and Regional Development, Western Australia.

WeedScan — an ID app and website for people to monitor and manage priority weeds

CONTACT

Hanwen Wu, NSW Department of Primary Industries.
hanwen.wu@dpi.nsw.gov.au

It's difficult to manage what you can't identify — especially with weeds!

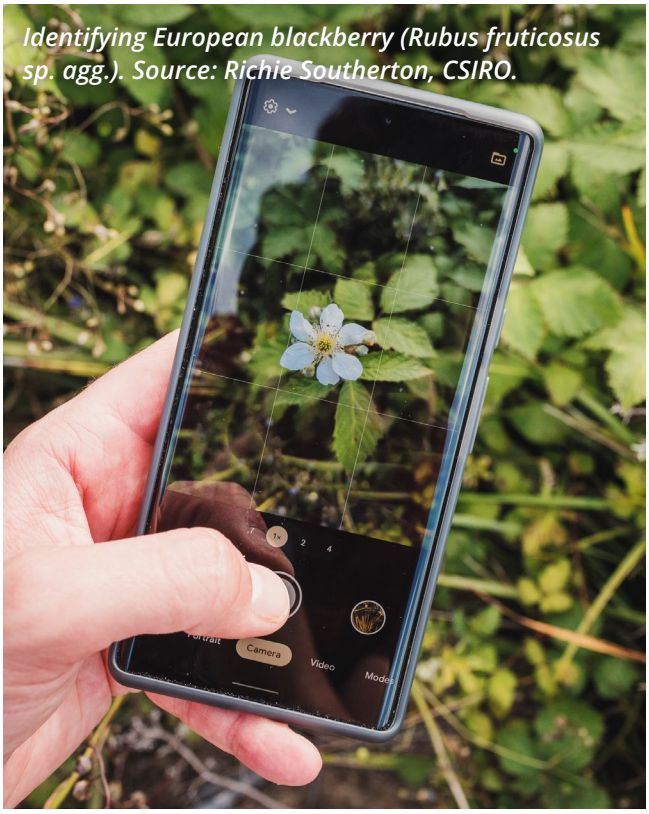
To overcome this, WeedScan (slated for release in mid-2023) is being developed by the Centre for Invasive Species Solutions, CSIRO, the NSW Department of Primary Industries along with other State and Territory partners.

Mobile apps like PlantSnap and PictureThis have already demonstrated that they can revolutionise plant identification through artificial intelligence, instantly suggesting plant names based on a digital photograph.

WeedScan is an easy-to-use digital tool that will help graziers; farmers; bush regenerators; communities; NRM bodies; and state, territory and Australian government bodies:

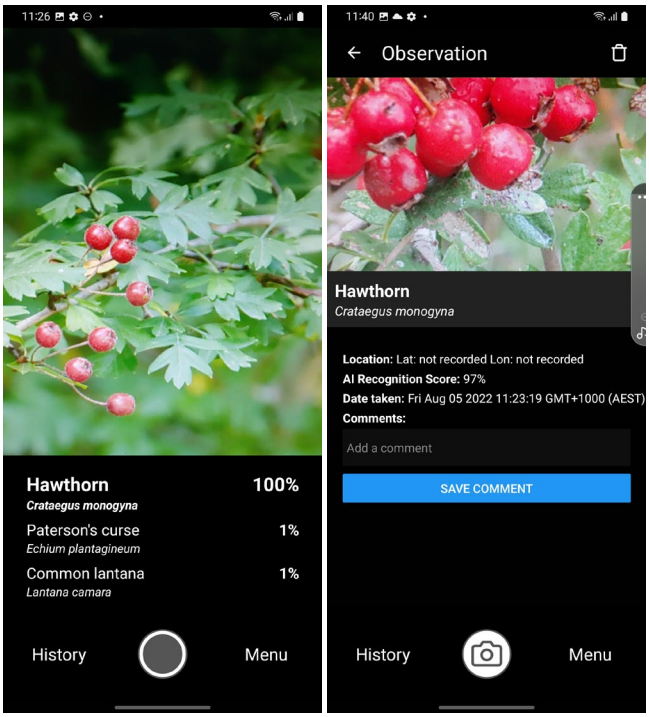
1. quickly identify priority weeds without expert knowledge
2. easily access best practice management information
3. facilitate the reporting of priority weeds, with alerts/notifications automatically sent to government control authorities
4. take action individually or as part of a community-led regional WeedScan network.

The WeedScan prototype correctly matches silverleaf nightshade with the photo submitted. Source: Hanwen Wu, NSW Department of Primary Industries.



Identifying European blackberry (Rubus fruticosus sp. agg.). Source: Richie Southerton, CSIRO.

Example of the current WeedScan App on an Android phone. Source: Alexander Schmidt-Lebuhn, CSIRO.



Developing and integrating active and passive surveillance systems and tools

COMPLETED

CONTACT

Dr Peter Caley, CSIRO.
peter.caley@csiro.au

For any chance of cost-effective containment and eradication when invasive exotic vertebrate pests invade, they need to be detected early. However, there is insufficient public funding available for structured, human-based, agency-delivered surveillance given the diverse array of exotic species of concern and the wide array of possible introduction points.

Harnessing the observational powers of community surveillance activities can potentially dramatically increase the scale and sensitivity of our surveillance efforts, though there are gaps in the coverage citizens provide. Luckily, in those areas where citizens aren't providing sufficient surveillance advances in sensor and genetic-sampling technology may enable more cost-effective surveillance by industry and government

Because there has been little testing of data streams from community surveillance about vertebrate pest biosecurity information, we have been unsure how they could contribute to the timely detection of incursions of invasive exotic vertebrates into Australia. It transpires that citizen are providing very effective surveillance for many of the exotic vertebrate pests considered high risk of entry.

The observations that citizens make are biased strongly towards where they live, however from a surveillance perspective this transpires to be ideal, as humans will be the underlying cause of most future vertebrate incursions. There are several reasons for this. First, deliberate introductions as were historically undertaken by acclimatisation societies have ceased and deliberate releases for other reasons (e.g. as biocontrol agents) are highly unlikely to be approved, or subject to stringent safeguards. The pet trade, however, provides an avenue for numerous species of vertebrate pests to enter Australia (both legally and illegally), and it is escapes and releases from this pool of animals from which the vast majority of future vertebrate incursions will arise. Conveniently, such escapes will occur right where the citizen surveillance effort is highly effective: perfect allocation of effort from a risk management perspective.

There are, however, gaps and blind spots in citizen surveillance activities. First, there are areas where access is difficult (e.g. urban wetlands) or prohibited (e.g. land around facilities such as airports). Second, actual sightings and photographic evidence of sightings from aquatic habitats are difficult to obtain, thus lessening the surveillance power inherent in the crowd-sourcing of species identification. This underlies the ability of exotic fish in particular and to a lesser extent turtles to become well established before citizen detections. In these situations and for these animal groups, active surveillance will be needed, and technological advances such as eDNA, bioacoustics monitoring and smart traps are part of the solution.

We want to create guidelines for how to best combine passive and active surveillance tools with community surveillance to enable the timely detection of invasive vertebrates, to prevent these vertebrate pests becoming established.

Case study: Testing Toadinator traps and toad attractors

The Queensland Department of Agriculture and Fisheries has been undertaking collaborative research with Bogor Agricultural Institute, University in Indonesia, and James Cook University to test the use of 'Toadinator' cane toad traps and 'ACTA attractors' for Asian black-spined toads in Indonesia. To date, the project has collected a reference library of calls and analysed the calls to determine their audio characteristics. Asian black-spined toads appear to call and respond to calls primarily from water (rather than from land like cane toads). Researchers have done an initial pilot study using an 'average' call in a Toadinator, and refinement of the Toadinator traps is ongoing.

A cane toad caught in the 'Toadinator'. Source: Steve Csurhes, Queensland Department of Agriculture and Fisheries.

COMPLETED

Responding to invasive pests: creating tools to determine cost-effective decisions for managing eradications

CONTACT

Dr Dave Ramsey, Arthur Rylah Institute, Department of Environment, Land, Water and Planning, Victoria. David.Ramsey@delwp.vic.gov.au or
Dean Anderson, Manaaki Whenua Landcare Research, New Zealand. andersond@landcareresearch.co.nz

Some of the highest benefit–cost investments in biosecurity are experienced in early interventions against new pest incursions that eradicate the pest before it becomes established.

Once managers decide to initiate eradication of a pest, they then must decide how and when to proceed — then once eradication appears to be successful and the pest is no longer being detected, they must decide whether to stop and declare success. In practice, these decisions are usually based on subjective reasoning rather than scientific evidence.

In this project, we aimed to develop an evidence-based approach for managing invasive pest eradications. We developed tools based on decision theory, to help managers develop optimal (cost-effective) decisions during an eradication response. The tools provide near-real-time analysis of data collected during an eradication program, which is then used to make optimal (cost-effective) decisions about how to deploy resources.

The most important result was a suite of decision tools packaged in a user-friendly web-based interface, flexible enough to be applied to most pest eradication response.

More specifically, the suite of decision tools were designed to address the following set of decisions:

- Estimate the feasibility of eradication (probability the response will fail)
- Cost-effective removal and surveillance strategies (decisions around which tools to use)
- Progress towards eradication

Cost effective “stopping rules” (when to declare successful eradication)These kinds of guidance tools improve the capability of government agencies to make cost-effective decisions about eradication responses and use of resources.

The software tools are available through the following links

- https://landcare.shinyapps.io/EradSim/
- https://landcare.shinyapps.io/eradication_app/
- https://landcare.shinyapps.io/proofofabsence/

COMPLETED

A National Incursion Management Framework for Invasive Species — developed!

Asian black-spined toad. Source: Department of Primary Industries and Regional Development, Western Australia.

CONTACT

Dr Michelle Christy, Department of Primary Industries and Regional Development, Western Australia.
michelle.christy@dpird.wa.gov.au

There is currently no specific emergency management framework for the invasive animal and plant sector, although responses may be carried out under the National Environmental Biosecurity Response Agreement 2.0 (NEBRA) and the Emergency Plant Pest Response Deed (EPPRD), and align with the Biosecurity Incident Management System (BIMS).

This project sought to bring the above approaches together under a single emergency-management framework. Key was building on existing resources; while identifying and addressing risks specific to the invasive animal and plant sector; incorporating vertebrates, weeds and other invasive species as part of the Environment and Invasives Committee (EIC) framework.

It aimed to increase our ability to prevent, detect early, and effectively respond to new animal and plant incursions by developing a national emergency response framework (provisionally called the "InvasivesPlan") for potentially invasive animal and plant incursions.

The resulting framework:

- is applicable across vertebrates, weeds and freshwater invertebrates
- is maximally consistent with existing approaches and structures in the animal and plant health sectors
- includes minimum standards/normal commitments for surveillance, diagnostics and response
- clearly defines the incident definition stage.

This project also led to the creation of a response manual for dealing the Asian black-spined toad, terrestrial snakes, factual extension material around 10 iconic National Surveillance Targets and the National Incursion Management toolkit.

CENTRE FOR
INVASIVE SPECIES SOLUTIONS

Building 22, University of Canberra
University Drive South, BRUCE ACT 2617
T 02 6201 2887 • **F** 61 2 6201 2532
E communications@invasives.com.au