Invasive Animals CRC

2005–12

Research portfolio summary

An Australian Government Initiative

CRC AUSTRALIA

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Cover images:

(Top photo, back row right) Jessica Marsh, NRM Liaison Officer - Invasive Animals CRC with landholders at Warialda in NSW, studying maps to identify priority sites for management of pest species in the Border Rivers-Gwydir CMA area. This led to the production of the Border Rivers-Gwydir Invasive Species Plan.

(Bottom photo) Niccy Aitken, University of Canberra, in the Wildlife Genetics Laboratory where genetic analysis of scats is undertaken as part of the Fox Eradication Program in Tasmania.

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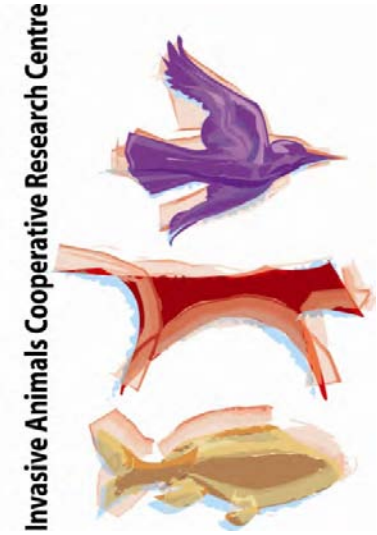

Research Portfolio Summary 2005–2012

An Australian Government Initiative

CRC AUSTRALIA

Foreword

This research portfolio summary reports on key Invasive Animals CRC projects undertaken during its 2005–2012 rounds of funding. The project summaries in this report are aligned with the Invasive Animals CRC's strategic goals to 30 June 2012. In some cases projects align to several goals — such as demonstration sites, products undergoing commercialisation, and Invasive Animals CRC-supported PhD students — and this is reflected in the summary structure.

The portfolio summary highlights the major project achievements for the Invasive Animals CRC. Our annual reports expand on the broader program and organisational achievements.

Invasive Animals CRC is more relevant today than when first envisaged, with emerging threats in wildlife diseases, increasing rabbit problems, mouse plagues and wild dog issues. We have serious bird problems and in our stressed rivers we have carp and the growing threat of tilapia. While we are looking at solutions at species and regional levels, there is an urgent need to establish early warning systems for emerging pests and continue efforts to commercialise our products.

Our biggest challenge into the future, now that the Invasive Animals CRC has secured new research investment to 30 June 2017, is not just discovering and developing the science, but to continue working successfully with the community in the application of control measures in coordinated ways across landscapes.

We have a remarkable group of people who have come together at all levels to form the Invasive Animals CRC. Thank you to our management, program and project teams and to each of our participants for your outstanding commitment and work towards our common goal: developing initiatives, new technologies and tools to cut through the costs of invasive animal impacts.

It's great to see the progress from the collaboration across different governments, companies and organisations, working "with" each other both nationally and internationally. We have new products and a mountain of strategic knowledge.

The exciting challenge ahead is ensuring product uptake and blending this brainpower into our PestSmart toolkits and training programs. Additionally, that ongoing research is kept alive and these prospective advantages are not lost.

It's just so important to give considered time to mapping out how we do ensure that this new knowledge is packaged so that our end users — the farmers, rangers, program planners, and policy analysts — just can't help but pick it up.

This is the value proposition that we originally put to the CRC Committee and through it the broader community: to highlight that we would make an actual difference on our farms, our nature reserves and in our waterways.

Helen Cathles
Chair

Andreas Glanznig
CEO

Participants of the Invasive Animals CRC

The Invasive Animals Cooperative Research Centre (2005–12) had 41 Participants. Along with our core staff, program leaders, coordinators, students, researchers and administration staff within our Participant organisations are vital to ensuring the delivery of our goals.

Core participants

University of Canberra – Australia's Capital University
acta
ACT Government – Environment and Sustainable Development
Australian Veterinary Association
CSIRO
Murray–Darling Basin Authority
Government of South Australia – Primary Industries and Regions SA
Environment & Climate Change
pestat Ltd
SARDI – South Australian Research and Development Institute
Queensland Government
The University of Newcastle Australia
The University of Sydney
Parasitech
The University of Queensland
State Government Victoria – Department of Primary Industries
NSW Department of Primary Industries
Department of Environment and Conservation
ValueMetrics Australia

Supporting participants

australian wildlife conservancy
ANU – The Australian National University
awi – Australian Wool Innovation Limited
Cattle Council of Australia
Department of Conservation – Te Papa Atawbai
Australian Government – Grains Research and Development Corporation
E&C Fisheries
LHPA – Safeguarding Agriculture in NSW
mla – Meat & Livestock Australia
State Government Victoria – Department of Sustainability and Environment
USDA
Queensland Government
Tasmanian Government
fera – The Food and Environment Research Agency
WWF
Department of Agriculture and Food – Government of Western Australia
Australian Government – Australian Bureau of Agricultural and Resource Economics and Sciences
University of Minnesota
The University of York
CONNOVATION – Conservation by Innovation
Landcare Research – Manaaki Whenua

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Introduction

The Research Portfolio Summary outlines research projects undertaken by the Invasive Animals Cooperative Research Centre between July 2005 and June 2012.

The Invasive Animals CRC's motto is 'together, create and apply solutions'. The CRC receives funding to foster collaboration between researchers, business, government and non-government agencies to reduce the economic, environmental and social impact of invasive animals.

The Invasive Animals CRC research program up to 30 June 2012 was structured into five program areas — terrestrial products and strategies, freshwater products and strategies, detection and prevention, commercialisation and utilisation (uptake) and education — which together worked to deliver our 12 goals (see right).

The Invasive Animals CRC is co-funded by the Australian Government's Cooperative Research Centres Program. The program's aim is to enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public/private research centres that achieve high levels of outcomes in adoption and commercialisation.

The following table relates goal numbers to the program responsible for leading the research projects within the goal, and major investors.

Invasive Animals CRC research goals 2005–2012:

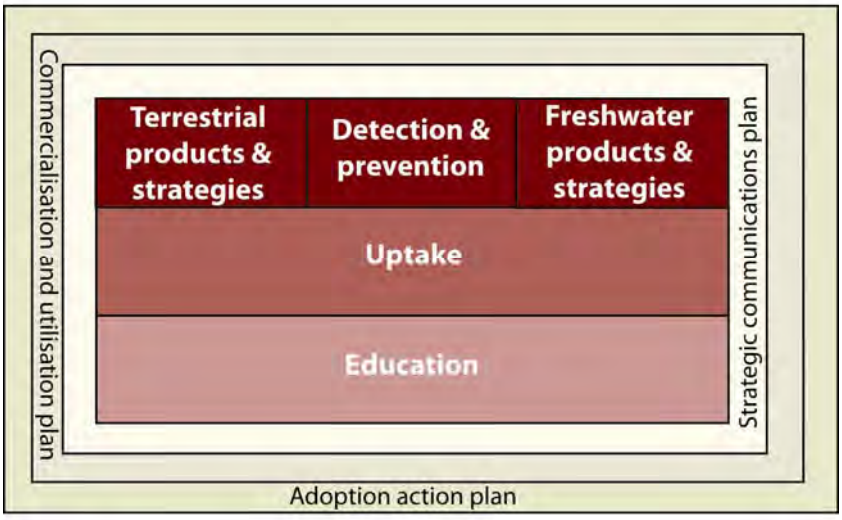
1. *Reducing fox and wild dog impacts*
2. *Reducing feral pig damage*
3. *Reducing rodent damage*
4. *Reducing carp and other pest fish species impacts*
5. *Cane toad control measures*
6. *Reducing feral cat impacts*
7. *Improved integrated rabbit control*
8. *Reducing expanding, overabundant and widespread invasive species impacts*
9. *Forecasting and responding to potential, new, expanding or emerging invasive pests*
10. *Growth in invasive animal control industries*
11. *Increased professional and practical skills in invasive animal management*
12. *Benchmarks for invasive animal impact, density and distribution*

Goal	Leading Program	Major investor
1	Terrestrial products & strategies	Australian Wool Innovation
2	Uptake	Meat & Livestock Australia
3	Uptake	Grains Research & Development Corporation, CSIRO, University of Western Australia
4	Freshwater products & strategies	Murray-Darling Basin Authority, CSIRO
5	Terrestrial products & strategies	Queensland Government
6	Uptake	WA Department of Environment and Conservation, Australian Wildlife Conservancy, Victorian Department of Sustainability & Environment
7	Terrestrial products & strategies	Australian Wool Innovation, CSIRO, Meat & Livestock Australia, NSW Department of Primary Industries
8	Terrestrial products & strategies	ABARES
9	Detection & prevention	ABARES
10	Uptake	Animal Control Technologies Australia
11	Education	University of Canberra (Institute for Applied Ecology), ABARES
12	Detection & prevention	ABARES, NSW Department of Environment & Conservation, NSW Department of Primary Industries

Research program structure

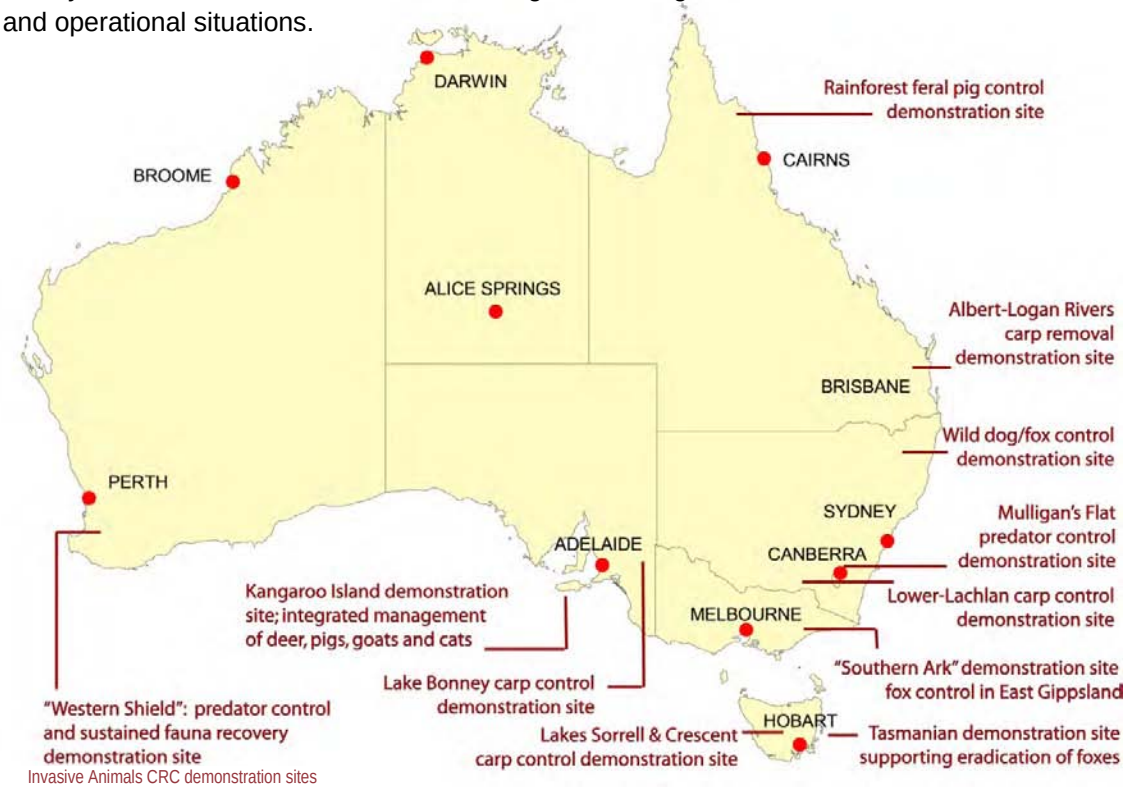
Invasive Animals CRC activities span vertebrate invasive animal species occupying terrestrial or freshwater habitats. The research portfolio was managed through five programs (terrestrial products and strategies, freshwater products and strategies, detection and prevention, uptake and education) including the two cross-cutting programs (uptake — commercialisation and utilisation — and education).

The below schematic demonstrates how the Invasive Animals CRC programs were integrated and the guiding strategies and plans that the leadership team referred to when implementing the research portfolio.



The role of our demonstration sites

Activities relating to the 12 goals were supported through 11 demonstration sites, where research activities were developed and refined through their implementation. The demonstration sites provided an opportunity for interaction and collaboration between the programs, research teams and more broadly between industry and policy makers. This on-the-ground collaboration is fundamental to the success of the Invasive Animals CRC and helps to accelerate progress and encourage a consistent national approach to the management of invasive pests. The demonstration sites encompassed a variety of Australian-based locations involving a wide range of stakeholders in various environmental and operational situations.



Invasive Animals CRC demonstration sites

About this document

The Research Portfolio Summary provides information on the full suite of research projects undertaken through the Invasive Animals CRC between 2005–2012.

Under each project summary headline, a summary of the project aim, along with the project number and name of the project leader, is outlined. A précis of associated projects and PhD or Masters-level projects that are embedded within the project is also provided.

The project duration and status is recorded under each summary headline.

Each summary provides information on the project, which is categorised into the following sub-headings: Project summary, Key achievements; Project team; Project partners and Further Information. Further Information is prioritised from the most recent publication to the oldest publication, followed by PestSmart communications products if applicable.

Format of the document

Each chapter of this document deals with a specific Invasive Animals CRC goal. Each summary is included in a goal heading that is most relevant to it. A table is included at the beginning of each chapter, which lists the project numbers that will deliver specific outputs under each goal. A list of the projects relevant to the goal (as well as PhD or Masters-level student projects) follows this table. A list of projects that have summaries included under other goals, but are still relevant to the goal the reader is looking up, is also included under the chapter/goal outline.

The projects have then been listed according to their output types. These output types are a way of categorising the intent of the research being conducted. While some projects deal with multiple output types, the projects have been listed under their primary output type, these being:

- Knowledge and tools — projects that contribute to developing a better understanding of the species of concern and the environments in which control efforts are attempting to be made.
- Strategic controls — best-practice methodologies for developing and implementing broad-scale pest animal control strategies.
- Tactical controls — projects that are delivering enhanced on-the-ground control methods and processes, such as new or novel baits, toxin delivery systems and containment or exclusion devices.
- Education and training — capacity development projects and initiatives that will improve our ability to implement more effective integrated pest control into the future.
- Demonstration Sites — projects that involve the above output types in a practical research environment, in order to test these outputs and refine research efforts).

An index is included at the front of this document (page ix). The index provides a way of cross-referencing projects according to the primary output type that the project addresses. This index helps readers find projects of interest based on the type of output.

Goal 1: Reducing fox and wild dog impacts

TARGET: A benefit of $29 million per annum by reducing the impacts of fox and wild dogs by 10%

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
1.1	New knowledge on fox and wild dog biology, ecology, impact, management, and the ecological interactions of control methods	2011	10.U.1, 10.U.3, 10.U.4, 10.T.5, 10.U.21 PhD (DNA-based monitoring), PhD (strategic mgt), PhD (neospora) PhD (fox ecology) PhD (social impacts of dogs)
1.2	New humane fox and wild dog toxin and antidote	2009–2011	1.T.3, 10.T.5, 1.U.1e, 1.U.2e
1.3	New approved fox and wild dog lures and new toxin delivery methods	2008–2011	1.T.1
1.4	Fox and wild dog management packages that include new and existing toxins, application strategies and end-user training	2012	1.T.2, 1.T.4, 1.T.5e, 10.U.1, 10.U.3, 10.U.4, 10.T.5, 10.U.21

* As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- Best practice fox, wild dog and feral cat management (including trialling novel toxins and delivery methods such as ejectors and lethal trap devices) (1.T.4, 10.U.1, 10.U.4, 10.T.5, 10.U.21– Completed)
- Molecular ecology of wild dogs and foxes in Australia (10.U.21 – Completed)
    - PhD: Developing DNA-based monitoring techniques for improved management of wild dog (Danielle Stephens)

Tactical control

- Foxecute® and Dogabate® fox and wild dog bait (1.T.3, 1.D.1 – Completed)
- Blue Healer® antidote (1.U.1e, 1.U.2e – Completed)
- Attitudes towards adoption new pest control technologies (1.D.1 – Completed)

Demonstration Site

- Demonstration Site: Southern Ark: benefitting the biodiversity of East Gippsland through fox control, Victoria (10.U.4, 6.U.1 – Completed)
    - PhD: Ecology of the feral cat (*Felis catus*) in the tall forests of Far East Gippsland, Victoria (Tony Buckmaster)
    - PhD: Monitoring the ecological impacts of invasive predator control (Alex Diment)
- Demonstration Site: integrated wild dogs and fox management, NSW / Queensland (10.T.5 – Completed)
    - PhD: Ecology of the dingo (*Canis lupus dingo*) in the Tanami Desert in relation to human-resource subsidies (Tom Newsome)
    - PhD: The social impacts on Australian farm families of wild dog predation on agricultural stock (Penelope Marshall)
    - PhD: Are wildlife and particularly wild canids associated with Neospora abortion in cattle? Investigating the prevalence, life cycle and risk to cattle and wildlife (Jessica King)
- Demonstration Site: detecting low fox abundance, Tasmania (10.U.3 – Completed)

Education and training

- National wild dog facilitator (1.T.2 – Completed)
- Best practice guidelines for the use of guardian dogs (1.T.5e – Completed)

Relevant projects included under other goals

Demonstration Site

- Demonstration Site: predator control and sustained fauna recovery, WA (10.U.1 – Completed)

Tactical control

- Feral cat bait uptake in eastern Australia (6.U.1 – Completed)

PestSmart

- Range of communications products stemming from research projects.

Best-practice fox, wild dog and feral cat management

Project Leader: Dr Peter Fleming, NSW Department of Primary Industries

Aim: *To develop new monitoring technologies to better target and monitor wild dog, fox and feral cat control programs*

Project 1.T.4

Project duration	February 2009 – March 2012
Status	Completed

Project summary

Wild dogs, foxes and feral cats are Invasive Animals CRC priority species for improved management. This project focused on means to achieve best practice that optimises the combination of techniques, target specificity, areas of application and time of year to achieve cost effective control. Of particular importance are the dual tasks of targeting of control actions and monitoring population responses of target invasive species.

The project:

- reviewed available technologies for monitoring and evaluating wild dog, feral cat and fox control programs
- developed and field-tested genetic and other technologies to remotely monitor wild dog, fox and feral cat control programs
- modelled the effects of wild dogs and fox control programs on co-occurring non-target native carnivores- focussing on spotted-tailed quolls
- identified opportunities to share data and resources and promoted collaboration between Invasive Animals CRC projects dealing with wild dogs, foxes and feral cats.

This project facilitated collaboration through sharing of resources, ideas and data. It comprised three sub-projects, each with a number of collaborators and relates to several PhD student projects.

It enabled development and assessment of techniques that support many of other Invasive Animals CRC activities, including DNA-based projects (project 10.U.21), PhD projects on fox and feral cat management associated with the Southern Ark demonstration site (project 10.U.4), wild dogs/fox and feral cat management in Western Australia (project 10.U.1) and wild dogs and fox management planning activities of the wild dogs and fox demonstration site in north-east NSW and south-east Queensland (project 10.T.5).

Monitoring predators is notoriously difficult, which makes the assessment of control program and new product efficacy difficult. This project investigated new remote technologies, including GPS / satellite / radio collars, remote-release cameras and remotely-sourced DNA, which can be used by all collaborators to assess wild dogs/fox and felid or cat population changes in their primary projects.

Knowledge of the day-to-day movement behaviours of wild dogs and foxes and cats enables more efficient deployment of baits, traps and new technologies such as M44 mechanical ejectors. Knowledge of animal dispersals enables strategic planning to occur at the most appropriate scale and we are using the ability of satellite technologies to identify and follow long-distance movements of wild dogs in real time.

Knowledge of target animals' habitat use is also essential for assessing the availability to them of Invasive Animals CRC's new control products (eg project 1.T.3) when assessing field efficacy.

Remote release cameras and remote DNA capture allows assessment of population reductions from control and of the remaining populations.

Such monitoring of control efficacy is an essential component of strategic / best-practice planning, determination of environmental effects of vertebrate pest control and for evaluation of field efficacy of new control products. Technical and methodological issues need to be measured and evaluated before these novel methods acquire universal acceptance.

Spotted-tailed quolls are considered the native predator most at risk from wild dogs and fox control activities. Two different types of models are being developed to investigate population-level responses of spotted-tailed quolls to wild dogs and fox control in north eastern NSW and in Victoria. Results will be used by managers in risk assessments of wild dogs and fox control programs where quolls are present.

Key achievements

- Collaborations fostered through a workshop (Aim 1, see Fleming and Jenkins 2007 report) for developing the use of remote technologies, including remote release cameras, GPS collars and remotely-sourced DNA (from hair, saliva and faeces) to monitor wild dog, fox and cats. (These collaborations between partners will continue into the Invasive Animals CRC extension).
- Camera trapping technical guide published. Meek, PD, Ballard, G and Fleming, P (2012) An Introduction to Camera Trapping for Wildlife Surveys in Australia. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia. This guide available online at http://www.feral.org.au/camera-trapping-for-wildlife-surveys/
- Techniques for population measurement from remotely-sourced DNA developed or enhanced for spotted-tailed quolls, foxes, feral cats and wild dogs.
- Two draft population dynamics models were constructed and data gaps identified from spotted-quoll DNA capture data. Further trapping of quolls was conducted in conjunction with project 10.T.5 to obtain the longer-time series of data required. Data will be collated post 2012 for use in population dynamics models.
- Cameras contrasted with sand plots and deployed to assist evaluation of wild dogs and fox control programs in the NE NSW Wild Dogs and Fox Demonstration Site.
- Training packages deployed to assist stakeholders use remote cameras monitor and evaluate wild dogs and fox control programs.
- An evaluation of the efficacy of remotely-sourced DNA for mark-recapture estimates of wild dog and fox responses to control showed that sampling is biased by individual differences in detection probability.

Project team

Dr Peter Fleming, Dr Guy Ballard, Steve McLeod (NSW DPI), Dr Danielle Stephens (University of Western Australia), Dr Tom Newsome, Dr Tony Buckmaster, Dr Alex Diment (University of Sydney), Dr David Jenkins (Charles Sturt University), Alan Robley, Charles Todd, Jenny Nelson (Victorian DSE), Andrew Claridge, Doug Mills, Andrew Lees (NSW OEH), Dr Al Glen (ex WADEC), Nicky Marlow, Dr Paul de Tores,
Dr Dave Algar (WA DEC), Dr Oliver Berry (ex UWA now CSIRO), Prof Steve Sarre (University of Canberra), Dr Roger Pech (NZ Landcare Research), Peter Cremasco (ex Queensland DAFF), Dr Gerhard Koertner (UNE), Stephanie Johnston (Griffith University).

Project partners

Invasive Animals CRC, NSW Department of Primary Industries (lead agency, Vertebrate Pest Research Unit, WA Department of Environment and Conservation, University of Western Australia, Victorian Department of Sustainability and Environment, University of Sydney, NSW Office of Environment & Heritage.

Further information

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Fleming PJS, Allen LR, Lapidge SJ, Robley A, Saunders GR and Thomson PC (2006) A strategic approach to mitigating the impacts of wild canids: proposed activities of the Invasive Animals Cooperative Research Centre. *Australian Journal of Experimental Agriculture* 46: 753-762.

Lapidge S, Dall D, Hunt R, Cowled B, Smith M and Staples L (2006) A review of the impact of sheep predators in Australia and new control methods under development. *Australasian Vertebrate Pest Conference* 22: 258-263.

Stephens, D et al (In Press) 'Bias in Population Estimators Derived from Non-Invasive DNA of Wild Dogs' submitted to *Journal of Wildlife Management* (in revision for re-submission).

Newsome, T (In Preparation) Chapter 6: Genetic profile of dingoes (*Canis lupus dingo*) and free-roaming domestic dogs (C. l. familiaris) in the Tanami Desert, Australia. This chapter is being prepared for publication in a peer-reviewed journal.

Invasive Animals CRC PhD students benefiting from project/using project funds for analysis

Dr Danielle Stephens conferred 2012: The molecular ecology of Australian wild dogs: hybridisation, gene flow and genetic structure at multiple geographic scales. University of Western Australia.

Dr Tom Newsome conferred 2011: Ecology of the Dingo (*Canis lupus* dingo) in the Tanami Desert in relation to Human-Resource Subsidies. University of Sydney.

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Molecular ecology of wild dogs/foxes in Australia

Project Leader: Dr Oliver Berry, University of Western Australia

Aim: *To provide more effective and efficient control of wild canids in Australia (foxes and wild dogs) by delivering key management-relevant ecological information on those pests*

Project 10.U.21
PhD (DNA monitoring)

Project duration	July 2008 – December 2009
Status	Completed

Project summary

Canids (foxes and wild dogs) represent one of the most significant threats to agricultural profitability and biodiversity conservation in Australia. Many key management-relevant aspects of the ecology of these animals, such as their abundance and dispersal behaviours have historically been difficult to measure, meaning that:

- management decisions may be made without reference to pest biology (potentially limiting their effectiveness)
- the effectiveness of management actions (including deployment of new products) may be difficult to accurately assess.

Advances in molecular biology and bioinformatics permit a range of management-relevant ecological questions to now be addressed, and there has been a major growth in this area of research.

This project took these tools and applied them to a variety of high profile and significant invasive animal issues involving wild dog and foxes in Australia.

The project was divided into four key project-elements:

- non-invasive monitoring of abundance and survivorship in fox populations subject to lethal control (Western Australia and Victoria)
- landscape genetics as a tool to define management units and estimate dispersal distances in foxes and wild dogs – co-funded by external partners
- determining the relatedness and mainland origins of foxes introduced to Tasmania
- estimating the number of breeding foxes and immigration rate onto Phillip Island, Victoria.

Distribution of WA samples collected for the fox DNA Project

The project incorporated the training of postgraduate students and involved significant collaboration and financial partnership with Invasive Animals CRC and non-CRC pest-management agencies, industry and individuals Australia-wide.

Key achievements

- More than 3,500 samples collected for the fox DNA project. Analysis demonstrated that foxes from WA are genetically distinct from those in the eastern states, with movements virtually non-existent across the deserts of central Australia.
- Genotyping of Karara (WA) trace DNA samples completed. Of the total 313 samples, 196 produced microsatellite genotypes of sufficient information content to identify individuals. These samples identified 58 unique individuals and demonstrated a 100% knockdown of the fox population by aerial baiting. The reduction in fox density was evident for at least 12 months post-baiting.
- Residency of foxes in baited wheatbelt reserves (WA) determined to be significantly shorter than in unbaited sites and rarely spanned baiting episodes. This indicates that 1080 baits effectively remove individual foxes.
- Dr Danielle Stephens (University of Western Australia) was conferred her doctorate on improved dog control via DNA-based monitoring system. The thesis was titled 'The Molecular Ecology of Australian Wild Dogs: Hybridisation, Gene Flow and Genetic Structure at Multiple Geographic Scales'.
- Microsatellite DNA genotyping successfully identified 10 individual foxes (5 male: 3 female: 2 unknown) in Tasmania, none of which were recaptures or are genetically related (related project 10.U.3)
- At least 15 individual foxes were genetically identified from scats found in Tasmania, none of which were related.
- First quantitative estimates of fox recruitment onto Phillip Island calculated by the Phillip Island fox genetic analysis component of the project.
- Collaboration with Professor Richard Barker and Dr Jamie Sanderlin (Department of Mathematics, University of Otago) on a method employing DNA parentage analysis to estimate abundance, survival and recruitment in animal populations and including a case study on foxes from Phillip Island, Victoria.

Project team

Dr Oliver Berry (UWA), Dr Danielle Stephens (PhD).

Project partners

Invasive Animals CRC, University of Western Australia, WA Department of Environment and Conservation, Department of Agriculture and Food WA, ABARES, Phillip Island Nature Park (Victoria), Rangelands NRM Coordinating Group (WA), Tasmanian Department of Primary Industries, Parks, Water and Environment.

Further information

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Fleming PJS, Ballard AG, Brown AA, Jenkins ADJ, King BJ, Stephens CD (2008) Remotely capturing DNA samples from wild dogs: pilot pen and paddock studies. Proceedings of NSW Pest Animal Control Conference: The Challenges of Change, 30 September–2 October 2008, Wagga Wagga.

Berry O and Sarre S (2007) Gel-free species identification using melt-curve analysis. *Molecular Ecology Notes* 7(1): 1-4.

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www.foxdna.animals.uwa.edu.au Fox NA project

www.wilddogdna.animals.uwa.edu.au Wild dog DNA project

Tatler, J (Honours thesis) Estimating the recovery dynamics of a baited population of red foxes (*Vulpes vulpes*) using non-invasive DNA mark recapture analysis.

Berry, O in collaboration with England, P (Draft manuscript) Provenance and levels of kinship among fox carcasses collected in Tasmania since 2001 (DPIPWE Tasmania).

PestSmart Factsheet: Advances in the molecular ecology of foxes.

www.invasiveanimals.com

Foxecute® and Dogabate® fox and wild dog bait

Project Leader: Dr Simon Humphrys, Invasive Animals CRC

Aim: *To deliver a new shelf-stable manufactured lethal bait for fox and wild dog control, with activity based on incorporation of the novel toxicant para-aminopropiophenone (PAPP)*

Projects 1.T.3, 1.D.1

Project duration	July 2003 – June 2012
Status	Completed

Project summary

Foxes and wild dogs cause at least $70 million in losses to Australian agriculture, and foxes also have major impacts on native animals. Both pests are primarily and most cost-effectively managed using baits containing compound 1080.

This project aims to deliver a complementary lethal bait that can be used in broad-acre landscape-scale fox and wild dog control. Its specific objectives are:

- delivery of new types of registered lethal baits with improved specificity and acceptability for use in control of canids (foxes and wild dogs) in Australia
- new toxicants and toxicant formulations, as well as new bait matrix compositions and systems for the novel delivery of the new toxicant to relevant pests through Invasive Animals CRC Participants
- an antidote to the primary toxicant that vets and dog owners can use in case of accidental poison of, for example, working and companion dogs (see Blue Healer® project summary).

Additionally, it is expected that some elements of the strategic knowledge encompassed within the development of this technology will be used for developing new and effective feral cat control products.

This technology may also be suitable for use in overseas locations where control of wild dogs/foxes and other carnivorous predators is required or desirable for improving the efficiency of agricultural production, protecting human welfare or protecting biodiversity.

This project also delivers the first new carnivore pesticide in about 50 years.

Key achievements

- Study on stakeholder attitude to PAPP relating to the marketing and uptake of this new commercial toxin completed.
- Dose ranging studies (foxes and wild dogs) confirmed that manufactured fox and wild dog baits containing para-aminopropiophenone (PAPP) are lethal and humane.
- Studies determining the sensitivity/risk of Australian non-target species to PAPP completed.
- Environmental fate and toxicity studies completed.
- Broad-acre PAPP bait efficacy field trial for fox control on land managed by Melbourne water (Werribee) covering 600 hectares completed.
- Field trials using manufactured baits containing PAPP successfully reduced indices of abundance for wild canids that were indicative of population knockdowns of between 65% to 91% for foxes and 48% to 78% for wild dogs.
- Veterinarians successfully treated accidentally poisoned working dogs during field trials using Blue Healer® antidote (see project 10.U.14c).
- Registration applications to the APVMA submitted and accepted for full assessment of products.

A remote camera monitors baiting sites

- Bait stability/shelf-life studies completed.
- Literature reviews, key informant interviews, discussion groups and structured survey analysis conducted to provide specific insights for proposed market roll-out programs for PAPP/Blue Healer®.
- First project publications submitted.

Project team

Dr Simon Humphrys, Dr Glen Saunders, Professor Linton Staples, Frank Gigliotti, Lee Allen, Ben Allen, Dr Guy Ballard, Dr Peter Fleming, Dr Jane Littlejohn and Dr Johann Schröder.

Project partners

Invasive Animals CRC, Australian Wool Innovation, Animal Control Technologies (Australia) P/L, Connovation Ltd (NZ), NSW Department of Primary Industries, Queensland Department of Agriculture and Forestry and Fisheries, Victorian Department of Primary Industries, Victorian Department of Sustainability and Environment.

Further information

Southwell, D, McCowen, S, Mewett, O and Hennecke, B (2011) Understanding the drivers and barriers towards the adoption of innovative wild dog and fox control technologies: a review. ABARES and the Invasive Animals CRC.

Eason CT, Fagerstone KA, Eisemann JD, Humphrys ST, O'Hare JR and Lapidge SJ (2011) A review of existing and potential new world vertebrate pesticides with a rationale for linking use patterns to registration requirements. *International Journal of Pest Management*. 56: 109-125.

Lapidge S, Dall D, Hunt R, Cowled B, Smith M and Staples L (2006) A review of the impact of sheep predators in Australia and new control methods under development. *Australasian Vertebrate Pest Conference* 22: 258-263.

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Blue Healer® antidote

Project Leader: Dr Simon Humphrys, Invasive Animals CRC

Aim: *To determine the efficacy and safety of methylene blue administered intravenously and orally as an antidote to methaemoglobin inducers*

Projects 1.U.1e, 1.U.2e

Project duration	February 2009 – June 2012
Status	Ongoing (as part of the new extension Invasive Animals CRC)

Project summary

A key barrier to increased participation in fox, wild dog and feral pig 1080 baiting programs is the risk that working and pet dogs will be accidentally poisoned. This risk has been significantly reduced with the development of para-aminopropiophenone (PAPP) and sodium nitrite baits which have an effective antidote.

This project's objective is to determine the efficacy and safety of intravenously and orally administered antidote — Blue Healer® — to otherwise lethal methaemoglobinaemia caused by PAPP / sodium nitrite poisoning of domestic dogs. The outputs and outcomes from this project will be used in registration applications for new veterinary medicine products that can be safely and effectively used by veterinary professionals and dog owners in case of accidental poisonings.

A registered antidote that can be integrated into best current wild dog and fox management will almost certainly overcome one of the most significant barriers to individuals and organizations participating in poison baiting programs.

This increased participation will flow-through to more effective scales of management (nil-tenure) and greater coverage within local and regional management units that will enhance sustained best practice management, return on investment to agricultural SMEs, pest animal SMEs, government agencies and directly benefit Australian biodiversity

Protecting working dogs is important for landholders

Key achievements

- Fox and wild dog 'strength' PAPP bait toxicosis profiles in domestic working dogs characterised.
- Intravenous treatment recommendations for reversal of methaemoglobinaemia (vet only).
- Oral formulations that overcome (bitter taste, poor dose compliance) determined.
- Six accidentally-poisoned working dogs saved (100%) during PAPP field trials due to the development of this veterinary medicine and treatment recommendation.
- Registration application for an intravenous treatment of induced methaemoglobinaemia submitted.
- Oral formulation of methylene blue that dog owners can treat accidentally poisoned animals with under veterinary direction assessed.
- Submit registration application for a product that dog owners can administer if results warrant.

Project team

Dr Simon Humphrys (Invasive Animals CRC), Assoc. Prof. Steve Lapidge (Invasive Animals CRC), Graeme Brown (University of Sydney), Bob Pigott (Bioquiv).

Project partners

Invasive Animals CRC, Australian Wool Innovation, Pestat Pty Ltd, University of Sydney, ABARES, Bioquiv.

Further information

PestSmart fact sheet: Glovebox Guide for Managing Wild Dogs

PestSmart: Invasive Animals CRC Product Pipeline

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Sheep farmer Angus Kelly and his four-legged friend 'Mick' — a dog that survived accidentally eating the new PAPP poisoned bait by being given the Blue Healer®

Aerial/ground PAPP baiting of wild dogs and foxes to enhance red meat production

Project Leader: Dr Simon Humphrys, Invasive Animals CRC

Aim: To demonstrate the feasibility of PAPP bait adoption into existing and new wild dog and fox management programs

Project 1.T.7e

Project duration	February 2011 – June 2013
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

Current best practice management of the European red fox and wild dog in Australia, for both agricultural and conservation purposes relies on broadscale, cooperative management programs, primarily using poison baits containing the compound 1080. The effectiveness of these programs is markedly constrained by the reluctance of some land managers to participate in group control programs. This reluctance is largely attributable to perceptions of risk about accidental poisoning of working dogs and other non-target animals, and a lack of recognition of fox and wild dog distributions. These social drivers override the evidence that group management provides more effective long-term, landscape respite from wild dog and fox predation.

One means of overcoming this social barrier to baiting may be through the availability of a new toxin, 4-aminopropiophenone or PAPP for short. It causes a fast humane death and has an antidote for cases where baits are accidentally taken by working dogs or other non-target animals. Baits containing PAPP are currently being assessed by the APVMA as fox and wild dog control products.

This project consists of two studies that will demonstrate how the new canid PAPP baits can be used and integrated into existing fox and wild dog management programs and how this adoption can contribute to the efficiency and sustainability of red meat production enterprises (prime lamb and cattle) under intensive and extensive production systems. The first aspect of the project will be a risk assessment of spreading baits containing PAPP by plane (that incorporates producer interviews) over intensively farmed agricultural land in NSW. At locations elsewhere the benefits out-weigh the risks highlighted in the risk assessment an aerial trial will be undertaken to demonstrate the potential for truly landscape application of fox control to increase the efficiency of prime lamb production.

The second aspect of the project will be ground deployment of PAPP baits to reduce wild dog numbers and impacts on cattle reproduction and calf marking rates in the pastoral zone.

During 2009–2010 the Invasive Animals CRC, including NSW DPI, Queensland Biosecurity and the South Australian Arid Lands Natural Resource Management (SAALNRM) Board demonstrated the efficacy of PAPP baits in reducing fox and wild dog indices of abundance in a field trials. The South Australian Arid Lands Natural Resource Management (SAALNRM) Board has also been coordinating a study for the past 2-3 years that has been assessing the impact of 1080 baiting on wild dog populations in the pastoral zone and what this intervention achieves in the way of impacting predation rates on cattle, respective wild dog diets and prey abundance. This foundation of benchmarking data makes this study site a strategically good one for leveraging additional results cost-effectively. The generally exceptionally good conditions in the arid zone north of the wild dog barrier fence resulted in an abundance of prey species in 2011 and wild dog abundance also increased commensurately.

The convergence of high cattle restocking rates and increasing wild dog abundance and the effects of wild dogs on cattle production under these circumstances, is an opportunity rarely presented and critical for determining future management practices for pastoralists to minimise wild dog impacts during and post- re-stocking. Unfortunately the ban on live export of cattle to SE-Asia and a bushfire across much of the Quinyambie station study site meant that re-stocking did not occur and the project had to be abandoned prior to completion. Despite this, the study did show that even in the midst of abundant prey (mouse and hopping mouse plague) baits containing PAPP could be used to significantly reduce wild dog indices of abundance that indicates a population reduction.

Key achievements

- A literature review and desktop risk analysis to investigate the feasibility of using PAPP for aerial baiting.
- Sites for aerial baiting trials have been identified and secured, in collaboration with the Central West Livestock Health and Pest Authority and local cooperative fox management groups.
- Established, conducted, and completed field efficacy trial of PAPP (ground baiting for wild dogs) in northern South Australia, inclusive of:
    - Four sandplot passive activity surveys
    - Collaring and tracking 13 dingoes
    - Deployment of 30 infrared cameras
    - Scat collection indices
    - Bait uptake surveys on over 100 bait stations.

NB: No cattle predation estimates were attainable (as originally intended) because restocking has been delayed due to market uncertainties arising from the halt of the live export trade in northern Australia.

- An aerial baiting trial will be conducted on intensive grazing properties in central west NSW during 2012–2013.
- Demonstrating the benefits of integrating aerial baiting using baits that are safer for working dogs into conventional ground baiting programs using 1080 to sheep producers.
- Final trial report to be included in APVMA registration.

Project team

Dr Andrew Bengsen, Benjamin Allen, Dr Glen Saunders, Dr Peter Fleming, Dr Guy Ballard, Dr Simon Humphrys.

Project partners

Invasive Animals Cooperative Research Centre, Meat & Livestock Australia (MLA) and NSW Department of Primary Industries (NSW DPI).

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Understanding stakeholders attitudes towards the adoption of new pest control technologies

Project Leader: Dr Bertie Hennecke, ABARES

Aim: To take a proactive approach to identifying the complex variables influencing individual stakeholder decisions about the adoption of new pest control technologies

Project 1.D.1

Project duration 1 July 2010 – 30 June 2012
Status Completed

Project summary

A number of agencies led by the Invasive Animals CRC are assessing para-aminopropiophenone (PAPP) as a new chemical for canid control.

PAPP and its associated antidote, Blue Healer®, are not yet available for commercial use in Australia but in a number of environments should pose fewer risks to non-target species, especially pet dogs, while being a highly effective chemical active for wild canid control.

These desirable attributes should translate into the uptake of this pest control innovation. This study reviewed a selection of innovation diffusion models to better understand the probable drivers and barriers to end users adopting innovative pest control strategies in general, and more specifically PAPP products, as best-practice integrated wild dog management.

Public and private land managers were also surveyed to elicit key perceptions towards canid management and identify the social and group forces operating to influence the adoption of a new canid control technology, PAPP.

The results of the survey suggest that PAPP is well-placed to address major barriers to participation in canid management. The presence of an antidote, Blue Healer®, will likely appeal to both public and private land managers who do not participate in management due to concerns over accidental poisoning of non-target species.

The improved humaneness of PAPP will likely be viewed as beneficial by public land managers. Marketing and extension should focus on communicating the benefits of these features to drive adoption.

However, the results of our study suggest that decisions to adopt new canid control technologies are not solely influenced by the benefits of a technology over existing methods.

Decisions to adopt new pest control technologies are complicated by beliefs about the role of canids in the ecosystem, neighbour participation and the coordination of management.

Increasing the adoption of PAPP and new technologies in general will be achieved by not only promoting the benefits of the product, but also by developing widespread participation in management and encouraging coordinated management practices.

Key achievements

- A better understanding of the factors that might influence the adoption of PAPP.
- Options for marketing canid toxins in Australia.

Project team

Dr Jeanine Baker, Dr Bertie Hennecke, Osman Mewett, Darren Southwell, V Boero and S McCowen,

Project partners

Invasive Animals CRC and ABARES

Further information

Southwell, DM, Boero, V, Mewett, O, McCowen, S, Baker, J and Hennecke, B. (In Press) Understanding the drivers and barriers to participation in canid management: implications for the adoption of a new toxin, para-aminopropiophenone (PAPP). *International Journal of Pest Management*

Southwell, D, McCowen, S, Mewett, O and Hennecke, B (2011) Understanding the drivers and barriers towards adoption of innovative canid control technologies: a review. ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) report prepared for the Invasive Animals Cooperative Research Centre, Canberra.

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Demonstration Site : Southern Ark, Victoria

Project Leader: Dr Anne Dennis, Vic Department of Sustainability and Environment

Aim: *To facilitate the recovery of native animals across one million hectares of public land in Far East Gippsland through the establishment of an integrated large-scale and on-going fox control program*

Projects 10.U.4, 6.U.1
PhD (feral cat ecology & control),
PhD (fox ecology & control)

Project duration	July 2005 – February 2011
Status	Completed

Project summary

Southern Ark was a major conservation initiative that aimed to facilitate the recovery of a suite of native mammals, birds and reptiles by significantly reducing fox numbers across about one million hectares of public land in Far East Gippsland. The Southern Ark project was:

- the largest-scale fox control project in SE Australia
- an established investment platform (more than $500,000 per annum) with the regional infrastructure required to manage a complex project and on which to build additional projects
- a collaborative cross-tenure project with strong stakeholder support among the relevant public land managers, research organisations and community.

Southern Ark involved study of:

- the ecology of feral cats in south-eastern Australian temperate forests. Little knowledge is available of feral cat ecology in temperate forested areas of south-east Australia. This project examined a range of issues related to increasing our knowledge of the impact and management of feral cats in the environment. It included interactions of feral cats with other predators and their responses to a lowering of fox numbers, habitat relationships, diet and trials of techniques for monitoring abundance.
- interactions between predator re-invasion rates and thresholds of prey species response to fox control in south-eastern Australia. This project investigated theoretical thresholds at which fox suppression elicits a response in prey organisms (ie the point at which fox predation is no longer the major force driving prey populations) and compared these with field observations. The interactions between prey responses and fox re-invasion rates (eg at the edges of baited areas or from unbaited 'control' areas) was also examined. Information generated will be used to guide the design and monitoring of predator management programs so as to optimise their efficiency and effectiveness.
- effective techniques for protecting biodiversity from the threat of feral cats in various habitats, as previously undertaken by Dr Liz Denny under project 6.U.1.

Alongside this project, Dr Tony Buckmaster examined a range of issues related to increasing our knowledge of the impact and management of feral cats in the environment including:

- interactions of feral cats with other predators and their responses to a lowering of fox numbers
    - habitat relationships
    - diet and trials of techniques for monitoring abundance
    - predicting native species response to fox control and evaluating methods to measure that response.

Dr Alex Diment also worked on the Southern Ark project. He investigated the ecology of foxes in response to lethal control and developed techniques for monitoring the efficacy of control programs. The major aims were to:

- investigate fox movements and mortality in relation to control measures
- develop techniques for estimating fox abundance
- predict native species response to fox control and evaluate methods to measure that response.

Information generated will be used to guide the design and monitoring of predator management programs so as to optimise their efficiency and effectiveness.

Key achievements

- Curiosity® cat bait uptake field trials at the Southern Ark demonstration site completed. Cats were found to take the cat bait, however this has met with strong competition from the corvids (the crow family: non-target animals) and highlights opportunities for future baiting technique refinement.
- Fox scat collection at the demonstration site completed. A total of 1,600 km was systematically searched for fox scats, (400 hours of search effort over an 18-month period). More than 1,000 predator scats were collected, of which 481 scats have been subject to DNA analysis.
- All PhD milestones met. Dr Alex Diment Doctorate 'Monitoring the ecological impacts of invasive predator control' conferred in November 2010. Dr Tony Buckmaster Doctorate 'Ecology of the feral cat (*Felis catus*) in the tall forests of Far East Gippsland' conferred in November 2011.
- Dr Tony Buckmaster submitted three further manuscripts to peer-reviewed journals.
- Presentations on the project and its results provided to stakeholders, conference attendees and students at forums and community information days.
- Population dynamics of feral cat prey determined.

- 'Review of cat ecology and management strategies in Australia' published and launched in February 2010.

Project team

Dr Alex Diment, Dr Tony Buckmaster, Professor Chris Dickman, Dr Liz Denny (Sydney Uni), Dr Anne Dennis, Mark Doyle, Stephen Henry, Andrew Murray, Alan Robley, Southern Ark field crew (Victorian DSE), Professor Stephen Sarre (UC).

Project partners

Invasive Animals CRC, University of Sydney, Victorian Department of Sustainability and Environment, University of Canberra.

Further information

Buckmaster, AJ (2012) Feral cats in the tall forests of Far East Gippsland, Australia. Proceedings of the Vertebrate Pest Conference Monterey, California.

Buckmaster, AJ and Dickman, CR (2012) Early onset of reproduction in the Agile Antechinus (*Antechinus agilis*) *Australian Mammalogy* (in press)

Buckmaster AJ, Dickman, CR and Johnston, MJ (2012) Assessing Risks to non-target species using poison baiting programs for feral cats. *Wildlife Research* (submitted)

Buckmaster, AJ, Osborne, WS and Webb, N (2010) The loss of native terrestrial small mammals in large urban reserves in the ACT. *Pacific Conservation Biology* 16, 36-45.

Buckmaster, AJ (2010) Potential for ingestion by non-target Australian animals of Curiosity© baits with toxicant enclosed in a hard shell delivery vehicle–a desktop analysis. Unpublished report to the Victorian Government, Department of Sustainability and Environment, Melbourne.

Denny E and Dickman C (2010) Review of cat ecology and management strategies in Australia, Invasive Animals CRC, Canberra.

Dickman, CR; Denny, E and Buckmaster, AJ (2010) Identification sites of high conservation priority impacted by feral cats. Report to the Australian Government, Department of the Environment, Water Heritage and the Arts, Canberra

The Ark. Benefiting the biodiversity of East Gippsland through fox control, Department of Sustainability and Environment. Issue No 3, June 2007.

Invasive Animals CRC PhD students benefiting from project/using project funds for analysis

Dr Tony Buckmaster conferred 2011: Ecology of the feral cat (*Felis catus*) in the tall forests of Far East Gippsland. University of Sydney.

Dr Alex Diment conferred 2010: Monitoring the ecological impacts of invasive predator control. University of Sydney.

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Demo Site: fox/wild dog mgt in NSW/Qld

Project Leader: Dr Peter Fleming, NSW Department of Primary Industries

Aim: *To implement a strategic approach to integrated wild dog and fox management for agricultural and environmental benefit*

Project 10.T.5
PhD (ecosystem management)
PhD (social impacts), PhD (neospora)

Project duration	January 2006 – June 2012
Status	Completed

Project summary

Wild dog and fox predation of livestock are continuing problems in the eastern tablelands and adjacent coastal hinterland regions of north-east NSW. The problem also occurs in the contiguous livestock-producing areas of south-east Queensland. The strategic approach to managing wild dogs is being progressively embraced in southern NSW and the ACT and has potential for wild-dog affected areas in northern NSW and neighbouring southern Queensland.

The strategic approach involves defining and quantifying the regional wild dog problem, identifying all stakeholders and working out the management, research, demonstration, training and education requirements. A series of actions are then planned, recorded and implemented, the results monitored and evaluated and each component revised and progressed.

Members of Red Range/Pinkett Wild Dog Control Association plan aerial baiting routes at a roadside meeting

The project:

- developed regional (at appropriate scales) nil-tenure based working plans for concurrent wild dog and fox management
- expanded the demonstration site to incorporate wild dog and fox management in pastoral zones of NSW, Queensland and Central Australia and extend the eastern boundary south to the Victorian border
- improved spatial and temporal deployment of wild dog and fox technologies by investigating the spatial overlap of wild dogs, foxes, cats and spotted-tailed quolls
- reviewed existing wild dog and fox management plans to determine social and practical factors that enhance success and ongoing investment of time and funds by stakeholders
- mapped monitoring and trapping courses to national standards and offered these as units of Certificate Three in Conservation and Land Management within and adjacent to wild dog control association boundaries.

At these locales, standardised sand pads are used to monitor target animal, prey animal and non-target carnivore responses to wild dog and fox control. Through greater familiarity with the demonstration site region, we have identified needs for regional planning at different scales to take into account administrative boundaries of collaborating organisations.

It is imperative that we understand the factors that limit or contribute to the ongoing success of the strategic planning approach.

The management of wild dogs is often intertwined with fox management. For example, baiting programs for wild dogs require additional effort to compensate for uptake by foxes. Sheep breeders and wildlife managers often need to manage both species together to reduce the impacts of both on different parts of their enterprise or land tenure. In addition, funding from CMAs and environmental funding sources is often restricted to fox control activities, which limits our ability to attract additional funds and adequately manage wild dogs.

Our training activities have been over-subscribed and there is great need for further training of stakeholders in management plan preparation, wild dog and fox trapping and monitoring.

The site rolled-out para-aminopropiophenone (PAPP) which provided the ideal adjunct to 1080 in peri-urban and industrial environments (eg mine sites) and broadened the availability of this toxin for managing wild dogs and foxes.

There are several Invasive Animals CRC PhD projects associated with this demonstration site, focusing on topics including disease transmission, wild dog movements and spatial genetics techniques and social impacts.

Key achievements

- New England LHPA Regional and NSW National Parks (northern rivers region) local Wild Dog Management Plans reviewed.
- Five plans in Myall Lakes Shire, including 1one regional plan facilitated.
- Barnard River and Niangala Wild Dog Assn. plans signed off.
- Interactions with northern NSW (Tenterfield) wild dog control stakeholder groups commenced in collaboration with National Wild Dog management Facilitator (project 1.T.2).
- Tenterfield Wild Dog Control Associations management plans operational 2012.
- Moona Winterbourne Wild Dog Control Association Wild Dog Management Plan baiting programs monitored and mapped.
- Moon-Winterbourne Wild Dog Control Association plan operational from 2010, but not signed off.
- Dog movement data and advice to Nowendoc and Yarrowitch Wild Dog Control Associations provided as first steps in re-establishing local management plans.
- Yarrowitch Wild Dog Control Association plan operational from 2011.
- After facilitation, Upper Yarras wild dog management plan is operational, but without sign-off.
- Fourth year of field research on effectiveness of combined wild dog control techniques completed and presented to local wild dog associations for review of their plans.
- One trapper training course conducted at Jeogla, with 15 participants.
- One wild dog and fox monitoring school for stakeholders, Woody Head; 15 OEH and NSW Forests participants trained in sandplot monitoring conducted.

- Trapping and GPS collaring for aerial bait rate assessment and local control effectiveness monitoring (39 dogs, 5 foxes, and 10 cats) completed. Assessment ongoing as dog collars are slowly recovered.
- Pre-baiting camera monitoring of wild dog and foxes and prey for assessment of aerial baiting rates for wild dogs and foxes completed.
- Pilot field studies of livestock guarding dog (maremmas) movements, and adjacent wild dogs completed.
- PhDs conferred on Tom Newsome, Danielle Stephens and Jessica King.
- Course planning and field component delivery for new Wild Canid Ecology third-year course at UNE provided.
- Wild Canid Ecology Course at UNE delivered 2012.
- Honours student Huw Nolan conferred 2011.
- Review of Newmont Tanami Operations results of improved tip hygiene changes postponed by restricted access to the mine.
- Pilot and first year for aerial bait rate assessment completed. Second year of assessment of aerial baiting efficacy begun (results August 2012).

Project team

Tim Seears (NSW LHPA), Lee Allen, Greg Mifsud (Queensland DAFF), Dr Peter Fleming, Dr Guy Ballard, Paul Meek, Ben Allen, Phil Gardner, Nigel Fuller, Bernadette York (NSW DPI), Stuart Boyd-Law, Sam Doak, Brad Nesbitt, Ken Pines, Lisa Wellman (NSW OEH), Brian Ferris (New England LHPA), Brian Tomalin (New England LHPA/NSW Farmers), Mick Thorman (Mid-Coast LHPA), Dean Chamberlain (North Coast LHPA), Bruce Moore (Barnard River Wild Dog Control Assoc.), Dr Tom Newsome (Low Ecological Services and Invasive Animals CRC PhD Student), Dr Jessica King (University of Sydney), Dr Danielle Stephens (University of Western Australia), Bob Harden (retired).

Project partners

NSW DPI (lead agency, including Forests NSW and the Vertebrate Pest Research Unit), NSW Management Council for Livestock Health and Pest Authorities, NSW Office of Environment & Heritage, University of Sydney, University of Western Australia, Low Ecological Services.

Further information

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PestSmart Factsheet: Wild dog policy and legislation considerations.

PestSmart Factsheet: Tools and strategies for wild dog management.

PestSmart Factsheet: Distribution of pure dingoes and dingo-dog hybrids in Australia

PestSmart Factsheet: Wild dog risks to threatened wildlife.

PestSmart Factsheet: Have you got wild dogs?

www.invasiveanimals.com

Demonstration Site: Detecting foxes, Tasmania

Project Leader: Prof Stephen Sarre, University of Canberra

Aim: *To provide the link between fox presence and control by undertaking a comprehensive survey of predator scats in Tasmania*

Project 10.U.3

Project duration	July 2003 – June 2012
Status	Completed

Project summary

A significant body of evidence now exists to confirm that foxes are present in Tasmania. This evidence includes more than 2,000 sightings, road-kills and substantial DNA-based evidence. The establishment of foxes in Tasmania poses significant risks to Tasmania's wildlife as well as impacting on the sheep industry and nature based tourism.

While the density of reported sightings may provide a general idea of where foxes may be found, greater accuracy would enable a concentration of baiting effort, targeted use of lures, baits and other Invasive Animals CRC technology, and a more accurate assessment of the task and cost of eradication. This project developed and implemented a monitoring survey to cover the whole State that will enable the localisation of foxes to exact sites based on scat collections. Analysis of the data will be used to inform the strategic baiting program.

This project builds on a two-year project Supporting Eradication of the Fox from Tasmania funded through the Invasive Animals CRC for 2007–09. The initial project focussed on the development and application of DNA technology that will enable the identification of foxes and other large carnivores from trace samples and hence localisation. The survey design developed and endorsed by the Technical Advisory Panel supporting the Program will be implemented over a three-year period and hence funding for an additional two years has been granted.

The project aimed to sample strategically for foxes and other carnivores from scat DNA samples across Tasmania over a three-year period. Modern DNA approaches were utilised combined with collections by staff of the Fox Eradication Program (Tasmanian Department of Primary Industries, Parks, Water and Environment) and selected volunteers.

The aim was to achieve the most comprehensive coverage of Tasmania possible within that time period to establish an estimation of the distribution of all target carnivore species particularly foxes. The estimates of distributions have been used to guide the fox eradication strategy.

Key achievements

- Analysis of all scats collected from phase 1 of the survey completed by the University of Canberra. A total of 2,685 scats were analysed with six identified as fox-positive. Fox positive scats are then sent for genotyping in the Wildlife Forensics Laboratory at the University of Western Australia.
- Systematic collection and screening of more than 2,566 scats from the Phase 2 Tasmania south-east survey completed.
- Analysis of all scats collected from phase 3 of the survey by the University of Canberra completed. A total of 1,441 scats were analysed with one scat identified as positive for fox DNA.
- In total, 61 scats collected in Tasmania have now been identified as positive for fox DNA. This demonstrates a widespread distribution for this top predator ranging from the central north, to many sites in the east and south east (related project 10.U.21).
- 208 scats of known, non-fox origin (cat, dog, quoll and Tasmanian Devil scats collected from captive animals) were sent from Tasmania to the University of Canberra with the phase 3 survey scats for blind testing. None of these scats were identified as positive for fox DNA.
- Fox DNA detected from a putative fox skull collected from Tasmania. DNA was extracted from the skull by researchers at the Australian Museum and sent to the University of Canberra for DNA sequencing. Results have now been sent to Tasmanian Department of Department of Primary Industries, Parks, Water and Environment.
- Microsatellite genotyping methods previously applied to fox DNA at the University of Western Australia were optimised for use at the University of Canberra's laboratories. Seven samples previously genotyped at the University of Western Australia were genotyped at the University of Canberra using the same six microsatellite loci and a sex marker (SRY). Obtaining genetic profiles for the same samples in both labs allowed comparison of results between labs, meaning that new genotypes could be compared with the 15 previously known Tasmanian fox scat genotypes.
- Genotyping was then attempted for an additional eight fox-positive scats collected in Tasmania since mid-2009, plus the fox skull described above and an ear tissue sample from the Cleveland roadkill fox. Good genotypes were obtained from one of the scat samples, the skull and the Cleveland fox. The three new genotypes obtained were found to be different from each other and from all 15 previously known Tasmanian fox scat genotypes, meaning that these samples represent 18 different individual foxes.

- An additional five microsatellite loci were identified from the literature and tested to assess their utility for genotyping from fox scat DNA. Fox scats collected from Victoria were genotyped using the six microsatellites originally applied to Tasmanian fox scats and the five additional loci. All loci show potential for genotyping from scat DNA, although samples from a wider geographic area should be genotyped to investigate levels of genetic variation at these loci within Australian foxes.
- New primers were designed to enable detection of DNA from several native mammal species, such as bandicoots and wallabies, in the scats of foxes and other carnivores. These primers are currently being tested for specificity to the target species and for reproducibility of results among individuals.
- All scats collected as part of the strategic survey of Tasmania have now been analysed at the University of Canberra's Wildlife Genetics Laboratory. A report on the final DNA analysis results has been submitted to the Invasive Animals CRC.

Project team

Prof Stephen Sarre, Dr Anna MacDonald (UC), Alan Johnston, Craig Elliot, Alison Foster, Nick Mooney, Peter Cremasco, Candida Barclay (Tas DPIPWE), Dr Oliver Berry (UWA).

Project partners

Invasive Animals CRC, University of Canberra, Tasmanian Department of Primary Industries, Parks, Water and Environment–Fox Eradication Program, Australian Government.

Further information

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Saunders, G, Lane, C, Harris, S and Dickman, C (2006) Foxes in Tasmania: A report on the incursion of an invasive species. Invasive Animals CRC, Canberra.

Draft report on the development of new markers for the analysis of DNA from faecal samples collected in Tasmania. This report focuses on markers for (i) microsatellite genotyping of fox DNA and (ii) species identification of prey DNA from Tasmanian fox scats.

A draft manuscript reporting on Phase 1, 2 and 3 surveys and all other hard evidence available has been prepared and awaits publication. Sarre SD, MacDonald AJ, Barclay C, Saunders GR, Ramsey DSL Foxes are now widespread in Tasmania: DNA detection defines the distribution of this rare but invasive carnivore. [In Review, *Journal of Applied Ecology*]

PestSmart Factsheet: Foxes in Tasmania

www.dpiw.tas.gov.au/foxes Tasmanian fox website, Tasmanian Department of Primary Industries, Parks, Water and Environment.

www.invasiveanimals.com

National wild dog facilitator

Project Leader: Greg Mifsud, Queensland Department of Agriculture, Fisheries and Forestry

Aim: *To promote and build capacity in developing and implementing strategic management approaches to control wild dogs*

Project 1.T.2

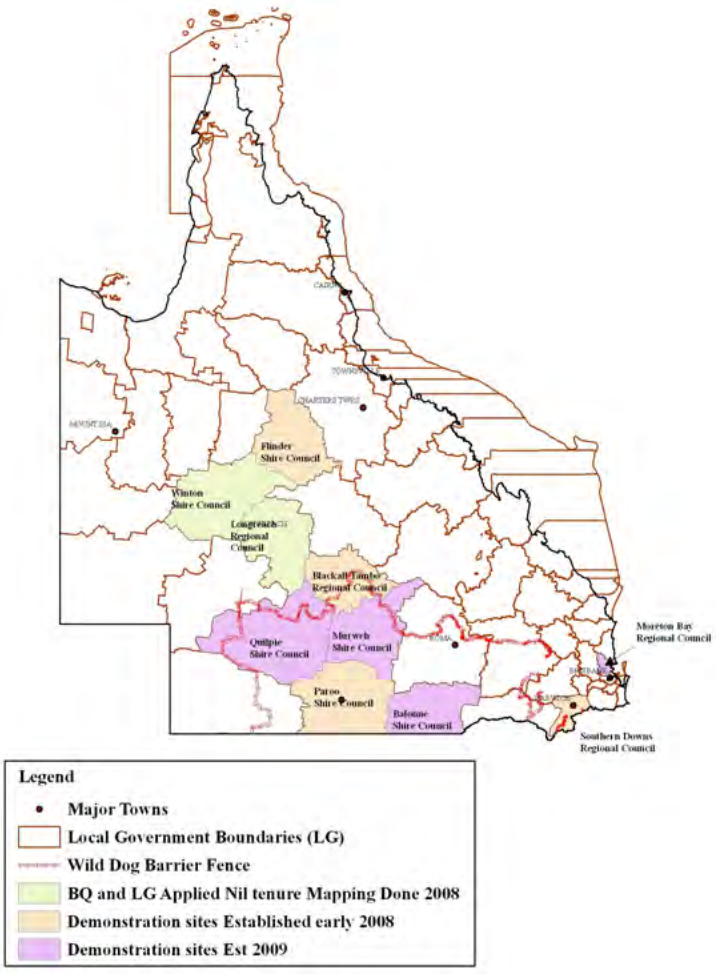
Project duration	August 2006 – June 2012
Status	Completed

Project summary

The primary aim of this project was to promote a nationally-consistent strategic approach to wild dog management, resulting in the development of cooperative wild dog management plans utilising all forms of control at both the local, regional and state government scale to effectively manage the impacts of wild dogs.

There is growing recognition of the need for coordinated and strategic management of wild dogs (including dingoes). Guidelines have been developed, but have yet to be fully implemented nationally. The limited examples of this approach have so far been successful, but the approach needs to be adapted and applied to other situations.

The National Wild Dog Facilitator project was developed to meet the growing need for coordinated and strategic management of wild dogs across Australia.



Improved wild dog control was achieved through:

- increased awareness of strategic management of wild dog, including a nil-tenure approach
- facilitated development and implementation of management plans consistent with this approach for 12 representative areas by local management groups
- fostered development of regional agreements (eg MOUs) for wild dog management developed between key stakeholders
- documented case studies for wild dog management
- promoted wild dog adaptive management programs
- implemented training programs for the control of wild dogs in the eastern states
- promoted uptake of Invasive Animals CRC-developed baits and delivery mechanisms, where appropriate
- participation in process to revise the strategic approach to wild dog management.

The project was initially managed by a steering committee. In December 2009, the National Wild Dog Management Advisory Group was established. This group, initially Chaired by Mr. Brent Finlay (President Agforce Queensland) and currently chaired by Michael McCormick (Cattle Council of Australia representative and member Victorian Farmers Federation Livestock Committee), has been instrumental in developing communication networks and effective working relationships between state government agencies involved in wild dog management across Australia and industry to promote integrated and strategic wild dog management.

Working in conjunction with the national facilitator, the National Wild Dog Management Advisory Group has generated improvements in State policy and stronger community involvement in the development and delivery of wild dog management programs across the country. One of these changes to state government policy is the implementation of aerial baiting inside the wild dog barrier fence in South Australia.

The strength of the National Wild Dog Management Advisory Group and the support it provides to the national wild dog facilitator project has been instrumental in obtaining external funding for the development of nationally applicable extension material as well as providing support to local community groups in their bid to access funds from the Australian Government and national industry bodies for the development of community wild dog management programs.

The facilitator promoted the development of a nationally consistent approach to wild dog management in accordance with the aims of the Australian Pest Animal Strategy, developed strong networks for the dissemination of information relating to wild dog management, research and control, highlighted the need for collaborative research programs and facilitated the development of a nationally applicable extension material on best practice wild dog management.

The economic benefits of these activities have been estimated at $6.7 million (AgTrans 2011).

Key achievements

- Wild dog management and planning field days with Department of Agriculture and Food WA in the Pilbara region of WA including Warrawagine and Mt Florence conducted.
- In collaboration with Industry, four Best Practice groups established through the Best Wool Best Lamb Initiative in areas of Victoria affected by wild dogs. This initiative provides landholder the opportunity to look at best practice land management and livestock production through a facilitated group. We have worked with these groups to add wild dog management to the program which has provided producers with the ability to meet regularly to discuss local wild dog management programs while also investigating the positive changes they can make to their property and livestock management. Groups have now been established in Tallangatta, Benambra and Swifts Creek with a fourth to be established in the Buchan –Gelantipy areas.
- Partnered with Granite Border Landcare and AWI to undertake a major wild dog management planning program in the Tenterfield region of NSW. Four wild dog management field days and eight planning workshops have been conducted throughout the region and draft management plans have been developed for the 13 associations in the region. As a result of this project a 14th association has now been formed in an area where there was little coordinated management occurring.
- Provided ongoing support to the Bite Back wild dog program in South Australia. This program has been very successful with 21 wild dog management groups now formed inside the wild dog barrier fence in SA. The success of the program and planning approach was recognised by state agencies and changes to legislation for allow aerial baiting inside the fence to compliment the ongoing ground baiting and trapping program.
- Released the instructional DVD for the use of foot hold traps in November 2011. Since then more than 5,000 thousand have been distributed with another 5,000 reprinted. Feedback received has been tremendous with producers now gaining far more confidence to set traps in order to protect their livestock.
- Worked with T&R pastoral company to roll out wild dog management rebate from the sale of goats. This program has seen a rebate of 50 cents/per goat returned back to the region the goats were purchased to support community based wild dog management.
- Two National Wild Dog Management Advisory Group meetings, in Sydney and Esperance conducted.
- More than 20 wild dog management workshops and field days conducted around the country to assist in the development of wild dog management plans and programs and build capacity amongst stakeholders to effectively manage wild dogs.
- The development of community wild dog management plans in South Australia, NSW, Victoria and Western Australia supported.
- Local communities and state government agencies supported through building the capacity of local landholders and staff to roll out community based wild dog management planning process.
- Continued to support the development of community wild dog management plans in South Australia, NSW, Victoria and Western Australia.
- Maintained support to local communities and state government agencies through building the capacity of local landholders and staff to roll out community based wild dog management planning process.
- Attended meetings around the country to promote the adoption of community based wild dog management plans, best practice control and the development of new control products.
- Continued to support the National Wild Dog Management Advisory Group in raising the profile of wild dogs and their impacts.

Project team

Greg Mifsud (Queensland DAFF–National Wild Dog Facilitator), Michael McCormick (Chair, NWDMAG), Brent Finlay, Andrew Wilke, Kevin Strong, Lee Allen, Mark Weaver, Dr Peter Fleming, Peter Bird, Andrew Crocos, Dr Guy Ballard, Geoff Power, Bruce Moore, Peter Lucas, Emily Lewis, Tony Pople, John Nankivell, Michael McCormick, Allan Brown, Scott Pickering, Ellen Greene, Ben Allen, Nicola Webb, Tim Seears, Dr Bertie Hennecke, Heather Miller and Marilyn Clydsdale.

Project partners

Invasive Animals CRC, Australia Bureau of Agricultural Resource Economics and Sciences (ABARES), Queensland Department of Agriculture, Fisheries and Forestry, Queensland Department of Employment, Economic Development and Innovation, Biosecurity Queensland, NSW Department of Primary Industries (NSW DPI), NSW Office of Environment & Heritage (OEH),, NSW Wild Dog Advisory Committee (NSW WDAC), South Australian Farmers Federation (SAFF), South Australian Department of Water, Land and Biodiversity Conservation (SA DWLBC), South Australian Arid Lands NRM (SAAL NRM), Victorian Department of Primary Industries (Victorian DPI), Victorian Farmers Federation (VFF), Department of Agriculture and Food WA (DAFWA), WA Pastoralists and Graziers Association (WA PGA, Western Australia Farmers Federation (WAFF), Australian Wool Innovation (AWI), Wool Producers Australia, Cattle Council of Australia (CCA), ACT Department of Territory and Municipal Services (ACT TAMS), NSW Livestock Health and Pest Authorities (LHPA), AgForce Queensland, Gippsland Wild Dog Advisory Group (GWDAG), and Victorian North-East Wild Dog Advisory Group (NEWDAG).

Further information

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AgTrans Research (2011) Economic Analysis of the National Wild Dog Facilitator Project. Invasive Animals Cooperative Research Centre, Canberra, Australia.

www.invasiveanimals.com

Guidelines for use of guardian dogs

Project Leader: Greg Mifsud, Queensland Department of Agriculture, Fisheries and Forestry

Aim: *To increase landholder capacity to effectively use guard dogs to protect livestock from wild dog and fox predation*

Project 1.T.5e

Project duration	July 2008 – December 2009
Status	Completed

Project summary

The need for a best practice manual for the use of guard dogs was identified by the National Wild Dog Management Advisory Group, and in reports to the Vertebrate Pests Committee in 2003. Graziers and producers have shown increasing interest in using these dogs to protect livestock given the rise in wild dog issues across the country but have expressed concerns about the lack of information to effectively apply them to their production practices. This sentiment was highlighted in a series of predator control field days held by Leading Sheep group across western Queensland in September 2008.

Guardian dogs at work

The development of a best practice manual for the use of guardian dogs to protect livestock will contain information to enable land holders to apply this measure as part of a property-wide approach to fox and wild dog control. The use of guardian dogs has been proven to be a cost effective means of managing predation when applied properly.

The best practice manual will provide a range of examples through case studies to demonstrate the implementation and management of guardian dogs to protect livestock in a range of environments and production settings. Participants in the case studies provided detailed information on the trials and errors they made when applying guardian dogs to their enterprise, while also illustrating the financial and emotional gain from utilising guardian dogs to protect livestock.

The development of the best practice manual also aims to address the issues of animal welfare associated with the use of guard dogs. At present no animal welfare codes exist that directly relate to the use of these dogs and in fact under the various states codes most users would be in breach simply by leaving their animals in a paddock unattended.

Key achievements

- Field days in locations throughout Queensland informing producers of the manual's development.
- Identified seven properties using guardian dogs for the case studies.
- Invasive Animals CRC best practice manual for the use of guardian dogs to protect livestock from predation published and launched.

Project team

Greg Mifsud (Queensland DAFF), Linda Van Bommel (JCU), Barry Davies (ex-DAFWA), Dr Peter Fleming (NSW DPI), Tim Seers (LHPA), Andrew Crocos (Victorian DPI), Ben Allen, (SAAL NRM), Peter Lucas, Marilyn Clydesdale, Victorian Wild Dog Advisory Group, Lee Allen, (Queensland DAFF), Chris Johnson (JCU), David Jenkins (CSU).

Project partners

Invasive Animals CRC, Queensland Department of Agriculture, Fisheries and Forestry, Victorian Department of Primary Industries, ABARES, James Cook University, Charles Sturt University, Department of Agriculture and Food WA, NSW Department of Primary Industries, Victorian Department of Primary Industries, South Australian Arid Lands NRM, Wild Dog Advisory Group.

Further information

http://www.dpi.nsw.gov.au/agriculture/livestock/sheep/management/general/guard-animals
Guard animals for livestock protection: existing and potential use in Australia, NSW Department of Primary Industries.

Van Bommel L (2011) Best practice manual for the use of livestock guardian dogs. Invasive Animals CRC, Canberra. Currently out-of-print but available free to download at http://www.feral.org.au/guardian-dogs/

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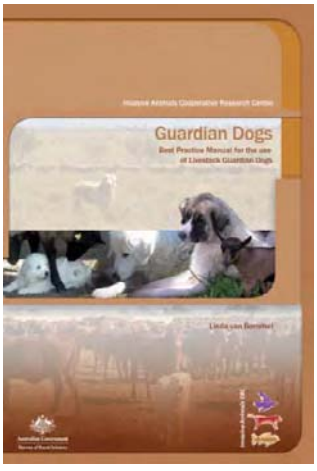

Trapping introduced predators DVD

Project Leader: Greg Mifsud, Queensland Department of Agriculture, Fisheries and Forestry

Aim: *To produce an instructional wild dog and fox trapping DVD to assist end-users adopt and implement best practice vertebrate pest management*

Project 1.T.5e

Project duration February 2009 – September 2011
Status Completed

Project summary

Introduced predators such as wild dogs (*Canis Lupis*) and the European Red Fox (*Vulpes vulpes*) are both considered serious agricultural pests causing significant economic damage to Australia's grazing industry and as a consequence are both considered of national concern by the Vertebrate Pest Committee. Conservative estimates of the impacts of wild dog and foxes on agriculture nationally were found to be $48.5 million and $22.5 million respectively in a recent report commissioned by the Invasive Animals CRC (Gong et al 2009). However, in a more-detailed recent study commissioned by Agforce Queensland, the economic cost of wild dogs on the grazing industry was found to be approximately $67 million a year in Queensland alone. The impacts of wild dogs on the cattle industry accounted for two thirds of the overall cost to the grazing industry in that State, with an estimated $22 million dollars in losses through calf predation alone.

The European Red fox (red fox) and another introduced predator the feral cat (*Felis catus*) have both been implicated with the extinction and decline of native mammals through predation particularly those falling in what is known as the critical weight range, >5kg. The wild dog is also currently threatening the Dingo with extinction due to hybridisation as wild dogs continue to cross breed with pure dingoes residing within National Parks and conservation areas as well as those in remote areas throughout Australia.

The control of these three species is a key goal of conservation and agricultural agencies in each state, however it has been identified that the public and in particular landholders do not have adequate skills to effectively control these animals particularly through trapping. While landholders may take part in coordinated and reactive baiting programs when possible they need additional skills and knowledge in utilising other forms of control in order to carry out integrated and strategic management of introduced predators on a regional and local scale.

The development of an education/instructional DVD assisted stakeholders to become competent and more confident in the use of nationally approved trapping devices for the control of these species. The DVD produced is intended to be a resource tool that can be disseminated amongst the community via training days conducted by NRM groups, government agencies and industry groups.

Key achievements

- Produced and launched the 'step by step' instructional DVD (more than 2,000 DVDs have been distributed to stakeholders across Australia) to:
  - Assist Association members and private contractors to control introduced predators in a more humane and efficient manner for the protection and conservation of biodiversity and livestock.
  - Provide stakeholders with additional skills to control these damaging species as part of an integrated control program utilising a variety of control techniques in accordance with the National Codes of Practice and Standard Operating Procedures
  - Instruct landholders 'step by step' on how to trap introduced predators, empowering them with the skills, knowledge and confidence to take action rather than having to rely on others to deal with the issue of feral animals for them.
  - Increase the capacity of landholders and land managers (local government officers, state agency staff, NRM Staff, NSW RLPB Rangers, community groups, conservation groups.

Project team

Greg Mifsud (Queensland DAFF - National Wild Dog Facilitator), Michael McCormick (Chair, NWDMAG), Brent Finlay, Andrew Wilke, Kevin Strong, Lee Allen, Mark Weaver, Dr Peter Fleming, Peter Bird, Andrew Crocos, Dr Guy Ballard, Geoff Power, Bruce Moore, Peter Lucas, Emily Lewis, Tony Pople, John Nankivell, Allan Brown, Scott Pickering, Ellen Greene, Ben Allen, Nicola Webb, Tim Seears, Dr Bertie Hennecke, Heather Miller and Marilyn Clydsdale.

Project partners

Invasive Animals CRC, Australia Bureau of Agricultural Resource Economics and Sciences (ABARES), Queensland Department of Agriculture, Fisheries and Forestry, Queensland Department of Employment, Economic Development and Innovation, Biosecurity Queensland, NSW Department of Primary Industries (NSW DPI), NSW Office or Environment and Heritage (NSW OEH), NSW Wild Dog Advisory Committee (NSW WDAC), South Australian Farmers Federation (SAFF), South Australian Department of Water, Land and Biodiversity Conservation (SA DWLBC), South Australian Arid Lands NRM (SAAL NRM), Victorian Department of Primary Industries (Victorian DPI), Victorian Farmers Federation (VFF), Department of Agriculture and Food WA (DAFWA), WA Pastoralists and Graziers Association (WA PGA, Western Australia Farmers Federation (WAFF), Australian Wool Innovation (AWI), Wool Producers Australia, Cattle Council of Australia (CCA), ACT Department of Territory and Municipal Services (ACT TAMS), NSW Livestock Health and Pest Authorities (LHPA), AgForce Queensland, Gippsland Wild Dog Advisory Group (GWDAG), and Victorian North-East Wild Dog Advisory Group (NEWDAG).

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Goal 2: Reducing feral pig damage

TARGET: A benefit of $16 million p.a. by reducing feral pig damage by 15%

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
2.1	New knowledge on feral pig ecology and impacts (eg economic and social impacts)	2011	2.U.1, 10.U.2, 10.U.6 PhD (Achilles' heel) PhD (domestic pig and wildlife interactions) PhD (environmental impacts in wet tropics) PhD (controlling pigs in wet tropics) PhD (conflict in feral pig management in the wet tropics) MSc (economics of feral pigs in wet tropics) MSc (feral pig management in the Macquarie Marshes) Hons (environmental impacts in wet tropics)
2.2	PIGOUT® – First generation manufactured shelf-stable feral pig bait that exhibits high target specificity	2008	2.U.1, 10.U.2, 10.U.6, 2.U.6e
2.3	HOGGONE® – Second generation feral pig toxin with improved humaneness profile	2012	2.U.5e, 10.U.2
2.4	Additional feral pig management technologies and bait technologies (including HOGHOPPER™	2012	2.U.1, 10.U.2, 2.U.4e, 10.U.6, 2.U.6e
2.5	Feral pig baits with capacity to carry contraceptives and/or vaccines (in collaboration with USA and UK scientists)	2011	2.U.1, 10.U.14
2.6	Feral pig management packages that include new and existing toxins, application strategies and end-user training	2011	2.U.5e, 2.U.1, 10.U.2, 10.U.6

* As per contract variation approved by DIISRTE

Projects

Tactical control

- New feral pig toxins, baits and delivery systems (2.U.1, 2.U.5e, 2.U.2e, 2.U.3e and 2.U.4e, 2.U.5e- current)
  - PhD: Feral pig Achilles' heel (Brendan Cowled)
  - MSc: An evaluation of feral pigs and their management in the Macquarie Marshes, NSW (Jason Wishart)

Knowledge and tools

- PhD: Understanding and mitigating domestic pig and wildlife interactions (Hayley Pearson)

Demonstration Site

- Demonstration Site: Program for deer, pigs, goats and cats on Kangaroo Island, SA (10.U.2–Completed)
- Demonstration Site: Controlling feral pigs in tropical rainforests, Queensland (10.U.6 – Completed)
  - PhD: Environmental impacts of feral pigs on coastal lowland rainforests (Amanda Elledge)
  - PhD: Target-specific vertebrate pest control in complex faunal communities: feral pig baiting in the wet tropics of Queensland (Andrew Bengsen)
  - PhD: Conflict in feral pig management in the wet tropics (Carla Meurk)
  - MSc: Socio-economic and ecological costs and benefits of feral pigs in the Wet Tropics (Kana Koichi)
  - Hons: Long-term environmental impacts of feral pigs on tropical lowland rainforest (Domonique Taylor)

Relevant projects included under other goals

Overarching project

- Commercialisation management (10.U.14 – Current)

Tactical control

- Cyanide pig and fox baits for monitoring(8.D.1 – Completed)

New feral pig toxins, baits and delivery systems

Project Leader: Assoc. Prof Steven Lapidge, Invasive Animals CRC

Aim: *To deliver PIGOUT®, HOGGONE®, HOGHOPPER™ and feral pig population optimal management unit research to improved feral pig management both in Australia and internationally*

Projects 2.U.1, 2.U.2e, 2.U.4e, 2.U.5e, 2.U.6e,10.U.2, 10.U.6
PhD (Achilles' heel)
MSc (Macquarie Marshes)

Project duration	July 2005 – June 2012
Status	2.U.5e (HOGGONE) – Current (under new extension Invasive Animals CRC) 2.U.6e (Macquarie Marshes) - Current (under the new extension IA CRC) PIGOUT econobait (1080) – Current (under the new extension IA CRC) HOGGONE econobait – Current (under the new extension IA CRC) Liquid Concentrate – Current (under the new extension IA CRC)

Project summary

Despite their worldwide impact, feral pig control has somewhat lagged behind that of other pest species in terms of broad-scale management tools, such as toxic and biological controls, although the ecology of the species is well studied in Australia.

A fresh batch of PIGOUT® feral pig bait

This project aims to:

- Identify optimal feral pig population management units in rangelands of southern Queensland.
- Register and commercialise a 1080 feral pig bait — PIGOUT®
- develop, register and commercialise an alternative toxin (sodium nitrite) feral pig bait, HOGGONE®
- adapt PIGOUT® baits to carry vaccines (pseudo-rabies) and fertility control agents for international collaborators
- develop and commercialise a feral pig-specific bait hopper, the HOGHOPPER™
- develop best practice feral pig management in the Macquarie Marshes, NSW, by incorporating new tools and strategies into conventional management programs.

This collection of projects had a distinctly commercial focus, aimed at enhancing feral pig control options for public and private land managers. The project tied in with the Kangaroo Island and the Daintree Wet Tropics World Heritage Area demonstration sites.

It also continues to be involved with overseas trials in New Zealand and America, as well as developing new markets, with recent interest expressed by Hong Kong and Israel.

Late in the life of the Pest Animal Control CRC (PAC CRC) and early in the life of the Invasive Animals CRC a number of feral pig molecular ecology studies were undertaken, initially to determine the effects of aerial baiting and shooting control efforts (Spencer et al. 2005; Cowled et al. 2007), and later to assess the necessary size of effective feral pig management units in various habitats after control efforts failed to genetically bottleneck the population (Cowled et al. 2008).

The latter study was conducted over 1M km2 and found that whilst some feral pig populations were defined by habitat, others were genetically contiguous over 100,000 km2. Feral pig control must take into account the scale of the management area, otherwise control efforts will only have short term effects.

PIGOUT® – a world first manufactured, shelf-stable, target specific lethal feral pig bait containing 1080 (sodium fluoroacetate) – was the first product commercialised from the project and was released in March 2008. PIGOUT® was the result of collaboration between Pest Animal Control CRC and Animal Control Technologies Australia (Animal Control Technologies (Australia) P/L) with support from Meat & Livestock Australia and ABARES.

The next generation feral pig bait, HOGGONE®, is currently being developed. The toxin in HOGGONE® is sodium nitrite, a common human food preservative, which is highly toxic to pigs and acts humanely by preventing red blood cells from carrying oxygen. Trials have shown it to be a quick-acting (1.5 hrs to death) and potentially reversible toxin for feral pigs when delivered in the HOGGONE® matrix. The project is sponsored by Meat & Livestock Australia, ABARES and the Commonwealth Department of Environment, Water, Heritage and Arts. In early 2011 Meat & Livestock Australia provided additional funding for the development and registration of a nitrite concentrate that can be added to grain or other foods attractive to feral pigs, a bite-sized Econobait for use in the HOGHOPPER™, and the filing of a final embodiment patent for HOGGONE®.

Key achievements

- HOGGONE® bait formulations assessed in field trials in tropical, sub-tropical, temperate and sub-alpine habitats - resulting in an average feral pig population decline of 79%. All trials demonstrated that HOGGONE® feral pig baits were target-specific with few non-target takes.
- Assessment of sodium nitrite residue levels in field poisoned feral pigs

- Commercial sales of the HOGHOPPER™, a low maintenance, target-specific bait hopper for population level feral pig management using PIGOUT®, HOGGONE® or other pig bait substrates commenced in March 2011. This peace-of-mind approach to pig control can also reduce labour and costs associated with chemical management of feral pigs. It is anticipated that the HOGHOPPER™ will contribute greatly to target-specificity, efficiency and convenience of feral pig management in Australia and overseas.
- Project leader awarded a Fulbright Professional Business/Industry (Coral Sea) Scholarship with the United States Department of Agriculture National Wildlife Research Centre, Fort Collins, Colorado, between July and October 2010. The sabbatical led to large-scale field testing of twenty-five HOGHOPPER™ units containing non-toxic HOGGONE® Econobaits in Texas, Alabama, Mississippi, Oklahoma, Florida and Missouri. Non-toxic HOGGONE®/HOGHOPPER™ trials were completed in the USA in 2011. With the success of HOGHOPPER™ in excluding non-target species, it is anticipated the product will become an integral part of America's future feral pig control programs; where toxic baiting has not been permitted due to non-target concerns. The product combination is currently on a five years registration pathway.
- In 2010, as part of a Caring for our Country bid by the Central West CMA (NSW), the Invasive Animals Cooperative Research Centre secured funding to devise best practice feral pig management for the Macquarie Marshes, NSW (2011-2013).
- More recently, Jason Wishart and the Lachlan CMA secured $870,000 from the inaugural round of the Biodiversity Fund for a project entitled 'Protecting the endangered Malleefowl from introduced predators near Mount Hope, NSW'.
- Product development of sodium nitrite-based products including a manufactured bait (HOGGONE®), nitrite concentrate and econobait.
- Best practice feral pig management for the Macquarie Marshes NSW demonstrated.
- Non-toxic HOGGONE®/HOGHOPPER™ trials completed in the USA.
- Advances in feral pig management promoted at PestSmart Roadshows in first half of 2012.

Feral pigs consuming baits on Glenrock Station (NSW)

Project team

Assoc. Prof. Steven Lapidge, Jason Wishart, Dr Brendan Cowled, Dr Andrew Bengsen and Dr Simon Humphrys (Invasive Animals CRC), Michelle Smith, Ebony Arms, Phil Morrow and Prof Linton Staples (Animal Control Technologies (Australia) P/L), Dr Johann Schrőder and Dr Wayne Hall (MLA), Dr Matt Gentle, Dr Jim Mitchell and Peter Elsworth (Biosecurity Queensland), Prof Charlie Eason and Duncan MacMorran (Connovation Ltd New Zealand), Dr Tyler Campbell, David Long, Dr Kathy Fagerstone, Dr Michael Avery, John Eisemann, Dr Stephanie Shwiff, Dr Aaron Anderson and Mike Bodenchuck (US Department of Agriculture, National Wildlife Research Centre); Justin Foster (Texas Parks and Wildlife).

Project partners

Invasive Animals CRC; Meat & Livestock Australia; Animal Control Technologies (Australia) P/L; Central West CMA; Biosecurity Queensland; Connovation Ltd (NZ); Landcare Research (NZ); Lachlan CMA; Kangaroo Island NRM Board; ACT Department of Territory and Municipal Services; NSW Livestock Health and Pest Authorities; US Department of Agriculture's National Wildlife Research Centre and Wildlife Services; Texas Parks and Wildlife; Australian Bureau of Agricultural and Resource Economics and Sciences; Department of Sustainability, Environment, Water, Population and Communities; NSW Primary Industries.

Further information

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PestSmart Factsheet: Practical feral pig control

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Damage caused by feral pig wallowing

Demonstration Site: Kangaroo Island

Project Leader: Dr Pip Masters, Kangaroo Island NRM Board

Aim: *To develop an integrated, cross-tenure strategy, which manages or eradicates feral goat, deer, pig and cat populations on Kangaroo Island using effective control measures, including new technologies PIGOUT® and HOGGONE®*

Project 10.U.2

Project duration	March 2006 – February 2012
Status	Completed

Project summary

This demonstration site - Repel the Invaders: management program for deer, pigs, goats and cats on Kangaroo Island - is a regionally-focused package of actions addressing priority vertebrate pest species threatening biodiversity and primary production across Kangaroo Island, South Australia.

Extensive feral pig damage on Kangaroo Island

The aim was to develop an integrated, cross-tenure strategy which manages, controls and eradicates targeted vertebrate pests using effective control measures including new technologies such as PIGOUT®, HOGGONE® and the HOGHOPPER™.

The actions undertaken included:

- eradication of goats from Kangaroo Island and the development of information packages for other regions considering similar actions
- eradication of deer from Kangaroo Island and the development of information packages for other regions considering similar actions
- assisting with the field trials of HOGGONE®
- developing a comprehensive management strategy for pigs across land tenures using genetic markers to identify management units, and a range of control measures including PIGOUT® baits, trapping and hunting
- assisting with the development of cat control measures including new toxins and baits.

This program has a distinct community focus, aimed at enhancing the ability of public and private land managers to control and eradicate pest species such as goats, deer, pigs and cats using the most up to date products and techniques.

Key achievements

- Complete eradication of feral goats from Kangaroo Island.
- Goat impact monitoring in place and sites surveyed annually.
- Community survey of residents to determine attitudes to biosecurity measures for domestic goats completed.
- Deer detection measures in place and eradication on the horizon.
- Domestic deer biosecurity strategy developed and waiting on Ministerial approval.
- Assisted with field trials of HOGGONE® and Curiosity® feral cat bait.
- Available cat spray tunnel designs trialled to determine success.
- An understanding of cat home range size and habitat use determined and the number of tunnels needed estimated.
- Cat population estimate technique using cameras and plots assessed.
- An assessment of the relatedness of cats on the Dudley Peninsula compared with the rest of the Island undertaken to determine the immigration rate in the event of an eradication trial.
- Goat eradication completed in all management units and in mop up and monitoring phase. Goat impact monitoring continued.
- Coordinated pig management program underway and the conditions in which PIGOUT® can be used identified.
- Judas pigs trialled and assessed as a control option.
- Domestic deer biosecurity strategy in place.
- Domestic goat biosecurity strategy developed.

Project team

Dr Pip Masters, Brenton Florance, Nick Markopoulos, Dr Andrew Bengsen, John Butler, Jeanette Gellard and Mark Morris (Kangaroo Island NRM Board), Robert Henzell (SA DLWBC).

Project partners

Invasive Animals CRC, SA Department for Environment and Heritage, SA Department of Water, Land and Biodiversity Conservation, Kangaroo Island Natural Resources Management Board, Kangaroo Island landholders, Animal Control Technologies (Australia) P/L.

Further information

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Demonstration Site: tropical rainforests, Qld

Project Leader: Prof Iain Gordon, CSIRO

Aim: *To assess the impacts of feral pigs on the conservation value of the Wet Tropics World Heritage Area and develop acceptable means of enhancing pig control in Queensland's Wet Tropics World Heritage Area*

Project 10.U.6
PhD (environmental impacts)
PhD (controlling feral pigs)
PhD (management conflict)

Project duration March 2006 – December 2011
Status Completed

Project summary

The rainforests of Queensland's Wet Tropics World Heritage Area (WTWHA) support a disproportionately large component of Australia's biodiversity, including numerous endangered plant and animal species. The WTWHA is also a major tourist draw card; and rainforest-related tourism is worth several hundred million dollars annually.

Feral pigs are regarded as one of the most important vertebrate pests of the WTWHA. They have, or can have, substantial deleterious impacts on a range of important environmental, economic, human health and social values in the WTWHA. Frequently cited environmental impacts include: predation of native plant and animal species, disruption of trophic webs, weed and pathogen transmission, and erosion and water quality deterioration.

Economic impacts are largely incurred by primary producers and include damage to produce and infrastructure, lost production potential, and the cost of control. The successful introduction of a serious exotic veterinary disease, such as foot and mouth disease, to the local feral pig population would be an economic catastrophe. Feral pigs may also serve as amplifiers and vectors for important human diseases such as Japanese Encephalitis and leptospirosis.

Feral pigs are currently widespread in the WTWHA. Methods currently used to mitigate the impacts of feral pigs in Australia are largely based on reducing pig abundance by increasing mortality, primarily through trapping, hunting and shooting. Poison baiting though is generally regarded as the most effective and efficient method of producing the population reduction required to significantly reduce the impacts of pigs on the environment. However, trapping remains the preferred pig control method within the WTWHA due to the potential for poison baiting programs to impact non-target species, particularly species of conservation significance such as the Cassowary and Northern Quoll. Trapping alone is unlikely to provide the level of population control required to prevent rapid recovery to pre-control levels.

This project:

- increased understanding of the ecological impacts of feral pigs in rainforest ecosystems
- assessed different methods for baiting pigs that minimise the impacts on native species in the wet tropics
- investigated novel frameworks for cooperative management of pigs in the wet tropics
- determined the socio-economic and ecological costs and benefits of pig control in the wet tropics.

Key achievements

- strategic knowledge through three PhDs and an MSc thesis
  - PhD conferred 2010 – Andrew Bengsen 'Target-specific vertebrate pest control in complex faunal communities: feral pig baiting in the wet tropics of Queensland'
  - PhD conferred 2011 – Amanda Elledge 'Habitat preferences and environmental impacts of feral pigs (*Sus scrofa*) in lowland tropical rainforests of north-eastern Australia'
  - PhD conferred 2011 – Carla Meurk 'Loving nature, killing nature, and the crises of caring: An anthropological investigation of conflicts affecting feral pig management in Queensland'
  - MSc conferred 2012– Kana Koichi 'Socio-economic and ecological costs and benefits of feral pigs in the Wet Tropics'.
- Stakeholder gaps workshop held.
- Cooperative baiting program for pigs implemented in the Wet Tropics based on minimising non-target species impacts and cost/benefit analysis.
- Three international peer reviewed papers submitted.
- Two presentations at international conference.
- Strategic knowledge developed by the project included:
  - determination that in the Wet Tropics, pig impacts are highly localised and short term in nature
  - development of novel methods of toxic bait delivery using a framework for target specific control in fauna communities
  - determination that generally stakeholders were against using poisoning as a method of control because of issues associated with welfare and non-target impacts, with stakeholders viewing trapping as effective and humane
  - finding that overall it is probable that broadscale control of pigs in the Wet Tropics is not cost-effective and that specific localised control is more appropriate in place where pig impacts are unacceptable.

Project team

Prof Iain Gordon (CSIRO), Dr Luke Leung, Wolfram Dressler, Dr Andrew Bengsen, Amanda Elledge, Dr Carla Meurk, Dr Clive McAlpine (UQ), Kana Koichi and Kamaljit Kaur (JCU).

Project partners

Invasive Animals CRC, CSIRO, University of Queensland, James Cook University, Animal Control Technologies (Australia) P/L.

Further information

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Goal 3: Reducing rodent damage

TARGET: A benefit of $7 million p.a. by reducing rodent damage by 20%

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
3.1	Knowledge on a virally vectored immunocontraceptive for the control of mouse plagues	2012	3.T.1
3.2	New and improved rodent control methods	2012	3.T.2
3.3	Improved and/or new rodent control options to protect produce in agricultural areas	2012	3.T.3e 3.D.1

* As per contract variation approved by DIISRTE

Projects

Strategic control

- Mouse infertility virus (3.T.1–Ceased)
- Chemical fertility control of rice field rats in Indonesia (3.T.3e – Completed)

Tactical control

- Control of rodent infestations in intensive crops, industrial and island situations (3.T.2 – Completed)

Education and training

- IslandNet – Offshore islands network (3.D.1 – Completed)

Virally-vectored mouse infertility

Project Leader: Dr Christopher Hardy, CSIRO

Aim: *To deliver an infertility vaccine for control of mouse plagues*

Project 3.U.1

Project duration July 2005 – December 2006

Status Ceased

Project summary

The European house mouse (*Mus domesticus*) is an introduced pest in Australia that causes significant losses to the grains industry. There is as yet no routine means of controlling infestations of wild mouse populations in Australia apart from chemical rodenticides that have significant environmental risks associated with their use. Results of laboratory and field studies conducted so far support the feasibility of applying a disseminating immunocontraceptive virus for mouse control. However movement to the field trial phase was contingent on demonstrating efficient induction of infertility through natural transmission of the contraceptive virus between mice in the laboratory.

The project objectives were to provide:

- a review of the feasibility of delivering virally vectored immunocontraception (VVICTORIAN) allowing the Grains Research and Development Corporation (GRDC) and the Invasive Animals CRC to decide whether continued investment or exploration of alternative methods of mouse control will follow
- the production of a recombinant mouse cytomegalovirus (MCMV) capable of transmitting naturally between wild mice and causing sterility in at least 50% of naturally infected female wild mice
- a strategy for consultation developed and updated survey of public and regulatory attitudes to release of a genetically modified house mouse immunocontraceptive vaccine
- an assessment of the potential for transmission of MCMV by insect vectors
- a business plan showing economic viability (including Net Present Value analysis), strategic uses and risk assessments for a mouse immunocontraceptive virus.

The project objectives were to consider whether:

- infertility can be transmitted by natural means
- constructs and vectors can be modified to increase infectiousness and transmission
- co-factors, such as infection by mice with other pathogens, enhance or reduce efficacy or transmission
- initial exposure dose to the contraceptive virus affects contraception and transmission
- pre-existing infection by non-recombinant MCMV reduces the efficacy and transmission of contraceptive viruses.

This project found that while infertility was observed in directly inoculated mice, no fertility as a result of natural transmission occurred. As such, a review of the project concluded that mice virally vectored immunocontraception is not feasible at this point in time and the project was suspended.

Key achievements

- Fertility and pathogenesis of two recombinant MCMVs predicted to have enhanced ability to transmit between mice fully assessed.
- An assessment of public and regulatory attitudes to release of a genetically modified house mouse immunocontraceptive vaccine was completed by the Invasive Animals CRC and included in the report Public attitudes to current and proposed forms of pest animal control (project 12.D.8).

Project team

Dr Christopher Hardy, Dr Lyn Hinds, Dr Tanja Strive, John Wright, Katrina Leslie (CSIRO), Geoff Shellam, Alec Redwood, Lee Smith (University of Western Australia).

Project partners

Invasive Animals CRC, CSIRO, University of Western Australia, Grains Research and Development Corporation.

Further information

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Control of rodent infestations

Project Leader: Prof Linton Staples, Animal Control Technologies (Australia) P/L

Aim: *To improve methods for monitoring and control of mice and rats*

Project 3.T.2

Project duration	July 2005 – July 2012
Status	Completed

Project summary

The Animal Control Technologies Australia (Animal Control Technologies (Australia) P/L) group was responsible for a key rodent research program within the Invasive Animals CRC. In collaboration with Dr Luke Leung and his rodent team at the University of Queensland (Gatton) campus, they aimed to improve methods for monitoring and control of mice and rats.

A second priority was to improve the management of rodents in intensive crops and for environmental management on islands. The replacement of large-scale misapplication of certain anticoagulant rodenticides is of great significance in protecting Australia's native wildlife. The prevention of overwhelming infestations of rats and mice is also important in protecting fragile habitat and seed banks.

This works builds on Animal Control Technologies (Australia) P/L's previous success in managing rats in sugar cane crops and tree plantations in far north Queensland and the control of plague mice in broadacre crops throughout Australia with MouseOff® and RattOff®.

The project aimed to:

- review all objective rodent monitoring systems against target situations
- survey industry stakeholders (difficulties with rodents, research priorities, suitable trial and test sites)
- source appropriate formulations and presentations of key active ingredients having regard to suitability, safety, regulatory framework, cost availability and humaneness (if appropriate)
- apply selected rodenticides to intensive crop, industrial and island situations
- obtain regulatory data that will support Animal Control Technologies (Australia) P/L registration applications for technology specific to certain rodent infestation problems
- develop advisory information to enable improved rodent management in industrial situations, intensive crops and on islands.

With the possible exception of the development of paste or drink formulations, this project did not require development of new technology.

It is anticipated that most data from the project will be published or released in technical reports to the Australian Pesticides and Veterinary Medicines Authority and sponsoring industry groups.

Key achievements

- Efficacy of rodenticide formulations for rodent control demonstrated in a variety of situations where no registered chemical control methods are currently available, or where improved techniques are required. This includes tree plantation and brassica cropping systems.
- Results to date have been published in scientific journals and four relevant national and international conferences.
- Minor Use and Emergency Use permits obtained for a variety of crops and rodent species. APVMA consequently requesting Animal Control Technologies (Australia) P/L to submit for registration to alleviate the necessity for issuance of permits.
- Animal Control Technologies (Australia) P/L's two anticoagulant blocks (MOUSEOFF® BD and MOUSEOFF® DF) will provide another option for use in industrial, intensive livestock, public service and domestic situations and have proven to be more effective than two of the leading registered products.
- Several of these project trials are fully completed and in a state ready to submit to the APVMA for extension of registration of products to new situations (eg for use in banana and teak plantations and other vegetable and cropping scenarios). The extension to registration will provide an efficacious and relatively target specific control option for rodents.

Project team

Prof Linton Staples, Michelle Smith, Marion Atyeo, Dario Rivera (Animal Control Technologies (Australia) P/L), Dr Luke Leung (UQ).

Project partners

Invasive Animals CRC, Animal Control Technologies (Australia) P/L, University of Queensland.

Further information

Rivera, DF, Smith M, Staples, L and Leung, LKP (2008) Effect of zinc phosphide baiting on canefield rat populations in teak. *Crop Protection* 27:877–881.

Cruz, J, Leung, LKP, Lisle, A, Rivera, DF, Staples, L and Smith, M (2008) Grain, pellet and wax block bait take by the house mouse (*Mus musculus*, Linnaeus 1758) and non-target species: implications for mouse eradications on coral cay islands in the Great Barrier Reef. *Journal of Integrative Zoology*, 3:227-234.

Leung, LKP, Seth, S, Starr, CR, El, S, Russell, IW, King, CA, Vong TR, and Chan P (2007) Selecting bait base to increase uptake of zinc phosphide and warfarin rodenticide baits. *Crop Protection* 26:1281-1286.

Internal documents to support registration:

The efficacy of RattOff® sachets to control Canefield Rat Rattus sordidus populations in a teak plantation (November 2006).

Efficacy Testing of Rodenticide Formulations–cage and pen trial evaluations of rodenticide formulations (February 2007).

Efficacy of the MouseOff® Bromadiolone (0.005%) blocks compared to reference products (November 2007).

Efficacy of the MouseOff® Difenacoum (0.005%) blocks compared to reference products (November 2007).

Application of RattOff® to control Rattus rattus in intensive livestock situations – piggeries (November 2007).

Closed-population enclosure trials to assess the efficacy of MouseOff® zinc phosphide bait in intensive crops (December 2007).

The efficacy of RattOff® sachets to control Canefield Rat Rattus sordidus populations in banana plantations (July 2008).

Chemical fertility control of rodents

Project Leader: Dr Lyn Hinds, CSIRO

Aim: *To deliver an orally active chemical fertility control agent for use in rodent management*

Project 3.T.3e

Project duration April 2008 – March 2011
Status Completed

Project summary

Current management of rodents in cropping systems mainly involves the use of rodenticides. These poisons require repeated application and can have effects on non-target species.

Additional tools for rodent management are needed to add to, or replace existing practices. Fertility control techniques are under development by various groups around the world. Efforts continue in the development of immuno-contraceptive vaccines and in the identification of chemical agents which can efficiently disrupt reproductive capacity.

In the field, these agents will need to be delivered orally in bait. The overall objective of this project is to deliver an orally active chemical fertility control agent for use in rodent management.

A new chemical fertility control technology that could substantially reduce rodent impacts on rice production in developing countries is being formulated by SenesTech based in Flagstaff, Arizona.

Studies are being conducted in parallel in the USA, Australia and Indonesia. The project aimed to:

- achieve a lab-based demonstration of the induction of ovarian follicle depletion by 4-vinylcylohexene diepoxide (VCD) delivered by oral gavage in Rattus norvegicus and Rattus argentiventer
- achieve a laboratory-based demonstration of the long-term effects on fertility of Rattus norvegicus and Rattus argentiventer after oral dosing with VCD
- if (1) and (2) are demonstrated move to field enclosure studies to demonstrate efficacy at a population level
- if field enclosure trials are successful move to farm-scale field experiments to assess efficacy in a wild population.

Key achievements

- VCD was incorporated into the preferred kibble bait formulation established during laboratory trials run in 2009-2010. The VCD in kibble bait was consumed at a rate of 4-5% body weight during a feeding trial over 5, 10 and 15 days. The concentration in the food bait was approximately 1/5 that expected and this did not cause depletion of follicles. The study will be repeated with higher concentrations of VCD in the kibble bait.
- The consumption of the preferred plain kibble was assessed under field enclosure conditions using Rhodamine B (RB) as a bait marker. Total bait consumption of ricefield rats increased during the first 4 to 5 days of the feeding period. After one of RB application high proportions (84.6 -100%) of animals were shown to be consuming baits in all enclosures. The average daily consumption per individual was estimated at approximately 10% body weight. There was no significant difference ($p > 0.05$) in bait acceptance between males and females.
- Similarly, after a second round of RB application (13 days after the 1st round), high proportions (93.8-100%) of animals were consuming the kibble bait. The average daily consumption per individual was similar (9.8% body weight). These results will help define the parameters for delivering effective doses of fertility control agents to ricefield rats.
- While project funding terminated in June 2011, results of bait uptake by ricefield rats in enclosures in Indonesia were presented at 8th European Vertebrate Pest Management Conference, Berlin, Germany, September 2012.
- PhD student Tung Thanh Tran was conferred in May 2012.

Project team

Dr Lyn Hinds, CSIRO is working collaboratively with Dr Loretta Mayer and Dr Cheryl Dyer, Directors of SenesTech Inc (formerly of Northern Arizona University), to assess the contraceptive and sterilising effects of the chemical 4-Vinylcyclohexene Diepoxide (VCD) in rodent species.

Dr Sudarmaji, Ms Nur'aini Herawati are working with the Indonesian Centre for Rice Research. Dr Simon Humphrys (Invasive Animals CRC) is also involved.

Project partners

Invasive Animals CRC, CSIRO, Indonesian Centre for Rice Research, Northern Arizona University (under contract to SenesTech).

Further information

Tung, TT, Henry, S, Cowan, D, Sudarmaji, Hinds, LA. 'Evaluation of bait uptake by ricefield rats using Rhodamine B as a bait marker under enclosure conditions'. 8th European Vertebrate Pest Management Conference, Berlin, Germany, September 2012.

Tung, TT, Hinds, LA and Blome, AK (2011). Effect of different periods of treatment with 4-vinylcyclohexene diepoxide on fertility of female rats. Proceedings 15th Australasian Vertebrate Pest Conference, Sydney, June 2011.

Humphrys, S and Lapidge, SJ (2008) A review of delivering and registering species-tailored oral anti-fertility products. *Wildlife Research* 35: 578-585.

http://www.senestech.com (select 'scientific journal publications')

A field rat infesting rice plants
(Photo courtesy of the International Rice Research Institute)

IslandNet – on-line network service

Project Leader: Dr Elaine Murphy, NZ Department of Conservation

Aim: *To share knowledge and experience between island conservation professionals*

Project 3.D.1

Project duration	February 2009 – June 2012
Status	Completed

Project summary

Australia's 8,300 islands provide homes for many of our unique animals and plants, including nine mammals no longer found on the mainland. Invasive animals, such as exotic rodents, account for more than half of the nation's bird extinctions and infest over 100 islands. To safeguard island life, numerous island eradication projects are underway or in planning. The islandNet project is essentially a network that aims to facilitate this conservation management of Australia's offshore islands by sharing knowledge between people interested in island conservation.

Initial funding for establishing the network was provided by the Department of Environment, Water, Heritage and the Arts. The project continued under Invasive Animals CRC funds.

Key achievements

- The network attracted more than 200 members from around the world, including Australia, New Zealand, USA, Canada, UK, Caribbean, Seychelles and various Pacific Islands.
- Eight newsletters produced (available on http://www.feral.org.au/islandnet/newsletter/) with contributions from members, highlighting island eradication efforts, conservation activities, recent conferences and publications.
- These newsletters proved to be a useful resource for island professionals, judging by the overwhelming positive feedback the research team received.
- Documents relevant to island conservation (particularly grey literature on eradications, threat abatement plans, photos etc) have been loaded into the feral.org.au searchable database.

Project team

Dr Elaine Murphy, Dr Wendy Henderson.

Project partners

Invasive Animals CRC, NZ Department of Conservation.

Further information

http://www.feral.org.au/islandnet/ (islandNet website home page)

Goal 4: Reducing carp and other pest fish impacts

TARGET: A capacity to deliver improved quality and availability of inland water through reduced impacts and rates of spread of carp and other pest fish species

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
4.1	New knowledge on carp and tilapia biology and/or ecological interactions and control options	2012	4.F.5, 4.F.6, 4.F.11, 4.F.15, 4.F.10 PhD (carp population genetics), 4.F.13, PhD (Environmental attractants), 4.F.14, 4.F.12, 4.F.17, 4.F.19, 4.F.18
4.2	Knowledge of the potential of daughterless platform technology	2012	4.F.3, PhD (sex determination) PhD (RNA interference)
4.3	Knowledge on the potential of Cyprinid herpesvirus 3 (CyHV-3) as a biocontrol agent for carp in Australia	2012	4.F.7
4.4	Improved technologies and cost-effective responses to management of new freshwater fish invasions and reduced rates of spread of existing pests	2012	9.D.5, 9.F.1, 4.F.4, 4.F.10, 4.F.17, 10.F.1, 4.F.19, 4.F.20
4.5	Adaptive management framework for assessing national control options for pest fish	2012	10.F.8, 10.F.9, 4.F.16 PhD (predator presence), 9.F.2
4.6	New generation biocidal products for controlling invasive fish investigated	2012	4.F.9
4.7	Integrated pest fish management package	2012	All projects

* As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- Reproduction and recruitment hotspots in the Murray-Darling Basin (4.F.5 – Completed)
- Carp movement and migration in the Murray-Darling Basin (4.F.6 – Completed)
- Age validation in the northern Murray-Darling Basin (4.F.11 – Completed)
- PhD: Population genetics of common carp (*Cyprinus carpio L*.) in the Murray-Darling Basin (Gwilym Haynes – Completed and PhD conferred)
- Carp vulnerability analysis synthesis (4.F.15 – Completed)
- Rapid response planning (9.F.1 – Completed)
- Decision support tool for freshwater incursions (9.F.2 – Completed)

Strategic control

- Daughterless pest fish technology (4.F.3 – Completed)
    - PhD: Sex determination and differentiation in carp, (*Cyprinus carpio*) (Megan Barney)
    - PhD: Mechanisms of RNA interference in fish (Lindsay McFarlane)
- Koi herpesvirus (Cyprinid herpesvirus 3) (4.F.7 – Current)
- Policy analysis of genetic techniques (4.F.8 – Completed)
- Reproduction and recruitment hotspots in the Murray-Darling Basin (4.F.5 – Completed)

Tactical control–carp

- Biocides review (4.F.9 – Completed)
- Pheromone attractants (4.F.4 – Completed)
- Environmental attractants (4.F.13 – Completed)
    - PhD: Environmental attractants (Aaron Elkins)
- Acoustic fish repellents and attractants (4.F.14 – Completed)
- Carp spawning migrations and attractant flows (4.F.12 – Completed)
- Optimised wetland carp separation cages–Lake Bonney (4.F.17 – Completed)
- Optimised wetland carp separation cages evaluation (4.F.20 – Completed)

Tactical control–tilapia

- Tilapia control and management strategies (4.F.10 – Completed)
- Tilapia toolkit (4.F.18 – Completed)
- Environmental DNA detection for tilapia (4.F.19 – Completed)

Demonstration Sites

- Demonstration Site: Albert-Logan, Queensland (10.F.8 – Completed)
    - PhD: Impact of increased predator presence through stocking on carp populations and the implications for management (Katie Doyle)
- Demonstration Site: Lachlan catchment, NSW (10.F.9 – Completed)
- Demonstration Site: Lakes Sorell and Crescent, Tas (4.F.16 – Completed)

Education and training

- Engaging communities of the Murray-Darling Basin (10.F.1 – Completed)

Relevant projects included under other goals

Knowledge and tools

- Validating and refining risk assessment models (9.D.1)

Strategic control

- Scoping current invasive fish measuring and reporting methods (9.D.5)

Knowledge and tools

- Mapping invasive animals in Australia (includes carp) (12.D.1)

Carp spawning hotspots in the Murray-Darling Basin

Project Leader: Dr Dean Gilligan, NSW Department of Primary Industries

Project 4.F.5

Aim: *To identify carp spawning hotspots within the Murray-Darling Basin*

Project duration	October 2005 – September 2008
Status	Completed

Project summary

This project identified preferred carp recruitment areas across the Murray–Darling Basin (MDB). It built on previous research suggesting carp exhibit a source-sink population structure (eg 98% of carp recruitment in the mid-Murray River originates from a single location (the Barmah-Millewa Forest), by collecting and analysing data from across the whole of the MDB. The project utilised electrofishing data from 1,677 sites in Queensland, Victoria, South Australia, NSW and the Australian Capital Territory to analyse and map the number and size of carp recruitment hotspots throughout the MDB.

The project assessed larval drift sampling as a cost-effective strategy to map the point sources of carp breeding within recruitment hotspots and developed an easily measurable condition factor for carp larvae. The outputs contribute towards best use of the CarpSim model by providing information on the spatial structure of carp populations of the MDB and specifying the population units (nodes) that contribute most to recruitment within the Basin (source populations). Population sinks were also identified. Accounting for this spatial variation will create more realistic CarpSim modelling of carp populations and assist in the development of an effective integrated carp management strategy.

More than 90% of the total standardised abundance of small juvenile carp was recorded at just 3.14% (34 sites) of the locations where carp were present, with 50% coming from just 1.38% (15). These sites were clustered, with spatial analysis of abundance of young-of-year, sub-adult and adult size classes identifying as few as 17 key recruitment hotspots within the MDB, with a proportion of these only important at the local scale. The spatial arrangement of hotspots suggests that large floodplain wetland systems (such as the Maquarie Marshes, Gwydir Wetlands, Narran Lakes, Great Cumbung Swamp and Barmah–Millewa Forest) are key sites for carp recruitment.

Control strategies focused on the 17 hotspots identified are likely to make a disproportionately positive contribution to achieving basin-wide carp control as part of an integrated pest management strategy. Especially for biocontrol strategies such as KHV, where knowledge of where and when high densities of the most susceptible juvenile size class are present will guide development of an effective virus release strategy.

Extensive drought conditions throughout the period of the study affected our ability to use a larval sampling method to map the point sources of carp breeding across the whole MDB. But the results from those valleys that were sampled are consistent with the recruitment hotspots identified using spatial analysis of electrofishing data. However, in the four valleys where repeat sampling was possible, results suggest that while larval sampling is certainly capable of identifying the recruitment areas within valleys, there is a high probability of false negative results. So whilst larval sampling is capable of confirming the presence of a breeding site within a recruitment hotspot, non-detection is not sufficient evidence to confirm the absence of one.

The identification of carp recruitment 'hot-spots' will assist an Integrated Pest Management strategy by guiding:

- appropriate spatial parameterisation of the CarpSim model
- identification of priority locations for control of adult carp migrating towards spawning areas
- identifying priority sites for the exclusion of spawning adults from spawning areas, targeted control of spawning aggregations (recruitment sabotage) and capture of dispersing juveniles
- guiding development of effective implementation plans for bio-control strategies.

Key achievements

- As few as 17 key carp hotspots were identified in the Murray-Darling Basin.
- This knowledge enables carp control to be targeted at a finite number of recruitment sources (hotspots) rather than being diluted over tens of thousands of kilometres of river. The information will assist the development of Integrated Carp Management Strategies across the Murray-Darling Basin and provides a cost-effective strategy to detect carp recruitment hotspots in other catchments in Australia and globally.

Project team

Dr Dean Gilligan, Dr Bob Creese, Tim Glasby, Vanessa Carracher, Peter Boyd, Ian Wooden, Simon Hartley, Dean Hartwell, Cameron McGregor, Paul Brown, Dr Qifeng Ye, Dr Michael Hutchinson and Dr Iain Suthers.

Project partners

Invasive Animals CRC, NSW Department of Primary Industries, SA Research and Development Institute, Queensland Department of Agriculture, Fisheries and Forestry, Victorian Department of Primary Industries, University of NSW, Murray–Darling Basin Authority.

Further information

Gilligan, D and Rayner, T (2007) The Distribution, Spread, Ecological Impacts and Potential Control of Carp in the Upper Murray River. NSW Department of Primary Industries Fisheries Research Report No 14, NSW Department of Primary Industries, Cronulla.

Gilligan, D (2007) Carp in Australian rivers. In: Lunney, D, Eby, P, Hutchings, P and Burgin, S (Eds), Pest or Guest: the Zoology of Overabundance. Proceedings of the Royal Zoological Society of NSW forum held at Taronga zoo, Mosman NSW, 22 October 2005. Pp 30–39.

PestSmart Case Study: Carp spawning hotspots

www.invasiveanimals.com

Carp movement and migration in Murray-Darling Basin

Project Leader: Paul Brown, Vic Department of Primary Industries

Aim: *To mark and recapture (or re-locate) individual carp to determine temporal and spatial movement patterns of carp*

Project 4.F.6

Project duration	October 2005 – June 2012
Status	Completed

Project summary

This major, long-term project coordinates a program of marking and recapturing (or re-locating) individual carp to determine temporal and spatial movement patterns of carp.

To efficiently plan and implement integrated pest management for carp there is a strong need to understand when, where, and why carp move around the Murray-Darling Basin (MDB) over time scales relevant to their life-history (that is, decades).

Tagged carp (NSW DPI)

Innovative use of combined technologies including passive integrated transponder (PIT) tags, coded acoustic tags (CAT), and embedded remote sensors will enable us to understand stock-structure within the MDB, quantify movement among stocks, and 'triggers' for movement. This ground-breaking project will also quantify the extent that movement behaviour creates vulnerability-to-control within carp life history (eg aggregation, passage through fishways etc).

Experience with integrated pest management for other major pests (for example, with mice and rabbits) has shown that knowledge of movement and spatial structure is essential for realistic evaluation of success.

Key achievements

- 21 pairs of acoustic receiver / data-loggers installed in strategic locations around the MDB.
- 234 carp implanted with CAT and PIT tags.
- Of these, there have been 2.2 million detections on the VR2 acoustic loggers from 33% of the tagged carp.
- Dispersal beyond the river of release has been rare; only 5% of tagged carp and all males.
- Five tagged carp recaptured (4 angled, 1 electrofished).
- Four tagged carp detected moving through fishways on the Murray River including two moving up the Broken Creek. Some tagged fish are also known to have passed-by weirs with a fish-way containing PIT tag detectors while avoiding detection.
- Emigration and source–sink dynamics are a key knowledge–gap and required as direct input into multi-stock CarpSim models. Information from this project has enabled simulation of realistic levels of stock-interaction.
- The phase two extension of this project enable collection of data over an extended time frame and thus improved the quality of the data.
- Articles for submission to peer-reviewed journals relating to:
  - the dispersal of tagged adult common carp around the Murray–Darling River Basin
  - modelling and data analysis for Invasive Animals CRC project 10.F.9 Lachlan River Demonstration Site.

Project team (past and present)

Paul Brown, Cameron McGregor, Ian Wooden, Dr Dean Gilligan, Daniel Steel, Corey Green.

Project partners

Invasive Animals CRC, Victorian Department of Primary Industries, NSW DPI, Murray-Darling Basin Authority.

www.invasiveanimals.com

Carp age validation in northern Murray-Darling Basin

Project Leader: Dr Michael Hutchison, Queensland DAFF

Aim: *To determine whether northern carp populations form annual check marks on their earstones or otoliths*

Project 4.F.11

Project duration	March 2006 – June 2009
Status	Completed

Project summary

Being able to accurately age carp is important for modelling carp population dynamics. Age at maturity, and carp growth rates may vary between catchments of the Murray–Darling Basin (MDB). Population dynamics models such as CarpSim assist in predictions of the effects of different carp management methods. Models such as these will be important for selection of control measures most likely to succeed in different parts of the catchment.

Before this study, carp aging validation in Australia had been based on southern temperate populations. Slow growth during the winter months followed by increased growth in spring had been shown to result in formation of annual check marks in the earstones or otoliths of carp in the southern Basin. However, in the northern MDB, with a subtropical climate, winter temperatures are not as low, so it was not known if checks formed annually in northern carp populations.

The project involved chemical marking of otoliths of over 200 adult and 200 young of the year (YOY) carp that were captured by electrofishing in the Macintyre River catchment near Goondiwindi, Queensland. A sub-sample of carp were held in tanks, and the remainder were released into two small lagoon habitats near Goondiwindi. Captive adult fish were held for up to 15 months. Examination of marked otoliths from fish at large from 12 to 20 months determined that checks do form annually in northern basin carp populations and estimated the timing of check formation as November/December, close to but slightly earlier than in southern Murray–Darling Basin carp populations. Biennial check formation was observed in a small number of sampled carp in this study and researchers advise caution in the use of ageing data from northern carp populations. Results from this study are applicable to the adjacent Logan–Albert River catchment population of carp.

Key achievements

- Results using otoliths from both juvenile and adult carp to check for the timing of first increment formation suggest that the northern Murray–Darling basin carp do appear to lay down their first check slightly earlier than fish in the southern Murray–Darling basin.
- At least one increment was observed to form each year in these northern Murray–Darling basin carp, but occasionally two formed. The reason for biennial check formation is unclear.
- Increments were less clear in some tank-held individuals than in lagoon fish.

Project team

Dr Michael Hutchison, Keith Chilcott, Adam Butcher, John Kirkwood, Mark McLennan, Stephanie Backhouse.

Project partners

Invasive Animals CRC, Queensland Department of Agriculture, Fisheries and Forestry, Victorian Department of Primary Industries, Murray-Darling Basin Authority.

Further information

Hutchison, M, McLennan, M, Chilcott, K, Norris, A and Stewart, D (2012) Validating the Age of Carp from the Northern Murray–Darling Basin. PestSmart Technical Report, Invasive Animals Cooperative Research Centre.

Smith, B, Thwaites, L and Conallin, A (2012) Guidelines for carp management at wetland inlets. A test case for South Australia. PestSmart Technical Report, Invasive Animals Cooperative Research Centre.

Ayres, R and Clunie, P (2012) Management of Freshwater Fish incursions. PestSmart Technical Report, Invasive Animals Cooperative Research Centre.

Ayres, R and Clunie, P (2012) Towards a national emergency response system for freshwater fish incursions. PestSmart Technical Report, Invasive Animals Cooperative Research Centre.

www.invasiveanimals.com

Carp vulnerability analysis synthesis

Project Leader: Dr Leigh Thwaites, SA Research and Development Institute

Aim: *To synthesise the Invasive Animals CRC multi-state, coordinated analysis of carp ecology and population dynamics to assess weaknesses that can be exploited for control*

Project 4.F.15

Project duration	September 2009 – June 2012
Status	Completed

Project summary

This project produced a report which synthesises the outputs of the Invasive Animals CRC multi-state, coordinated analysis of carp ecology and population dynamics to assess weaknesses that can be exploited for control. The report summarises major findings from Invasive Animals CRC projects and incorporate other relevant information from the scientific literature.

The report also includes a review of the current literature on carp population dynamics.

It includes relevant information from the following projects:

- carp movement
- carp ageing validation
- carp trapping studies
- carp reproduction hotspots
- carp populations genetics
- sex determination and differentiation pathways in carp
- early gonad development in carp.

The final report is a reference document for resource managers that brings together relevant information on carp to assist in control of this species.

Key achievements

Carp vulnerability analysis synthesis report produced.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, SA Research and Development Institute.

Further information

Gherig, S, Smith, B and Thwaites, L (2011) Exploitable Biological Vulnerabilities of Common Carp. Invasive Animals CRC PestSmart Toolkit Publication, Invasive Animals Cooperative Research Centre, Canberra, Australia.

www.invasiveanimals.com

Daughterless fish technology

Project Leader: Dr Ron Thresher, CSIRO Marine

Aim: *To conduct laboratory development and trials of daughterless technology for the control of invasive fish species*

Project 4.F.3
2 PhD projects (sex-determination)

Project duration October 2005 – June 2012
Status Completed (with new research progressing, under new short-term external funding)

Project summary

Development of 'daughterless' technology, that is, an inherited genetic construct that biases offspring sex ratios towards males, offers hope as the first long-term sustainable management tool for the control and possible eradication of alien fish species in the Murray–Darling Basin. Detailed modelling and the initial development of a suitable construct was started by CSIRO Marine and Atmospheric Research and continued under the auspices of the Pest Animal Control CRC. Encouraging results (including viable daughterless fish swimming in the lab) were achieved, warranting the continuation of daughterless development in the Invasive Animals CRC.

The global objective of the project remains to develop a practical option for controlling, if not eradicating, carp from the Murray–Darling Basin using as a core technology a genetic construct that biases population sex ratios and drives population fertility to zero.

The Invasive Animals CRC daughterless project successfully tested two variants of a prototype sex-determining construct in a model species (medaka) and researched whether the construct can be integrated into the species genome to make the sex-distortion an inherited feature.

A prototype carp daughterless construct was built, wholly of native carp genetic material.

Preliminary trials were undertaken on options for sterilising or killing females as complementary options for sex ratio distortion.

Options for including an 'off-switch' in the construct, as an ultimate safety feature for the technology were assessed. Advice from stakeholders indicated that this not a useful feature for the technology.

The project:

- continued trials of the genetic technology in carp. This has been done through an already established collaboration with fisheries geneticists at Auburn University (USA), which has accredited facilities for and experience with genetic transformation of carp. The existing daughterless carp prototype (DC–1) has been tested for effects on sex determination, along with complementary genetic constructs that hypothetically also distort operational sex ratio. The results of the trials have been positive, so first steps are being taken to develop an integrated carp lineage.
- completed testing the effect of the technology on laboratory fish populations. This was achieved by assessing the long-term patterns of inheritance and effectiveness of sex-determining constructs at altering sex in a model fish species, by refining and optimising the technology in the light of recent developments in genetic technology to improve its efficacy and gene targeting, and by stocking fish carrying sex-ratio altering constructs into model species populations in the laboratory to quantify effects on population viability.
- This work has been supported by two Invasive Animals CRC PhD projects that have investigated the physiological and genetic basis of sex determination and RNA interference (the key gene blocking technology being used in this study) in fish.
- Undertaken a risk assessment and synthesis of the technology for input into a national carp control plan. This material is summarised in a project final report that also includes a recommended program and cost estimates for field testing and implementation of the technology.

Key achievements

- Successful testing of a prototype female-lethal (daughterless) construct through three generations of zebrafish, with marked effects on offspring sex ratios.
- Successful testing of a prototype female-lethal carp construct built wholly of native carp genetic material. Evidence of similar efficacy in carp.
- Native-fish replacements for ricin alpha in the lethal and sterility constructs (complementary options for sex ratio distortion) developed.
- Overall synthesis of genetic approaches to pest fish control submitted to journal (*Biological Invasions*) and synthesis of
- relevant risk analysis frameworks in near completed draft form.

The first daughterless carp?
(Auburn University)

- Screening of model species lineages for construct integration and effectiveness completed:
  - Three construct lineages have been achieved in a model species (zebrafish), two female-lethal constructs (with and without a tet-off regulating element) and a potential female-sterility construct. The female-lethal constructs are based on the vitellogenin promotor driving ricin alpha as a cell death gene.

The female-sterility construct uses the egg-coat-protein specific promotor ZP3 to drive expression of a fish apoptosis (cell death) sequence, Caspase2.

- The female-lethal construct has been demonstrated as effective in severely biasing offspring sex ratios through at least three generations (F3). Trials have compared effects of copy number (heterozygous vs homozygous carriers). F1 female-sterile carriers are being reared to assess the possible effects of the construct on mature females.

- The efficacy of using a female lethal construct to control a pest fish population depends in part on the fitness of male carriers relative to wild type males. If the carriers are not competitive for females or have low reproductive success, then high numbers have to be stocked in order for control to be effected (Bax and Thresher, 2009). Hence a key performance indicator for the approach is the relative fitness of male carriers. This report outlines the results of experiments that measure this fitness. It concluded that on the basis of results to date, heterozygous (copy number 1) and homozygous (copy number 2) male carriers have a fitness and level of reproductive success similar to wild-type males.
- For none of the three fitness parameters measured was a significant difference found between wild-type males, construct-positive males or full sibling construct-negative males. The report concluded that any effect of the construct or its integration on male fitness is subtle, if present at all.
- Completed tests of effectiveness and fitness effects of constructs in carp. Sex ratios of mature carp are consistent with sex ratio biasing effects of the prototype carp daughterless construct and the vitellogenin female lethal construct. Carriers of other constructs were tested (several variants on the female lethal and female sterile approaches) are too young as yet to screen. Eggs and sperm of mature fish have been screened for carriers.
- Determination of effectiveness of constructs on population viability and production of data for model revisions:
  - Updated models have been developed that incorporate population dynamics data for Gambusia and for carp. The models also have been broadened to include a comparison with the Trojan Y chromosomal approach. The results confirm previous suggestions that efficacy is strongly dependent on both reproductive dynamics (particularly spawning frequency and early stage mortality rates) and degree of density dependent population regulation. The Trojan Y approach was surprisingly effective and could provide a valuable interim control option while more potent recombinant approaches are completed.
- Improved efficacy of genetic technology by incorporating latest developments of genetic technology into construct design:
  - Constructs have been enhanced by incorporating improved enhancing elements up-stream of the promoters and by developing and building into a new generation of constructs fish-specific cell death sequences (to replace the plant-based ricin alpha sequences used in the proof-of-concept constructs). These alternative configurations have been transfected into carp and zebrafish and are being evaluated for efficacy as the fish reach sexual maturity. Pre-maturational testing of the fish-based cell death sequences has been done using juvenile carp, by triggering the constructs with exogenous estradiol, confirming their lethality.
- Completed analysis of female lethal/sterile constructs, production of brood line, and results of pond trials.

Project team (past and present)

Dr Ron Thresher, Dr Peter Grewe, Dr Jodie van de Kamp, Dr Nic Bax, Dr Jawahar Patil, Rob Gurney, Dr Keith Hayes, Dr Rasanthi Gunasekera, Giles Campbell, Miles Canning, Tim Fountain, Dr Janina Beyer, Prof Peter Koopman, Dagmar Wilhelm, Keith Bell, Prof Anne Kapuchinski (University of Minnesota), Michael Jones (Michigan State University), Dr Megan Barney, Lindsey McFarlane.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, CSIRO Marine, University of Queensland, K&C Fisheries, University of Minnesota, Michigan State University, University of Tasmania, Auburn University Alabama.

Further information

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PestSmart 'Daughterless Carp' fact sheet.

www.invasiveanimals.com

Cyprinid herpesvirus 3 biocontrol agent

Project Leaders: Dr Ken McColl and Dr Mark Crane, CSIRO Australian Animal Health Laboratory

Aim: *To determine the potential of Cyprinid herpesvirus 3 (CyHV-3) as a biocontrol agent for carp in Australia*

Project 4.F.7

Project duration	April 2006 – June 2012 (continuing in the new extension Invasive Animals CRC)
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

Koi herpesvirus (KHV) or Cyprinid herpesvirus 3 (CyHV–3) has devastated carp populations in the US, Israel, Europe, Indonesia and China. Having not yet presented in Australia, KHV may be a highly effective biocontrol if managed and implemented correctly as opposed to unregulated escape. Overseas evidence is very promising, suggesting KHV is species specific (carp only) and highly effective against carp. The Fish Diseases Laboratory at the high-security CSIRO Australian Animal Health Laboratory is examining the potential of KHV as a biological control agent for carp in Australia, undertaking a rigorous assessment of KHV

The project includes:

- screening of wild Australian carp for cyprinid herpesviruses:
- At least two other cyprinid herpesviruses are known: CyHV–1 (carp pox) and CyHV–2 (goldfish haematopoietic virus). It is essential that samples of carp are screened from different areas of Australia in order to test for the presence of such potentially cross-reactive viruses that could conceivably confer a degree of resistance on Australian carp. Screening of carp has involved collaboration with epidemiologists to establish the required sample sizes, and the distribution of samples to be considered statistically significant.
- susceptibility studies of non-target species:
    - If KHV were to be released into Australian waterways, it is crucial to demonstrate that only carp would be affected.
    - susceptibility of carp of different ages/sizes–epidemiological considerations:
    - In the long-term, modelling that simulates the release of KHV in a naive population of carp is required to predict how effective KHV would be in the carp population, how it would spread, how it would persist, the influence of the hydrodynamics of different river systems on these parameters. In order to develop future epidemiological models, baseline information on the biology of the virus is required.
    - Much of this information is in the literature, while some (eg temporal patterns of virus excretion by infected carp, the sensitivity of carp to bath infection, the susceptibility of different size carp in Australia) will be supplied by this project.

These preliminary studies will be strictly confined to the laboratory, and, even if the results are encouraging, it is likely to be many years, and after much public consultation, before the virus would be considered for use in a multi-pronged attempt to control carp in Australia.

Key achievements

- Methods for isolation and growth of KHV in cell culture established to international standards.
- Methods for detection and identification of KHV by PCR established to international standards.
- Demonstration that the KHV Indonesian strain is the most effective strain.
- During collection of juvenile carp in May and June 2009, a number of larger carp were also collected. These were used for a PhD project (funded outside the Invasive Animals CRC), and, in the process, some of these fish also provided further data on the susceptibility of Australian carp to KHV. These results complement earlier data (from January/February 2008) on the susceptibility of smaller Australian carp (approximately 1.8 – 4.4 cm) to KHV.
- From December 2008 to June 2009 immuno-cytochemical studies on KHV in tissue culture were conducted. Preliminary studies have indicated that viral antigens in tissue culture can be localised using the same commercial antibody that is also used for immune-histochemistry.
- Molecular and histopathological data demonstrate that Murray cod, silver perch, golden perch, a galaxiid and rainbow trout are not susceptible to infection with KHV.
- Susceptibility studies have revealed that carp–goldfish hybrids appear to be, at the very least, much less susceptible to KHV than pure carp.
- Preliminary studies indicate that there is little evidence for viruses cross-reactive with KHV in carp in the Murray-Darling Basin.
- A preliminary study of 100 carp collected from rivers in Victoria revealed no evidence for carp-goldfish hybrids.

Project team

Dr Mark Crane, Dr Ken McColl, Dr Agus Sunarto and Lynette Williams.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, CSIRO.

Further information

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PestSmart Factsheet: Koi herpesvirus as a biological control method for carp

www.invasiveanimals.com

Policy analysis of genetic techniques

Project Leader: Wayne Fulton, Vic Department of Primary Industries

Aim: *To determine information requirements for use of new biological control techniques for fish into inland waters in Australia*

Project 4.F.8

Project duration September 2011 – June 2012
Status Completed

Project summary

Policy and regulations pertaining to the use of genetically modified (GM) organisms in natural environments are still in development. There is no doubt that existing policy will need to be reviewed and assessed if the release of 'daughterless' carp and other GM biotechnologies for pest animal control are to be initiated.

If a new technology such as 'daughterless' or KHV does get to the stage where it can be implemented, further work will be required prior to approval for public release. This project will identify the various processes and pathways that need to be taken for the implementation of control strategies. The emphasis will be on existing processes that need to be satisfied including the information requirements for permits etc.

Key achievements

- Presentation made on the Australian GM legislative framework at the International Symposium on Genetic Biocontrol of Invasive Fish (Minneapolis, Minnesota, USA, 21-24 June, 2010).
- Victorian jurisdictional frameworks for the use of a virus to control freshwater fish determined.
- Existing national and state policy frameworks for the use of relevant biological control options reviewed .
- A pathway to adoption for these tools outlined.

Project partners

Invasive Animals CRC, Victorian Department of Primary Industries, NSW Department Primary Industries.

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Scoping fish-specific biocides

Project Leader: Graeme Allison, Vic Department of Primary Industries

Aim: *To review fish specific biocides and their delivery mechanisms to assess potential biocides for use in Australia*

Project 4.F.9

Project duration July 2007 – July 2008
Status Completed

Project summary

Piscicides represent a potentially highly effective control option for aquatic species and are a standard fisheries management tool in North America. They are an essential component of any integrated pest management system, and would be a primary tool in any rapid incursion responses against new invasive fish populations. They are also an effective tool in the restoration of small to medium-sized waterbodies.

Research and development of new piscicides has been limited and most countries still rely upon the non specific fish poisons, rotenone and antimycin.

This project undertook literature reviews, summarising the legislative and regulatory framework for the registration of chemicals as piscicides for use in Australia and New Zealand, identifying the scientific data and administrative processes required to enable the registration of known non-specific piscicides (rotenone and antimycin) in Australian and New Zealand freshwater environments, summarising the range of candidate compounds that are known to be lethal to selected invasive fish of concern in Australia and New Zealand, eg carp and tilapia.

Key achievements

- A report that summarises the regulatory framework for use of rotenone and antimycin in Australia.
- Information on a range of candidate compounds known to be lethal to selected invasive fish of concern in Australia and New Zealand.

Project team

Trevor Theodoroupolous, Fiona Baranowski, Bill Gingerich.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Victorian Department of Primary Industries, US Geological Survey.

Further information

Allinson, G and Theodoropoulos, T (2008) Report Summary: A Strategy for Developing Fish Specific Biocides and Delivery Mechanisms. Victorian DPI Queenscliff.

PestSmart Factsheet: Use of chemicals as poisons for pest fish control.

www.invasiveanimals.com

Carp sensory attractants

Project Leader: Prof Peter Sorensen, University of Minnesota, USA

Aim: *To identify male and female sex pheromonal attractants for the common carp*

Project 4.F.4

Project duration December 2006 – December 2011
Status Completed

Project summary

The Sorensen laboratory has made significant advances in isolating and identifying male and female sex pheromones in carp. This project also successfully developed a means to administer the female sex pheromone in the field, where its ability to attract male carp has been validated. This technology has been adopted by the Tasmanian Inland Fisheries Service.

The project objectives were to:

- determine whether sexually mature male carp release a sex pheromone that attracts conspecific females and then identify this cue
- determine whether ovulated female carp release a sex pheromone and then identify this cue
- determine whether the release of the female carp pheromone can be elicited at supra-normal levels and on a long-term basis by implanting carp with prostaglandin F2α (determining the optimal dose of prostaglandin for implants, the role of gender and how implants work in the laboratory)
- prepare and deliver 20 implants for use in Australia along with a user manual and instructions on how to make more implants
- submit at least one manuscript on pheromone implants for peer-reviewed publication.

Key achievements

- The male carp sex pheromone cue was found to be species-specific, sex-specific and potent. Androstenedione (a potent olfactory stimulant of carp and a known component of the goldfish sex pheromone) can explain about half of the extract's behavioural activity in the laboratory. The other components appear to be as yet unidentified sex steroids and body metabolites. A publication is expected in about a year's time.
- The female carp pheromone was found to be species-specific, sex-specific and potent. Prostaglandin F2α explains the majority of its activity.
- Production and release of the female carp sex pheromone can be easily elicited by implanting male or female carp with prostaglandin F2α.
- Synthetic prostaglandin implants can induce pheromone release in female carp for up to a week and field trials have shown attraction of male carp into the vicinity of cage held PGF2α-implanted female carp.
- Production and release of the carp sex pheromone is highly effective in the laboratory and field (trials in USA and Australia).
- Immature and female carp are also attracted to implanted female odour.
- Implants and guidance were provided for testing in Tasmania, along with a technical manual.

Project team

Prof Peter Sorensen, Dr Hangkyo Lim, Mario Travaline.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, University of Minnesota, USA.

Further information

Bajer PG, Chizinski, CJ, Silbernagel ,JJ and Sorensen, PW (2012) Variation in native micro-predator abundance explains recruitment of a mobile invasive fish, the common carp, in a naturally unstable environment. *Biological Invasions* 14: 1919–1929

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Sisler, SP and Sorensen, PW (2008) Common carp and goldfish discern conspecific identity using chemical cues. *Behaviour* 145:1409–1425.

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Carp environmental attractants

Project Leader: Dr Simone Rochfort, Victorian Department of Primary Industries

Aim: *To analyse the use of natural odours to direct carp behaviour and movements*

Project 4.F.13
PhD (environmental attractants)

Project duration	December 2006 – June 2012
Status	Completed

Project summary

This project explored an important strategy for the control of invasive species, studying the use of natural odours to direct carp behaviour and movements.

The project aimed to:

- identify plants that are potential attractants through chemical screening and biological testing
- identify plant chemicals by mass spectroscopy (MS) and nuclear magnetic resonance spectroscopy (NMR).

Synthetic routes for synthesis of plant compounds for carp attraction were then identified and the most active were synthesised. Phase 2 funding allowed the continued supervision, operating costs and overheads for Invasive Animals CRC PhD student, Aaron Elkins.

Key achievements

- As part of this project, a publication 'Carp Chemical Sensing and the Potential of Natural Environmental Attractants for Control of Carp: A Review' was completed, which critically examined the scientific literature around environmental chemo-attractants for fish in general and carp in particular.
- The review highlighted the general paucity of research in this area. The olfactory system is the most sensitive receptor site and plays significant roles in behavioural processes. Carp appear predominantly attracted to amino acid combinations containing glycine and alanine (food related).
- Chemical screening and biological testing was undertaken of four plant species identified as sources of potential chemical attractants. Initial studies suggest that two of the collected plants have some attractant properties for juvenile carp.
- These plant based attractants were chemically isolated and identified by MS and NMR and assessed for their potential as attractants.

Project team

Dr Simone Rochfort, Dr Russell Barrow, Matt McDonagh, Aaron Elkins.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Victorian Department of Primary Industries, Australian National University.

Further information

Elkins, A, Barrow R and Rochfort, S (2009) Carp chemical sensing and the potential of natural environmental attractants for the control of carp: A Review. *Environmental Chemistry* 6(5):357–368

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Acoustic fish repellents and attractants

Project Leader: Dr Leigh Thwaites, SA Research and Development Institute

Aim: *To develop a range of techniques incorporating attractants and repellents to remove carp from areas difficult to operate in effectively with current control methods*

Project 4.F.14

Project duration	March 2009 – May 2012
Status	Completed

Project summary

The application of underwater acoustical equipment to reproduce 'fish sounds' has been tested on cyprinids to illicit trained responses, restrict movements and to attract and concentrate dispersed populations. When used in conjunction with current integrated pest management technology, acoustics may increase carp harvesting success, particularly in lentic systems (ie wetlands) where traditional sensory attractants (pheromones, amino acids) that rely on current flow are not effective.

Key achievements

- Two 'attractive' carp feeding sounds have been recorded (feeding and flowing water) and a sound bank of potential 'repellent' noises (explosions, various frequencies, etc) has been developed.
- Preliminary attractant trials have been conducted and acoustic equipment has been verified for underwater acoustic attractant / repellent trials.
- A mobile waterproof underwater playback sound station was constructed. Preliminary 'system tests' were undertaken and the sound station has faithfully reproduced the attractive/repellent sounds via two underwater speakers, this is important as an attractive sound can be a repulsive sound if not played back at natural levels. This part of the work has been conducted in collaboration with technical experts from Deakin University, Warrnambool.
- Sound pressure levels (SPL) of all experimental sounds were calculated and confined that sounds were played back at biologically relevant levels.
- Advanced eonfusion training has been completed, providing vital steps towards the development of further training to be delivered in the field and by way of DVD.
- Further stimulus sounds (ie other fish jumping) were identified to optimise trapping rates in carp jump/push traps by stimulating jumping/pushing behaviour in carp outside of traps.
- Use of sounds as carp repellents for netting harvest optimisation was demonstrated.
- To monitor the response of eight acoustic tagged carp to attractant and repellent sounds A VEMCO VPS array was established in the Adelaide botanic gardens. This system provided positional data of each tagged carp approximately every 60 seconds.
- Two attractant sounds (carp feeding and flowing water) and one repellent sound (high, mid, low frequency coupled with explosion sounds) was tested over a series 28 experiments from three different locations within the experimental lake.
- The response of carp was assessed using customised Eonfusion fish movement analytical model. As a measure of attraction or repellence, this model was used to determine the time each tagged carp spent within four distances (5m, 10m, 25m and 50m) from the playback system both before and during each experimental period.
- Preliminary results indicate that feeding and flowing water sounds only had a limited effect and are therefore not suitable for effective harvesting of carp. Interestingly, repellent sounds seemed to stimulate exploration for the sound source which may indicate that a component of the repellent sound (ie low or mid frequency) may prove useful as an attractant.

Project team

Dr Leigh Thwaites, Dr Qifeng Ye, David Fleer, Aaron Strawbridge, Dr Ben Smith.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, SA Research and Development Institute.

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Optimised wetland carp separation cage demonstration

Project Leader: Dr Ben Smith, SA Research and Development Institute

Aim: *To identify ways of exploiting carp spawning aggregations at wetland inlets*

Project 4.F.12

Project duration	July 2006 – September 2009
Status	Completed

Project summary

In temperate lowland rivers, carp are allied with two important habitats: a shallow well-vegetated spawning habitat, preferably in off steam wetlands, and a deep over wintering habitat in the main river channel. The shallow wetland habitat enables spawning and the replenishment of populations via recruitment. The deep habitat is thought to provide refuge from flow and maintain stable temperatures in comparison with shallow surface waters.

Movement between these two habitats is annually predictable, and results in localised accumulations of carp (spawning and over wintering aggregations). Carp aggregations are vulnerable to targeted removal programs and allow focussed, effective carp management efforts.

This project focussed on identifying ways of exploiting carp spawning aggregations at wetland inlets. Investigations evaluated the migratory (and jumping) ecology of carp through wetland inlets, including the application of existing Carp Separation Cage (CSC) technology for trapping and removing carp at wetland inlets. Required modifications to the existing Carp Separation Cage design were investigated, and a carp 'pushing' trap component was subsequently developed and incorporated into the cages and field trialled.

Key achievements

- As part of this project, a literature review of carp movement and migration and possible sensory attractants for laboratory and field testing was completed, with four promising carp attractants identified: current flow, amino acids, water temperature and sound.
- Experiments conducted by this project found carp were able to push as much as twice their body weight. The results of these measurements were used for the development and manufacture of a pushing trap element for incorporation into a wetland Carp Separation Cage.
- An evaluation of wetland carp separation cages incorporating 'pushing' and 'jumping' trap elements was made at the inlet and outlet to South Australia's Banrock Station wetland during 2nd June to 19th December 2008. Weekly sampling occurred to evaluate the performance of the traps and the lateral migrations of native and alien fishes. Carp were absent from June through until early August and this may offer some support for filling wetlands during the colder winter months to prevent their rapid colonisation and recruitment by carp.
- Both the jumping and pushing traps proved a great success in removing large numbers of carp (around 8 tonne in 4 months) and both show great promise for wider application wherever carp migration pathways become spatially constrained ie wetlands, fishways, irrigation channels.
- Decision support guidelines to inform the selection and implementation of carp management options at wetland inlets were prepared from this project.

Project team

Matt Pellizari, Anthony Conallin, Dr Leigh Thwaites, Michael Decelis, Karl Hillyard.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, SA Research and Development Institute, University of Adelaide.

Further information

Thwaites, LA, Smith, BB, Decelis, M, Fleer, D and Conallin, A (2010) A novel push trap element to manage carp (Cyrinus carpio L.): a laboratory trial. *Marine and Freshwater Research* 61:42–48.

Smith, B, Thwaites, L and Conallin, A (2009) Guidelines to Inform the Selection and Implementation of Carp Management Options at Wetland Inlets: A Test Case for South Australia. PestSmart Toolkit Publication. Invasive Animals Cooperative Research Centre, Canberra.

Smith, B and Thwaites, L (2007) Carp Spawning Migrations and Identification of Sensory Attractants – A Scoping Report for the Invasive Animals CRC. SARDI Aquatic Sciences Publication Number F2007/000712-1. SARDI Research Report Series Number 226.

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Optimised wetland carp separation cage evaluation

Project Leader: Dr Ben Smith, SA Research and Development Institute

Aim: *To evaluate the use of a carp separation cage in a field situation: Lake Bonney, SA*

Project 4.F.17

Project duration	September 2009 – March 2011
Status	Completed

Project summary

This project followed on from the earlier work done in project 4.F.12 that developed a wetland carp separation cage with a push trap component. This project aimed to design a wetland carp cage approved by professional engineers to be safe, effective, easy to operate by just one person, vandal-resistant and transferable to other wetland sites across the Basin. The cage was built and installed at Lake Bonney, South Australia for field testing.

Lake Bonney in South Australia is a 1,700 ha shallow freshwater lake fed from the Murray River through the Chambers Creek Wetlands. Lake Bonney was disconnected from the Murray River in mid–2007 (to reduce the amount of water lost to evaporation), resulting in water quality deterioration and fish kills. The lake received a partial refill allocation of 10 GL, which reduced salinities and prevented further fish kills. This filling event created a large aggregation of resident carp at the inflow point, comprised of large numbers of adult carp vigorously attempting to migrate from the lake, the majority of which were harvested. In 2008–09 the SA MDB NRM Board invested in the installation of two box culverts, the design, construction and installation of an optimised wetland carp separation cage, and the establishment of routine reporting requirements to ensure that carp were harvested when delivery of a second environmental water allocation (26 GL) occurred towards the end of 2009.

In preparation for the installation of the cage and the subsequent carp removal trial, a number of carp in the lake were captured, tagged and released back into the system. This was to enable a quantitative estimate to be made of the lake carp population. The wetland carp harvesting system was not able to be demonstrated during the time frame of this study. However, standard operating procedures and a video guide for operating the wetland carp harvesting system were completed and the set-up was ready for operation in 2010.

Key achievements

- The conceptual design, engineered design, fabrication, installation, and commissioning of the WCHS occurred.
- The OHS&W assessment and confirmation of the Lake Bonney WCSC occurred.
- The resident carp and native fish populations in Lake Bonney were quantified/assessed. The size of the resident adult carp population was estimated at ≈173,833 kg (or ≈44,606 individuals, given an average weight of 3.9 kg). A similarly large but unquantified biomass of bony herring was also detected.
- Two new carp screen designs ('optimised' jail bar and grid mesh designs) were fabricated and evaluated.
- New 'Carp Pivot Screens' and 'Carp Deflector Screens' were designed, engineered, fabricated, installed and commissioned.

Project team

Dr Ben Smith, Dr Qifeng Ye, Dr Leigh Thwaites, David Fleer.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, SA Research and Development Institute.

Further information

Thwaites, L and Smith, B (2010) Design and Installation of a Novel Wetland Carp Harvesting Set-up at Lake Bonney, South Australia. A Summary Report for the South Australian Murray-Darling Basin Natural Resources Management Board, Invasive Animals Cooperative Research Centre and the Murray-Darling Basin Authority. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, SARDI Publication Number F2010/000295-1. SARDI Research Report Series Number 469.

www.invasiveanimals.com

Optimised wetland carp separation cage demonstration

Project Leader: Dr Ben Smith/Dr Leigh Thwaites - SA Research and Development Institute

Project 4.F.20

Aim: To field test and demonstrate the optimised wetland carp harvesting system

Project duration: September 2010 – January 2011
Status: Completed

Project summary

This project was an extension of Project 4.F.17, that led to the conceptual design, engineered design, fabrication, installation, commissioning, and the OHS&W assessment and confirmation of the Lake Bonney Wetland Carp Harvesting system (WCHS). In addition, the resident carp population was quantified, commercial fishing operations and the native fish population were assessed, two new carp screen designs were fabricated and evaluated, and a new carp pivot screen and carp deflector screen were designed, engineered, fabricated, installed and commissioned (see Thwaites and Smith 2010). Despite the successes of Project 4.F.17, the Lake Bonney WCHS was not able to be demonstrated during that project due to the various teething problems associated with taking concept designs to fruition. On 24 June 2010, the South Australian Murray-Darling Basin Natural Resources Management Board began providing an additional 25 GL of environmental water to Lake Bonney, which presented an opportunity to prove the WCHS as a breakthrough product for the Freshwater Products and Strategies Program.

This project provided for two weeks field work after carp had begun aggregating around the inflow point, to demonstrate the use of the WCHS at Lake Bonney. The output included a brief report describing the wetland carp harvesting system, catch summary and catch comparison with previous commercial harvest. The report also provided the finalised Standard Operating Procedures and User guide and an itemised cost breakdown of the WCHS.

Key achievements

- Demonstration of operation of the WCHS occurred. Although there were no observable large aggregations of carp adjacent to the cage, within the weir pool or within the inflow plume (in contrast to the environmental water allocations of the previous two years), a total of 529 carp (607.6 mm TL ± 8.1 S.E.; 4400 g ± 155 S.E.; width ≈ 83 mm) were captured over 13 harvesting events. Given their average weight, this equates to the removal of approximately 2.3 tonnes of carp.
- The reduction in the magnitude of carp movement during 2010 was explained by the timing of the allocation, the seasonal increase in water temperatures and the temporal improvement in the Lake's water quality.
- A total of 356 bony herring, 2 goldfish, 1 golden perch and 4 birds were additionally captured as by-catch. The level of by-catch recorded highlights the need to assess the resident native fauna assemblage on a site by site basis before the installation of any carp management infrastructure. If iconic or high value species are encountered then appropriated design modifications and management protocols are required to ensure carp trapping infrastructure has minimal or no impact.
- Although the WCSC operated according to its intended design and function, some operational issues were observed during the 2010 trial. These issues were associated with the funnel, the door mechanism and the cage supports and recommendations were made to improve the 'performance' of the cage.

Project team

Dr Ben Smith, Dr Qifeng Ye, Dr Leigh Thwaites, David Fleer

Project partners

Invasive Animals CRC, Murray–Darling Basin Authority, SA Research and Development Institute.

Further information

Thwaites, LA (2011) Proof of Concept of a Novel Wetland Carp Harvesting Set-up at Lake Bonney, South Australia. A Summary Report for the Invasive Animals Cooperative Research Centre and the South Australian Murray-Darling Basin Natural Resources Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 38 pp. SARDI Publication Number F2011/000086-1. SARDI Research Report Series Number 530.

www.invasiveanimals.com

Demonstration Site: Albert-Logan, Queensland

Project Leaders: Andrew Norris and Dr Michael Hutchison, Queensland DAFF

Aim: *To look at community involvement in carp management and control, especially the value of recreational fishing competitions as a control option*

Project 10.F.8
PhD (predator presence)

Project duration	November 2005 – August 2011
Status	Completed

Project summary

The Albert and Logan Rivers are located in South-east Queensland between Brisbane and the Gold Coast. The objectives of this demonstration site were to investigate the impact and effectiveness of community involvement in the effective management of invasive species, and to demonstrate the feasibility of eradicating or managing an established invasive fish species in a catchment system using new and current technologies. This project examined pest fish control options at the catchment scale. Control measures involved both low tech and high tech solutions and strong community participation. Each of these were comprehensively tested and evaluated under field conditions, leading to an analysis of cost-effectiveness that highlights methods most appropriate to different habitats and circumstances. Methods proven to be successful are now available for take-up in other catchments in Australia and elsewhere.

Associated PhD student Katie Doyle has continued her investigation on the impact of increased predator presence on carp populations, completing tank trials with Australian bass and Murray cod.

PhD student Katie Doyle

Key achievements

- Research into the impacts of carp fishing competitions on local carp populations has been completed and reported on.
- Surveys of three carp fishing events resulted in minimal carp population reductions (<1.8%), especially when compared with electrofishing (resulting in carp population reductions up to 16.1%). The catch per unit effort was nearly 100 times greater for electrofishing than for angling.
- Although carp population impacts are negligible from competitions, the report highlights the non-tangible benefits of competitions, and discusses how competitions can be incorporated into an integrated management strategy.
- A second report has been completed that provides instructions, in the form of a handbook, for running carp competitions.
- Research assessing the effectiveness of individual techniques was completed at nine sites (3 upland sites, 3 main river sections and 3 off-stream water bodies). At each site a range of techniques was applied concurrently, and where possible in an integrated manner for a period of one week. The effectiveness assessment included a comparison of catch rates, non-target by-catch, size selectivity, cost, and catch per unit effort.
- Report on the human dimensions of carp competitions.
- Report on the cost-effectiveness of single or integrated control techniques.
- Relating to the associated PhD project, laboratory and field trials were completed in May 2010

Project team

Keith Chilcott, Danielle Stewart, David Moffatt, Darryl McPhee, Katie Doyle, Dr Gimme Walters.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Queensland Department of Agriculture, Fisheries and Forestry, University of Queensland.

Further information

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Norris, A, Chilcott, K, Hutchison, M and Stewart, D (2012 In Press) 2009 Logan and Albert Rivers Catchment Carp Survey. PestSmart Toolkit Publication. Invasive Animals Cooperative Research Centre, Canberra.

Norris, A and Ballard, G (2012 In Press) Social Drivers Behind Participation in Pest Fish-out Competitions. PestSmart Toolkit Publication. Invasive Animals Cooperative Research Centre, Canberra.

Norris, A, Chilcott, K and Hutchison, M (2011) A Guide to Planning and Running Carp Fishing Competitions. PestSmart Toolkit Publication. Invasive Animals Cooperative Research Centre, Canberra.

Norris, A, Hutchison, M and Chilcott, K (2008) Fished out – The role of fishing competitions in pest fish management. Proceedings of the Queensland Pest Animal Symposium, 19–22 October 2008. Hilton, Cairns, Queensland.

PestSmart Factsheet: Fishing as a carp control method

www.invasiveanimals.com

Demonstration Site: Lachlan River, NSW

Project Leader: Dr Dean Gilligan, NSW Department of Primary Industries

Aim: *To identify and implement targeted carp control options for the Lower Lachlan Catchment* Project 10.F.9

Project duration	January 2006 – June 2012
Status	Completed

Project summary

The lower Lachlan River, including its tributaries and floodplain wetlands is recognised as a Priority High Conservation Value Aquatic Ecosystem in NSW.

Key threats to this vulnerable area include invasive species such as carp and the impact of river regulation on fish passage and the habitat of vulnerable species. The density of carp in the Lachlan catchment is the highest of any catchment in NSW and is probably the most abundant carp population in Australia.

The carp population in the lower Lachlan is supported by several carp recruitment 'hotspots': the Great Cumbung Swamp, Lake Brewster, Lake Cargelligo and Lake Cowal, each having features amenable to trialling of control options. The Lachlan River is also largely isolated from the remainder of the Murray-Darling Basin.

In the initial two years (the benchmarking phase), the focus of the project was on benchmarking the status of the carp population and the aquatic ecosystem in the lower catchment (and control sites established in the Macquarie-Bogan catchment to the north and the lower Murrumbidgee catchment to the south).

Additionally, exclosures were established and assessed (these quantify the impact of carp on aquatic vegetation, macroinvertebrates and native fishes, quantify the expected rate and potential for ecosystem recovery within the broader catchment and provide a visible focal point for demonstration of the benefits of carp control to the community).

Ian Kiernan (Carp Cleanup Ambassador), Rob Gledhill (Chair, Lachlan CMA), Adrian Wells (National Carp Taskforce), Tony Peacock (previously Invasive Aniamls CRC)

Key achievements

- Benchmarks were established for the size of the carp population, relative level of carp recruitment from each hotspot and the status of water project) could be gauged on the proportion of the population removed.
- 50 carp were collected from five locations. Otolith micro-chemistry was analysed to determine if their spawning location could be identified by intrinsic otolith micro-chemical signatures.
- Fish surveys were completed in the lower Lachlan River, in mid–Autumn in 2007, 2008 and 2009. Carp made up 84.5% of the total biomass within the Lachlan River and were present at every site that was sampled.
- The Lachlan River Carp Cleanup held the official launch of the River Revival in Forbes on 16 September 2009. The launch introduced the next stage of the Lachlan River Carp Cleanup.
- Six carp-proof exclusion plots were installed at three locations throughout the demonstration reach. These have been monitored for 1.5 years in a carp-free state.
- A 'Judas Carp' approach was utilised to maximise commercial harvest of carp from Lake Cargelligo.
- Field trials of pheromone technology developed under project 4.F.4 were undertaken at Lake Cargelligo and in riverine environments.
- Carp were removed from Williams Carp Separation Cages installed at Island Bend Weir, Bumbuggan Weir and wetland-style Carp Separation Cages developed at Lake Cargelligo.
- Multi-partner project initiated in response to community pressure, aims to continue for at least 30 years.
- Three components, the Benchmarking phase from 2007–09, the Implementation phase from 2009–11 and the Community Engagement Strategy which has been ongoing for the life of the project.
- Community engagement is a key LCMA activity, has included sponsorship of local carp fishing events, Cleanup a Lachlan Carp Day in November each year, attendance at field days, carp cooking film, survey of community attitudes, and carp cooking competition.
- Commercial-scale carp harvesting has been subsidised by the LCMA in the Lachlan, partnering with K&C Fisheries Global.
- LCMA contracted GHD to completed a commercial carp harvesting feasibility study and business plan.
- Fisheries have been trialling Invasive Animals CRC products and strategies and coordinating installation and management of CSCs on behalf of LCMA.
- CSC installation targeted at Island Creek and Bumbuggan purely because there were operating vertical slot fishways there. However, there has been no in-depth consideration of site hydraulics, carp population or use of fishways.
- Flood and drought have affected the operation and effectiveness of the CSCs installed to date through water levels and debris issues.
- Island Creek, when operational, harvested reasonable numbers of carp initially but then dropped off.
- Pit tag readers have been installed on both fishways and to date there has been little fish movement recorded.
- quality parameters, riverbank stability, aquatic vegetation cover, native fish community composition throughout the lower catchment and social attitudes towards carp, their impacts and the activities of the project.
- 3,122 carp were tagged and released so that mark-recapture estimates of population size can be obtained, and so that the effectiveness of carp removal activities (planned for the phase 2

- Some native by-catch has been found in the CSCs to date but this is believed to be from over-topping of the cage rather than a design fault.
- Otolith studies have been completed to identify key spawning and recruitment locations in the catchment. The Great Cumbung Swamp was identified as contributing recruits all the way to Lake Brewster.

The following components appear in the project's final report:

- a case study on the efficacy of an integrated carp management plan for inclusion in the Invasive Animals CRC carp management toolkit
- a concise 'how to develop an integrated carp control plan guide' for managers based on lessons learnt from the demonstration site
- a model 'Best Practice' Lachlan River Revival integrated carp control plan and related plan documents.

Additionally, the following peer reviewed journal articles have been submitted:

- Modelling the long-term outcomes of an integrated pest control strategy for carp using CARPSIM (Submitted to *Journal of Applied Ecology*).
- A comparison of the effectiveness of pheromone traps for harvesting carp in lentic and lotic aquatic environments (Submitted to *Fisheries Management and Ecology*).
- Using otolith micro-chemical analysis to identify carp recruitment hotspots at a catchment scale (Submitted to *Canadian Journal of Fisheries and Aquatic Sciences*).
- The effectiveness of targeting carp recruitment hotspots as a strategy to achieve catchment-wide control of invasive carp populations (Submitted to *Freshwater Biology* – in review).

Project team

Dr Dean Gilligan, Dr Bob Creese, Simon Hartley, Dean Hartwell, Cameron McGregor, Adam Vey, Sam Davis, Bill Bardsley, Dr Ben Smith, Dr Dale McNeil, Anthony Conallin, Karl Hillyard, Dr David Crook, Ivor Stuart, Keith Bell, Allan McGufficke, Michelle Jefferies and Wayne Fulton.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, NSW DPI, SA Research and Development Institute, Lachlan CMA, Victorian DSE, Kingfisher Research Pty Ltd, K&C Fisheries Global Pty Ltd, NSW State Water, Local community representatives as coordinated by the Lachlan CMA.

Further information

McNeil, DG, Hartwell D, Conallin, AJ and Stuart, IG (2011) Baseline Trials of Carp Control Technologies in Wetlands of the Lower Lachlan River. A Report to the Lachlan Catchment Management Authority and the Invasive Animals Cooperative Research Centre. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000615-1. SARDI Research Report Series No. 516.

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Macdonald, J, Crook, D and McNeil, D (2010) Identification of Carp Recruitment Hotspots in the Lachlan River using Otolith Chemistry. Report to the Invasive Animals CRC and Lachlan CMA prepared by SARDI Aquatic Sciences. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000682-1. SARDI Research Report Series No. 434.

Penfold, K (2009) Lachlan trial for carp removal. *Fish*, Fisheries Research and Development Corporation, (June 2009):24–27.

Wallis et al (2009) Benchmarking social attitudes to river health and carp management in the Lachlan River catchment, NSW. Knowledge Media Division, Deakin University, Geelong, Victoria, 3217.

www.invasiveanimals.com

Demonstration Site: Lakes Sorell and Cresent, Tas.

Project Leader: Chris Wisniewski, Inland Fisheries Service Tasmania

Project 4.F.16

Aim: To implement targeted carp control options in a benchmarked system

Project duration	July 2009 – Dec 2011
Status	Completed

Project summary

Since its inception within the Tasmanian Inland Fisheries Service (IFS) in 1995, the Carp Management Program (CMP) has successfully contained carp in lakes Sorell and Crescent. These lakes represented the only known sites where carp were present in Tasmania. It is a realistic objective to completely eradicate this species from Tasmania.

The data, knowledge, skills and infrastructure that have been built over the removal period (1995 to present) have enabled the program to demonstrate completed carp eradication in Lake Crescent. Physical removal of the last remaining carp in Lake Crescent was challenging owing to reduced catch per unit effort.

The eradication of carp from Lake Sorell has been even more difficult due to the larger size of the lake, its wetland spread and response to rainfall, as well as the effect of a spawning event during the process. Integration of additional methods/approaches was required to assist rapid and efficient removal of the remaining carp in both lakes.

This project provided an opportunity not only to efficiently remove the remaining small population of carp in Lake Crescent, to continue removal of carp from Lake Sorell and to learn and build contingencies

for future management of this species in similar situations elsewhere.

Key achievements

- Since 1995, to March 2012, a total of 31,989 carp have been removed from Lake Sorell and 7,797 from Lake Crescent.
- Despite intensive fishing pressure over the December-March 2011 period, no carp were removed from Lake Crescent. This indicates that Lake Crescent is carp free and has remained so despite ideal spawning conditions for the past three years.
- Recording and mapping of all transmitter fish movement during three preliminary pheromone trials were undertaken.
- Potential improvements in experimental design were identified, and process and procedure documentation was completed.
- Water samples and trial results were provided to Invasive Animals CRC project 4.F.13 (Aaron Elkins PhD)
- An Invasive Animals CRC PestSmart toolkit publication 'A Manual of Carp Control Methodologies based on the Tasmanian Model' in revision.
- Publication of two scientific journal articles and one technical report:

1. Carp population modelling in lakes Crescent and Sorell (under intensive fishing pressure) – accepted for publication by Journal of Applied Ichthyology.
2. Seasonal carp movement and opportunities for exploitation - under review by Marine and Freshwater Research.
3. Pheromone trials in lakes Sorell and Crescent (technical report) has been completed.

- Carp population modelling in lakes Crescent and Sorell (under intensive fishing pressure) – published by *Journal of Applied Ichthyology*
- Seasonal carp movement and opportunities for exploitation (in revision)
- Pheromone trials in lakes Sorell and Crescent (technical report) has been completed.

Project team

Chris Wisniewski, John Diggle, Robert Cordwell, Terry Byard, Robert Keeley, Paul Donkers, Jonah Yick, Andrew Taylor, Dr Jawahar Patil, Prof Peter Sorensen.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Inland Fisheries Service, Tasmania.

Further information

www.ifs.tas.gov.au (see 'Fishery Management' > 'Publications') includes annual reports, fishery management plans, management and project reports.

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Walker, RM and Donkers, PD (2011) An Examination of the Selectivity of Fishing Equipment in Relation to Controlling Carp (*Cyprinus carpio*) in Lakes Sorell and Crescent.

Donkers, PD (2011) Age, Growth and Maturity of European Carp (*Cyprinus carpio*) in Lakes Sorell and Crescent. Revision of (2003) Technical Report No 4, Inland Fisheries Service, Hobart.

Macdonald, A and Wisniewski, C (2011) The Use of Biotelemetry in Controlling the Common Carp (*Cyprinus carpio*) in Lakes Crescent and Sorell.

Patil, JG and Wisniewski, C (2011) Hypophysation: A Technique for Deployment of Odour Donor Fish to Control the Common Carp (*Cyprinus carpio*). Revision of Patil, JG (2006) Technical Report No 5, Inland Fisheries Service, Hobart.

Donkers, P, Patil, JG, Wisniewski, C and Diggle, JE (2011) Validation of mark-recapture population estimates for invasive common carp, (*Cyprinus carpio*) in Lake Crescent, Tasmania. *Journal of Applied Ichthyology* 28 (1) pp. 7-14.

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Donkers D (2003) An Investigation into the Abundance of European Carp (*Cyprinus carpio*) in Lakes Sorell and Crescent. Technical Report No 3, Inland Fisheries Service, Hobart.

www.invasiveanimals.com

Rapid response planning

Project Leader: Pam Clunie, Arthur Rylah Institute – Vic Department of Sustainability and Environment

Aim: *To develop a national plan to guide responses to new fish incursions*

Project 9.F.1

Project duration July 2006 – June 2009
Status Completed

Project summary

The initial objective was to develop a National Rapid Response Plan for invasive freshwater fish in Australia, however this was deemed inappropriate given the changing national biosecurity arrangements including the activities of the Biosecurity Emergency Preparedness Working Group (BEPWG), and the growing recognition of the need to align with, and learn from, other sector approaches. The project team liaised closely with members of this working group and those within other sectors with expertise in national biosecurity to align project development.

Freshwater fish incursions are a significant issue in Australia and a major biosecurity risk to freshwater ecosystems. The introduction of freshwater fish to areas outside their natural range can exert various environmental, social and economic impacts. More than 40 alien freshwater fish have been recorded in Australian freshwaters and more than 70 native freshwater fish species are found outside their natural range.

Current responses to freshwater fish incursions in Australia are generally ad hoc, inconsistent and uncoordinated. Early detection and rapid response best limits emerging problems and provides best returns on investment, however management measures frequently commence only when problems are well entrenched. Key outcomes of this project included literature reviews of national and international management approaches to new freshwater fish incursions, of surveillance, eradication and control programs in Australia, and of international short term containment methods. These reviews will provide a valuable resource for managers. This project identified a suite of recommendations to progress national arrangements for the management of freshwater fish incursions – these encompass preparedness and emergency response, prevention, ongoing management and control as well as supporting arrangements.

Tilapia and carp are major pest fish species in Australia

Key achievements

- A Steering Committee was established with representation from all State and Territory jurisdictions. This Steering Committee recognised that creating a National Rapid Response Plan for Invasive Freshwater Fish in Australia was no longer the most appropriate or relevant outcome for this project. The initial bid was developed prior to changing national biosecurity arrangements including the establishment of BEPWG, whose actions are proceeding. Several people involved in managing emergency response arrangements for other sectors advised that there was no value in developing a 'plan' without recognition of the issue on a national level. They provided valuable guidance in identifying actions required to align with other sector procedures.
- Two key documents have resulted from this project which will strategically assist key groups/representatives to foster national support for developing national emergency response arrangements for freshwater fish incursions:
- Management of Freshwater Fish Incursions – A Review. This review covers international approaches to the management of freshwater fish incursions; existing prevention, detection and management programs and tools in Australia; and international freshwater fish containment methods.
- Towards a National Emergency Response System for Freshwater Fish Incursions. This report outlines the scope of the initial project, its components, outcomes and evolution. Thirty-seven recommendations are provided, including context and explanation of their need and value.
- These two documents have proven to be useful resources during the subsequent development of the draft National Strategy for Management of Freshwater Pest Fish, which is currently being prepared by the Vertebrate Pests Committee – Freshwater Fish Working Group.

Project team

Pam Clunie, Renae Ayres, Dr John Koehn, Dr Tarmo Raadik.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Victorian Department of Sustainability and Environment.

Further information

Ayres, R and Clunie, P (2010) Management of Freshwater Fish Incursions – A Review. PestSmart Toolkit Publication. Invasive Animals Cooperative Research Centre, Canberra.

Ayres, R and Clunie, P (2010) Towards a National Emergency Response System for Freshwater Fish Incursions. PestSmart Toolkit Publication. Invasive Animals Cooperative Research Centre, Canberra.

www.invasiveanimals.com

Decision support tool for pest fish incursions

Project Leader: Steven Saddlier, Arthur Rylah institute - Victorian Department of Sustainability and Environment

Aim: To develop a decision support tool for the management of freshwater fish incursions. Project 9.F.2

Project duration	July 2006 – November 2011
Status	Completed

Project summary

This project addressed one of the recommendations within the Invasive Animals CRC project 9.F.1, to 'Develop a Decision-Support Tool for the Management of Freshwater Fish Incursions'. A review of previous approaches in managing freshwater fish incursions in Australia indicated many are ad hoc, unclear in their purpose and approach, lack comprehensive documentation, monitoring and follow up (Ayres and Clunie 2010). Staff also vary in their knowledge of invaders and appropriate management options. There is a need to clearly document the range of complex issues which should be considered to best manage fish incursions, and facilitate staff having access to relevant, targeted information.

This project is developing a web-based decision-support tool to assist staff in making rapid, effective management decisions once an incursion has been confirmed. The user answers a series of questions (with drop down boxes) and follows steps to ensure all appropriate issues are considered in a logical sequence. This process guides managers through the options and feasibility of eradication, containment and control techniques.

Key achievements

- Draft decision-support tool developed.
- A report that reviews relevant existing international and national invasive species websites and decision-support tools.
- A user's manual for the web-based decision-support tool.
- A web-based decision-support tool that includes information (or direction to existing information/sources) on:
  - species' characterisation (biology, ecology etc)–particularly aspects to be considered in assessment of control options
  - infestation characterisation (what, how many, when, who etc)
  - environmental characterisation (open/closed system, water quality, flow, tenure, social/economic/environmental values, priorities etc)
  - likely impacts (incorporating risk assessment approaches)
  - response management toolbox (pros, cons including guidance on costing considerations, practicalities, methodologies etc).
  - procedural considerations (stakeholders, legislation etc)
  - links to additional information, resources and contacts

Project team

Pam Clunie, Renae Ayres, Silvana Acevedo, Tarmo Raadik.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Victorian Department of Sustainability and Environment.

Further information

Decision support tool for the management of freshwater fish incursions
http://www.feral.org.au/dss/

www.invasiveanimals.com

Tilapia control and management

Project Leader: John Russell, Queensland DAFF

Aim: *To collect baseline information on tilapia populations in the wild in Queensland*

Project 4.F.10
Project 4.F.18

Project duration	July 2006 – June 2012
Status	Completed

Project summary

Two species of Tilapia were introduced into Queensland from about the 1970s. Tilapia species have also been introduced into Western Australia catchments and various nearby countries including Papua New Guinea and some Pacific Islands. Tilapia have since spread to many Queensland catchments and are now seriously threatening invasion of the Murray–Darling Basin. This project provides critical biological and population data to inform tilapia control strategies and assess any 'Achilles Heel' which may be exploited for control and management.

Key achievements

- Baseline information was collected on existing tilapia populations *Tilapia mariae* (black mangrove cichlid) and *Oreochromis* cf. *mossambicus* (Mozambique mouth brooder) in Queensland. Field sampling has resulted in the capture of more than 8,500 tilapia, thereby providing critical ecological and life history data on these species to input into the development of control and management strategies.
- CarpSim 2.0 software has been modified to allow for the assessment of the efficacy of various tilapia management scenarios and as an enhanced education and extension tool. The CarpSim model will now simulate, for tilapia, various management interventions including fishing, poisoning, recruitment sabotage, predation (on juveniles and adults) and removal of females through the use of 'daughterless technology'. Simultaneous use of some of these management interventions can also be modelled.
- An integrated control experiment has proved successful in reducing tilapia numbers in a small tropical weir from 2008–2011.
- The assessment of novel control methodologies including the use of predator introduction.
- Movement studies using acoustically-tagged O. cf mossambicus in a small impoundment have been used to define home ranges and habitat preferences.
- A series of tilapia factsheets and case studies published on a PestSmart web page. Other technical and scientific publications are now available (see below).
- Collaboration with researchers from the University of Notre Dame in the US to determine the feasibility of using environmental DNA as an early detection technology for tilapia incursions.

Project Team

John Russell, Paul Thuesen, Fiona Thomson.

Project partners

Invasive Animals CRC, Queensland Department of Agriculture, Fisheries and Forestry and the Victorian Department of Primary Industries.

Further information

Russell, DJ, Thuesen, PA and Thomson, FE (2012) Tilapia in Australia: Development of Management Strategies for the Control and Eradication of Feral Tilapia Populations in Australia. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia.

Russell, DJ, Thuesen, PA and Thomson, FE (2012) Reproductive strategies of two invasive tilapia species *Oreochromis mossambicus* (Peters 1852) and *Tilapia mariae* (Boulenger 1899) in northern Australia, Journal of Fish Biology 80 (6) , pp. 2176-2197

Russell, DJ, Thuesen, PA and Thomson, FE (2012) A review of the biology, ecology, distribution and control of Mozambique tilapia, *Oreochromis mossambicus* (Peters 1852) (Pisces: Cichlidae) with particular emphasis on invasive Australian populations. Reviews in *Fish Biology and Fisheries* pp. 1-22.

Thuesen, PA, Russell, DJ, Thomson, FE, Pearce, MG and Vallance, TD (2011) An evaluation of electrofishing as a control measure for an invasive tilapia (*Oreochromis mossambicus*) population in northern Australia. *Marine and Freshwater Research* 62:110–118.

Bradford, M, Kroon, FJ and Russell, DJ (2011) The biology and management of Tilapia mariae (Pisces:Cichlidae) as a native and invasive species: a review. *Marine and Freshwater Research* 62(8):902–917.

Kroon, F, Russell, J, Thuesen, P, Lawson, T and Hogan, A (2011) Using Environmental Variables to Predict Distribution and Abundance of Invasive Fish in the Wet Tropics. CSIRO/MTRSF 2.6.2 Final Report, Atherton, Queensland, Australia.

See also various fact sheets and case studies at http://www.feral.org.au/pestsmart/tilapia/

Dead tilapia in Port Douglas pond after eradication effort (Image courtesy of Queensland Department of Agriculture, Fisheries and Forestry)

Development of a surveillance method for feral tilapia using environmental DNA

Project 4.F.19
(with new e-DNA research project with new extension Invasive Animals CRC

Project Leader: Prof David Lodge (University of Notre Dame)

Aim: *To develop a rapid field detection process for tilapia*

Project duration	August 2011 – June 2012
Status	Completed

Project summary

Environmental DNA (eDNA) surveillance methods have potential to provide a reliable tool that could enable rapid surveys to be undertaken over large spatial scales with high levels of sensitivity and low detection errors. It is a technique ideally suited for sampling farm ponds and wetlands and for identifying the first incursions into new watersheds. The project team demonstrated that eDNA monitoring could more reliably detect the presence of low densities of Asian carp species (*Hypopthalmichthys nobilis and H. molitrix*) in a Chicago waterway than traditional boat-based electrofishing or static gill and trammel nets.

This project focused on both *Oreochromis* cf. *mossambicus* and *Tilapia mariae*. A team from the University of Notre Dame visited Australia in late 2011 and, in cooperation with researchers from the Queensland Department of Agriculture, Fisheries and Forestry, collected water samples that were, after initial processing, analysed at the University of Notre Dame.

This project tested the following hypotheses:

- The presence of tilapia can be reliably and rapidly detected from water samples that contain tilapia environmental DNA.
- eDNA provides a cost-effective surveillance method that allows more regular and comprehensive monitoring to be undertaken at greater spatial scales than traditional sampling tools (eg electrofishing and nets).
- Feral populations of tilapia in north-eastern Queensland comprise two species that can reliably detected and differentiated using species-specific molecular markers.
- eDNA provides a rapid, accurate method to determine success or failure of eradication attempts by enabling detection of any surviving individuals before eradication objectives are compromised.

Key achievements

- Species-specific eDNA markers for targeted amplification of two or more tilapia species that are invasive in north-eastern Australia developed.
- DNA accumulation and degradation rates quantified through a series of tank trials.
- High-priority drainages at the invasion front of *O. mossambicus* and *T. mariae* surveyed.
- The cost effectiveness and efficacy of eDNA surveillance evaluated compared to current tilapia detection methods.
- A technology transfer workshop was conducted by Lindsay Chaddderton of the US Nature Conservancy to inform for Australian scientists and managers of the project results.

Project team

Prof David Lodge, Andy Deines, Andrew Mahon, Christopher Jerde and Lindsay Chadderton in the USA. John Russell, Andrew Norris and Dr Michael Hutchison in Australia.

Project partners

Invasive Animals CRC, University of Notre Dame, Queensland Department of Agriculture, Fisheries and Forestry.

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Engaging communities of the Murray-Darling Basin

Project Leader: Adrian Wells, Murray-Darling Association

Aim: *To engage communities of the Murray-Darling Basin on the Freshwater Products and Strategies Program*

Project 10.F.1

Project duration	July 2006 – June 2008
Status	Completed

Project summary

Levels of understanding of any control technology will be needed to gain acceptance from the broader community. Often without adequate consultation and engagement, the public feels despondent and are likely to reject or disapprove of the Invasive Animals CRC's efforts and thereby jeopardise the rollout of the control strategies. This project built on and expanded and enhanced the community engagement process of the PAC CRC's Daughterless Carp project. This Invasive Animals CRC program had a broadened agenda, and engaged Murray-Darling Basin communities and the broader Australian community on the Invasive Animals CRC's Freshwater Program.

This project consisted of an extensive program of visits, presentations and meetings to provide information on invasive species in general and the Invasive Animals CRC Freshwater Program in particular. It had a grass roots focus across the basin with audiences including schools and local community groups.

Staff help out at a carp competition weigh-in

Key achievements

- An extensive program of visits, presentations and meetings.
- Release of the updated educational brochure 'Aliens in the Basin'.

Project partners

Invasive Animals CRC, Murray-Darling Basin Authority, Murray-Darling Association.

Further information

Wells, A (2007) The National Carp Task and Pest Fish Task Force – 10 years on. Proceedings of the Murray Darling Association National Conference – Sept 2007 Bourke, NSW.

Wells, A (2007) Community understanding and attitudes to alien fish. pp 69-72 in Ansell D and Jackson P (2007) Emerging Issues in Alien Fish Management in the Murray-Darling Basin: Statement, Recommendations and Supporting Papers of a Workshop held in Brisbane, May 2006. Murray-Darling Basin Commission 74pp.

Murray-Darling Association (2009) 'Aliens in the Basin' brochure.

www.invasiveanimals.com

Goal 5: Cane toad control measures

TARGET: Deliver innovative, practical control measures against cane toads

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
5.1	Bait and other lethal control technologies reviewed and where possible tested and registered for local control of cane toads	2007	5.T.1, 5.T.2, 5.T.3, 5.T.5e, 5.T.6e PhD (daughterless), PhD (*Rhabdias*)

* As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- Cane toad ecology and control (5.T.1 – Completed)
    - PhD: Host-parasite interactions during a biological invasion: the potential of a lungworm *Rhabdias* as a biocontrol against cane toads (Crystal Kelehear)
- Cane toad toxic venom and pheromones (5.T.2 – Completed)

Strategic control

- PhD: Biology of sex determination and sexual development in the cane toad (*Bufo marinus*) (John Abramyan)

Knowledge and tools

- Cane toad impact assessment and national action plan (5.T.5e – Completed)
- COPs and SOPs for the humane control of cane toads (5.T.6e – Completed)

Cane toad ecology and control

Project Leader: Prof Rick Shine, University of Sydney

Project 5.T.1
PhD (Rhabdias)

Aim: *To develop a detailed and quantitative picture of the impact of parasite infestation on the biology of feral cane toads*

Project duration	July 2005 – February 2008
Status	Completed

Project summary

The spread of feral cane toads through tropical Australia has created major ecological problems, notably by increasing mortality rates of native predators. Thus, we need to find ways to reduce toad densities. Pathogens may play a significant role in affecting toad populations, but the ways in which the pathogens of Australian amphibians affect the behaviour and ecology of toads remains poorly understood. This project experimentally manipulated parasite (helminth) infestations and examined resultant effects on toad behaviour.

The project developed a detailed and quantitative picture of the impact of parasite infestation on the biology of feral cane toads. More specifically, the project determined whether infestation by helminths changes a toad's body condition, activity levels, feeding behaviour and locomotor performance. This was done by experimentation, to ensure a direct test of causality (because correlations between pathogen levels and toad fitness could arise in many ways, mostly indirect): that is, we will see whether or not experimentally-induced elevations in parasite (lungworm) infestation affect significant behavioural and ecological traits of cane toads. Information on these topics is directly relevant to hypotheses that pathogens can influence the viability of individual toads, as well as the rate of migration of toads into previously unoccupied areas.

Key achievements

- The parasites have been shown to strongly affect the survival, growth and speed of small toads, but had no measurable effect on adult toads.
- Several manuscripts describing the identity, pathogenecity, geographic variation and effects of lung parasites.
- PhD conferred to Crystal Kelehear.

Project team

Prof Rick Shine, Jonathan Webb, John Llewelyn, Dr Crystal Kelehear.

Project partners

Invasive Animals CRC, University of Sydney, James Cook University.

Further information

Kelehear, C (2012) PhD thesis 'Host-parasite interactions during a biological invasion: the potential of a lungworm Rhabdias as a biocontrol against cane toads'.

Graham, SP, Kelehear, C, Brown, GP and Shine, R (2012) Corticosterone-immune interactions during captive stress in invading Australian cane toads (*Rhinella marina*) *Hormones and Behaviour* doi: 10.1016/j.yhbeh.2012.06.001

Pizzatto, L, Kelehear, C, Dubey, S, Barton, D, and Shine, R (In Press) Host-parasite relationships during a biological invasion: 75 years post-invasion, cane toads and sympatric Australian frogs retain separate lungworm. *Journal of Wildlife Diseases*.

Brown, GP, Kelehear, C and Shine, R (In Press) The early toad gets the ant: cane toads at an invasion front benefit from higher prey availability. *Ecology*.

Kelehear, C, Brown, GP and Shine, R (In Press) Invasive parasites in multiple invasive hosts: the arrival of a new host revives a stalled prior parasite invasion. *Biological Invasions*.

Kelehear, C, Brown, GP and Shine, R (2012) Size and sex matter: infection dynamics of an invading parasite (*Raillietiella frenatus*) in an invading host (*Rhinella marina*). *Parasitology* 139: doi: 10.1017/S0031182012000832

Kelehear, C, Cabrera-Guzmán, E and Shine, R (2012) Inadvertent consequences of community-based efforts to control invasive species. *Conservation Letters*. doi: 10.1111/j.1755-263X.2012.00251.x

Kelehear, C, Brown, GP and Shine, R (2012) Rapid evolution of parasite life history traits on an expanding range edge. *Ecology Letters* 15: 329-337.

Shine R (2011) The Ecological Impact of Invasive Cane Toads (*Bufo Marinus*) in Australia. *The Quarterly Review of Biology*, vol. 85 (3) pp. 253-291

Kelehear, C, Spratt, DM, Dubey, S, Brown, GP and Shine, R (2011) Using combined morphological, allometric and molecular approaches to identify species of the genus *Raillietiella* (Pentastomida). *PLoS ONE* 6: e24936

Brown, GP, Kelehear, C and Shine, R (2011) Effects of seasonal aridity on the ecology and behaviour of invasive cane toads (*Rhinella marina*) in the Australian wet-dry tropics. *Functional Ecology* 25: 1339-1347

Kelehar C and Jones HI (2011) Nematode larvae (*Order Spiurida*) in gastric tissues of Australian anurans: a comparison between the introduced cane toad and sympatric native frogs. *Journal of Wildlife Diseases* (in press)

www.invasiveanimals.com

Cane toad toxic venom and pheromones

Project Leader: Prof Rob Capon, University of Queensland

Aim: To develop strategic knowledge on cane toad chemicals and ecology

Project 5.T.2

Project duration	July 2005 – July 2008
Status	Completed

Project summary

This project aimed to approach the control of cane toads by exploring and understanding the chemical composition and ecology of cane toads and to use this knowledge to develop strategies capable of enhancing the success of baiting and trapping programs.

Despite many prior studies, the chemical composition of cane toad toxin has not benefited from modern chemical analysis. Comprehensive chemical analysis is revealing classes of toxic molecules with potent and selective biological mechanisms of action.

This study aimed to assess the full suite of toxic chemical constituents (small molecules, peptides, proteins, volatiles, involatiles etc), as well as their natural occurrence against a range of variables including, sex (male versus female); fertility cycle; life cycle (tadpole - juvenile - mature); healthy versus stressed; season, ecosystem and geography.

Knowledge of the molecular structure and distribution of venom constituents, along with their mode of action, will reveal a selection of potential biological targets able to support the development of toad specific poisons.

Key achievements

- Alarm Pheromones: The only reproducible pheromone behavioural response that has been reported for the cane toad is the tadpole alarm pheromone. Preliminary investigations suggest that the alarm pheromone can be isolated and identified and assessed as a potential cane toad control strategy.
- Bufadienolides: Cardiotoxic steroids, bufadienolides are common to many species of plant and animal and are closely related to the cardenolides, with both compound classes displaying a common inhibition of the Na/K ATPase. Studies confirmed that the distribution of bufadienolides across the glands, organs and tissues of the Australian cane toad is quantitatively and qualitatively different from those reported in overseas cane toads.
- It was also demonstrated that the bufadienolide content varies significantly across life-stages, an observation that has particular significance with respect to toxicity. Investigations also revealed the Australian cane toad parotoid secretion contains not 4 but >100 bufadienolides, the majority of which remain unidentified.
- Alkaloids: Cane toad alkaloids are fast acting hallucinogens that target the central nervous system (CNS) and are very likely the true defensive chemicals deployed by adult cane toads, capable of confusing and distracting predators. Long overlooked by their more readily analysable bufadienolide cousins, the qualitative and quantitative distribution of cane toad alkaloids has received only cursory attention in the scientific literature, with no serious published analysis of their occurrence in Australian cane toads. Cane toad alkaloids are a critical element in the defensive strategy and play a pivotal role in the interactions between cane toads and Australian predators.

Project team

Rob Capon, Paul Alewood, Gordon Grigg, Richard Lewis, Andrew Hayes, Alexis Barrett (University of Queensland).

Project partners

IA CRC, University of Queensland.

Further information

Hagman, M, Hayes, RA, Capon, RJ and Shine, R (2008) Alarm cues experienced by cane toad tadpoles affect post-metamorphic morphology and chemical defences. *Functional Ecology* 23: 126-132.

Hayes, RA, Barrett, A, Alewood, PF, Grigg GC and Capon, RJ (2008). *Chemical Signals in Vertebrates* 11, Use of chemical ecology for control of the cane toad? Springer: 2008.

www.invasiveanimals.com

Daughterless cane toads

Project Leader: Prof Peter Koopman, University of Queensland

Aim: To provide a scientific basis for efforts to make a daughterless toad

Project 5.T.3
PhD (daughterless cane toads)

Project duration	July 2005 – July 2008
Status	Completed

Project summary

Daughterless strategies are designed to limit the number of females and dramatically halt the growth and further spread of the cane toad population and reduce the threat they pose. The strategy is non-toxic and poses no risk beyond the target species — the ideal biological control system. The project aimed to carry out the basic biological studies required to underpin successful transfer of this technology to cane toads.

Daughterless Toads is an innovative strategy based on manipulation of sex ratios. The explosion in cane toad numbers is essentially determined by the availability of females, each of which lays up to 35,000 eggs in a single clutch. Strategies designed to limit the number of females will dramatically halt the growth and further spread of the cane toad population and reduce the threat they pose.

The project aimed to:

- determine the basic embryology, molecular genetics and endocrinology of gonadal development in the cane toad and identify an effective point of interference with this process
- determine whether cane toads can be hormonally sex reversed and which hormones can be used, how much to use, and when, in order to achieve sex reversal.

Key achievements

- Determined the basic embryology, molecular genetics and endocrinology of gonadal development in the cane toad and identified an effective point of interference with this process.
- Determined that cane toads hormonal sex reversal will not provide a productive avenue for pest control in this species.
- John Abramyan, PhD conferred in July 2010.

Project team

Peter Koopman, John Abramyan.

Project partners

IA CRC, University of Queensland.

Further information

Abramyan, J, Wilhelm, D, Koopman, P (2010) Molecular characterisation of the Bidder's organ in the cane toad (Bufo marinus) *Journal of Experimental Zoology Part B: Molecular and Developmental Evolution* 2010 Sep 15; 314(6):503-13 doi: 10.1002/jez.b.21357.

Abramyan, J, Feng, CW, Koopman, P (2009) Cloning and Expression of Candidate Sexual Development Genes in Cane Toad (*Bufo marinus*) *Developmental Dynamics* 238:2430-2441.

Abramyan, J, Ezaz, T, Graves, JA, Koopman, P (2009) Z and W sex chromosomes in the cane toad (*Bufo marinus*) *Chromosome Research* 17(8):1015-24. doi: 10.1007/s10577-009-9095-1

Koopman P (2006) Daughterless cane toads. In: KL Molloy and WR Henderson (Eds.) Science of Cane Toad Invasion and Control. Invasive Animals Cooperative Research Centre, Canberra.

www.invasiveanimals.com

Cane toad impact assessment and national plan

Project Leader: Prof Rick Shine, University of Sydney

Aim: *To provide draft advice to the Commonwealth Threatened Species Scientific Committee on cane toad research and developments*

Project 5.T.5e

Project duration	April 2009 – July 2011
Status	Completed

Project summary

Research is rapidly advancing our knowledge of the impact of cane toads on Australia's environment and biodiversity. Cane toads continue to expand their range and knowledge of their impact on wildlife is important in order to best conserve at risk species. This project will review all current literature on the impact of toads on the environment (Prof. Rick Shine, the University of Sydney). The review will be published in its own right and be used to inform advice on cane toad management under the Environmental and Biodiversity Conservation Act 1999 (EPBC Act).

In 2005, the then Minister for the Environment determined that cane toads should be considered a 'Key Threatening Process' under the EPBC Act, but that a Threat Abatement Plan would be neither feasible nor efficient. This project drafted advice to the Threatened Species Scientific Committee on research and developments since that time. The Threatened Species Scientific Committee will then use the project information to make advice to the Minister for the Environment.

Key achievements

- Report, 'Review of the Environmental Impact of Cane Toads', completed and submitted for peer-reviewed publication and used as basis for advice to the Commonwealth Threatened Species Scientific Committee.
- Report to the Commonwealth Threatened Species Scientific Committee on the need and feasibility of a Threat Abatement Plan (TAP) for cane toads completed and provided.
- Advice accepted by the Commonwealth Threatened Species Scientific Committee.

Project team

Dr Tony Peacock (previously Invasive Animals CRC), Prof Rick Shine (Uni of Sydney).

Project partners

Invasive Animals CRC, University of Sydney.

Further Information

Sharp, T, Lothian, A, Munn, A and Saunders, G (2012) Methods for the field euthanasia of cane toads (Standard Operating Procedure Guideline). Australian Government Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) website.

Threat Abatement Plan for the biological effects, including lethal toxic ingestion, caused by cane toads.
http://www.environment.gov.au/biodiversity/threatened/publications/tap/pubs/tap-cane-toads.pdf

www.invasiveanimals.com

Humane control of cane toads

Project Leader: Dr Trudy Sharp, NSW Department of Primary Industries

Aim: *To develop Codes of Practice and Standard Operating Procedures for the humane control of cane toads*

Project 5.T.6e

Project duration	March 2009 – September 2011
Status	Completed

Project summary

Tens of thousands of cane toads are captured each year (mostly by volunteers) and subsequently killed using a variety of methods. These include cooling and freezing; gassing with carbon dioxide; exposure to Dettol solution and stunning. However the animal welfare impact of many of the techniques is unknown, doubtful or disputed. There is a pressing need to assess the humaneness of toad euthanasia methods and to promote the use of those that are humane, safe and effective.

Information generated from this research will be used to:

- assess the relative humaneness of techniques using a nationally accepted model
- develop and publish standard operating procedures for humane euthanasia techniques that can be used in the field by community groups, researchers and other individuals
- determine suitable practical criteria for determining death in toads.

Key achievements

- A draft standard operating procedure (SOP) for the field euthanasia of cane toads, funded under the Australian Government's Caring for our Country program was developed. This document contains background information, applications, animal welfare considerations for both target and non-target animals as well as health and safety considerations. The SOP provides detailed guidelines on how to perform acceptable euthanasia techniques and also discusses why some methods are not acceptable. Note that a code of practice (COP) was not considered necessary since control strategies and methods have not been established for this species. Other relevant background information normally included in a COP was therefore included in the SOP.
- The SOP contains current best practice for the euthanasia (or humane killing) of cane toads. The recommendations are based on information in the literature as well as behavioural observations and time to death recorded in a project to examine the welfare impact on cane toads of a range of euthanasia techniques. The research was conducted at the School of Biological Sciences, University of Wollongong (UOW): 'Evaluating the humaneness of known-to-be-lethal euthanasia techniques for cane toads that are used by community groups' (Munn and Lothian, 2010, unpublished). As new information becomes available the appropriateness of euthanasia methods for cane toads will be reviewed.
- Criteria for determining death can be more challenging with amphibians compared to other animals. Heart rate can be difficult to detect and respiration can occur through the skin as well as the lungs
- It was determined that a number of criteria must be met before confirming that a toad is dead. These are:
    - loss of righting reflex – the toad will not right itself onto its ventral surface when turned onto its back
    - loss of withdrawal reflex–there will be no response to a light squeeze to the skin in-between the digits
    - loss of deep pain reflex – there will be no response to moderate pressure applied to a digit bone
    - absence of respiratory movement–cessation of the throat movements that indicate breathing
    - absence of heart contractions – cessation of heart beat as determined by observing the chest for a visual cardiac impulse beneath the skin and/or by palpation of the chest and/or by listening with a stethoscope.
- The SOP was circulated to the Cane Toad Advisory Group (CTAG) members, RSPCA Australia and NSW Animal Welfare Advisory Council (AWAC) for comment. The comments were collated and changes made to the SOP where necessary. The SOP, 'Methods for euthanasia of cane toads', was finalised and endorsed by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (SEWPAC). The SOP was published on the SEWPAC website in January 2012.

Project team

Dr Trudy Sharp, Dr Glen Saunders (NSW DPI), Dr Adam Munn.

Project partners

Invasive Animals CRC, NSW Department of Primary Industries, Department of Sustainability, Environment, Water, Population and Communities and University of Wollongong.

Further information

Sharp, T & Saunders, G (2008). A model for assessing the relative humaneness of pest animal control methods (Second edition). Canberra, ACT: Department of Agriculture Fisheries and Forestry. Available at: http://www.daff.gov.au/animal-plant-health/welfare/aaws/humaneness_of_pest_animal_control_methods

Sharp, T and Saunders, G (2005) Humane pest animal control: codes of practice and standard operating procedures. Orange: NSW Department of Primary Industries. Available at: http://www.dpi.nsw.gov.au/agriculture/pests-weeds/vertebrate-pests/codes/humane-pest-animal-control

Publication of the standard operating procedure on the SEWPAC website: http://www.environment.gov.au/biodiversity/invasive/publications/pubs/can001-euthanasia-cane-toads.pdf

The SOP can be accessed from the following pages: http://www.environment.gov.au/biodiversity/invasive/ferals/cane-toads/index.html http://www.environment.gov.au/biodiversity/invasive/publications/humane-control.html#canetoads

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Goal 6: Reducing feral cat impacts

TARGET: Reduced impact of feral cats over five million hectares

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
6.1	New knowledge on feral cat ecology and ecological interactions of control methods	2011	6.U.1, 10.U.1, 10.U.2, 10.U.4, PhD (Gippsland feral cats) PhD (predation and resource availability)
6.2	Tools and strategies for reducing the impact of feral cats	2012	6.U.1, 10.U.1, 10.U.2, 10.U.4, PhD (Gippsland feral cats) PhD (predation and resource availability)
6.3	Humane and species tailored (PAPP) Curiosity® feral cat baits	2011	6.U.1, 10.U.1, 10.U.2, 10.U.4
6.4	Education and management package	2012	11.U.3

* As per contract variation approved by DIISRTE

Projects

Tactical control

- Feral cat bait uptake in eastern Australia (6.U.1 – Completed)

Demonstration Site

- Demonstration Site: Introduced predator control and fauna recovery, WA (10.U.1 – Completed)
    - PhD: Effects of predation and resource availability on western brushtail possum populations (Jennyfer Cruz-Bernal)

Relevant projects included under other goals

Demonstration Site

- Demonstration Site: Southern Ark: benefitting the biodiversity of East Gippsland through fox control, Victoria (10.U.4 see goal 1 – Completed)
    - PhD: The ecology of feral cats in forested habitats and their response to broad scale fox control measures in East Gippsland (10.U.4 Tony Buckmaster)
- Demonstration Site: Management program for deer, pigs, goats and cats on Kangaroo Island, SA (10.U.2, Completed) (see goal 2 – Completed)

Knowledge and tools

- Development of a national pest animal genotyping facility (9.D.2 – Completed)

Feral cat bait uptake in eastern Australia

Project Leader: Dr Elizabeth Denny, University of Sydney

Aim: *To provide basic field data essential for the registration of Curiosity® PAPP feral cat bait and the future implementation of broad-scale baiting of feral cats on the Australian mainland*

Project 6.U.1

Project duration	August 2007 – March 2009
Status	Completed

Project summary

The control of feral cats in the eastern states of Australia has been limited to reserved areas bounded by predator-proof exclusion fencing. Although the toxin 1080 (sodium monofluoroacetate) has been used for some decades for the control of foxes and wild dogs over broad areas, the regulations covering the use of 1080, as well as the diet preferences and feeding behaviour of cats, has mitigated against the use of this toxin for broad-scale cat control throughout eastern Australia. Trapping, shooting and exclusion fencing are the only available cat control methods, all of which are time and labour intensive.

In Western Australia, because of naturally occurring fluoroacetatic acid in native flora and high tolerance of native species to 1080, broad-scale, above ground baiting is used effectively against introduced predators. In eastern Australia, the susceptibility of the native fauna to 1080 is higher, and broad-scale baiting with 1080 generally comprises buried, manufactured or dried meat baits that are less attractive to native species. However, buried baits and dried meat baits are less attractive to cats, and broad-scale baiting for foxes and wild dogs has had little impact on feral cats.

The search for a method of broad-scale baiting of feral cats has led to the development of a chipolata-sized bait that is attractive to cats and has been proven effective in WA rangeland trials. Eradicat® is a 1080 bait that when applied at 50 baits per square kilometre in late summer / early autumn has led to substantial declines in feral cat populations.

Research is ongoing by DEWHA into the development of para-aminopropiophenone (PAPP) for feral cats. A species specific delivery system — the Hard Shell Delivery Vehicle — which is a pea-sized capsule that is apparently ingested by cats but rejected by non-target species has been developed by Scientec for delivery of PAPP in the Eradicat® bait. The new product has been named Curiosity®.

The possibility of broad-scale baiting for feral cats in eastern Australia may be increased through the use of the Curiosity® bait. Consequently non-toxic, broad-scale field trials were conducted in NSW, SA and WA to provide essential data on the specificity of both the baits and the delivery system in NSW open arid habitats and on Kangaroo Island. Such trials are essential for the registration of the product by Invasive Animals CRC partners DEWHA, Victorian DPI and WA DEC.

Key achievements

- Trials of the Curiosity® cat bait have been conducted at the Australian Wildlife Conservancy's Scotia Sanctuary (western NSW) and on Kangaroo Island. Results are currently being prepared for journal publication.
- The report Review of cat ecology and management strategies in Australia by Dr Liz Denny and Prof Chris Dickman was published and launched in February 2011.
- The launch of this report, with the RSPCA, generated a great deal of media, and has caused many follow up articles on the impact of feral cats.

Report authors Liz Denny and Chris Dickman at the launch

Project team

Dr Elizabeth Denny, Prof Chris Dickman (Uni of Sydney), Assoc. Prof Steven Lapidge (Invasive Animals CRC), Pip Masters (KI NRMB), Richard Southgate (Envisage Scientific Services.), Tony Cathcart (Australian Wildlife Conservancy).

Project partners

Invasive Animals CRC, University of Sydney, Australian Wildlife Conservancy, Kangaroo Island Natural Resource Management Board, Department of Sustainability, Environment, Water, Population and Communities, Victorian Department of Sustainability and Environment, Victorian Department of Primary Industries, WA Department of Environment and Conservation.

Further information

Bengsen, AJ, Butler, JA and Masters, P (2012) Applying home-range and landscape-use data to design effective feral-cat control programs. *Wildlife Research* 39: 258-265

Denny, E and Dickman, C (2011) Review of cat ecology and management strategies in Australia, Invasive Animals CRC.

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Fox and feral cat control using spray tunnel technology

Project Leader: Assoc. Prof. Steve Lapidge, Invasive Animals CRC

Aim: *To test an alternative approach to managing foxes and feral cats- automated control using spray tunnel technology through targeting the propensity of both species to orally groom.*

Project 6.U.3e

Project duration	March 2011 – ongoing
Status	Current (under the new extension Invasive Animals CRC)

Project summary

Feral cats and foxes have been implicated in the spread of diseases to sheep and goats that cause foetal abortions and lamb and kid deaths and foxes are a known predator of lambs and goat kids. As such both species are an impediment to small livestock production in Australia, as well as being the two most devastating invasive mammals to wildlife.

This project aims to develop a device that could potential automate fox and feral cat control on-farm or park, and significantly reduce the predation and disease spread impacts of these two invasive species. Spray tunnel technology was initially developed to target feral cats due to their fastidious grooming nature and their inclination not to take baits (Read 2010).

As red foxes exhibit the same inquisitive behaviour and propensity to groom as cats, and they are not dissimilar in size, the same technology could potentially target both species without posing a risk to smaller and shorter marsupials (animals need to be a minimum height to trigger spraying) or larger mammals, working dogs and livestock which will be too tall to enter tunnels.

Furthermore, tunnels offer the possibility of co-managing foxes and feral cats, where fox baiting alone often results in an increase in feral cat numbers and greater potential for disease spread and biodiversity losses.

Currently Connovation Ltd (NZ) and Ecological Horizons (John Read; SA) have been working on a tunnel that delivers a measured spray of PAPP paste to the upper back (Ecological Horizons) or underbelly (Connovation) of a feral cat that enters the tunnel.

The proof-of-concept research conducted thus far indicates that the technique is currently highly specific for cats (currently not tried on foxes though), with target-specificity being further safeguarded by the propensity of cats and foxes to enter tunnels in search of food and shelter, the upper back spray location, the PAPP dose required and the size of the animals (tunnels can exclude 15+kg working dogs).

Such an advance is not meant to replace baiting though, but rather provide a constant and integrated technique to stop fox populations building up between baiting events.

It is noteworthy that this project proposal will see both inventors working collaboratively with the Invasive Animals CRC, as well as Animal Control Technologies Australia (likely Australian distributor), to ensure the best product is delivered.

Key achievements

- Project commenced with a team meeting in February in Melbourne, including a visit to the Victorian DPI Frankston facility where fox and feral cat pen trials will be conducted.
- Contract signed with Meat & Livestock Australia in March 2011.
- Various new designs created.
- Tender for Sensor-triggered Aerosol Activator conducted.
- Undertake pen trials to examine the most appropriate tunnel diameter, length, trigger system, spray mechanism, spray dose, spray location and PAPP gel consistency.
- Conduct lethal pen trials with cats and foxes once unit has been optimised.
- Undertake non-toxic efficacy and target-specificity field trials on Kangaroo Island, South Australian rangelands and NSW tablelands. Determine the best primary (sights, sounds and smells to draw foxes and cats to area) and secondary (to initiate tunnel investigation) lures for foxes and feral cats.
- Undertake toxic field trials if time and finances allow.
- Prepare business case for the registration, manufacture and commercialisation of spray tunnels should results and market potential research prove promising.

Project team

Assoc. Prof Steve Lapidge, Dr John Read, Duncan MacMorran, Steve Hix, Frank Gigliotti, Ebony Arms.

Project partners

Invasive Animals CRC, Ecological Horizons, Connovation Ltd (New Zealand), Meat & Livestock Australia, Kangaroo Island NRM Board, Desert Recovery (Roxby Downs), Animal Control Technologies (Australia) P/L.

Further information

Read, J, Taylor, C and Bengsen, A (2011) Pest management while you're sleeping: Initial trials of an automatic poison delivery device. Poster at Australasian Vertebrate Pest Management Conference, Sydney.

Read, J (2010) Can fastidiousness kill the cat? The potential for target-specific poisoning of feral cats through oral grooming. *Ecological Management & Restoration* 11: 230-233.

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Demonstration Site: introduced predator control and fauna recovery, WA

Leader: Dr Paul de Tores, WA Department of Environment and Conservation

Aim: *To investigate the relationships between introduced predators (mainly fox and cat), their control and sustained fauna recovery in South-Western Australia – is there a mesopredator release effect?*

Project 10.U.1
PhD (predation and resource availability)

Project duration	January 2006 – December 2011
Status	Completed

Project summary

In Western Australia there have been considerable conservation gains from effective control of foxes. By 2001, this led to delisting three marsupial species from the threatened species list. However, despite ongoing fox control, fauna recovery in WA has not been sustained, possibly due to mesopredator release of cats, varanids, chuditch and/or pythons. The project — Ecological interactions of pest animals in regional Western Australia — assesses the conservation implications of predator interactions and examines whether introduced predator species are 'turned over' or show any evidence of bait shyness and/or bait avoidance. To achieve this, the project will determine the effectiveness of existing fox baiting programs.

The primary project aimed to:

- determine if cats show a mesopredator release response when fox density is reduced through baiting with the 1080 bait — Probait
- assess the biodiversity conservation implications of such a response if it occurs,
- develop tools and techniques for integrated control of the fox and feral cat,
- determine and demonstrate the effectiveness of Probait for fox control and assess the value of Eradicat® and Curiosity® cat baits (either separately or with Probait) for cat control,
- achieve one, two and three above at a local and landscape scale.

The project was undertaken in four biogeographical regions and focused on sites at:

- the landscape scale at Mt Gibson (AWC property), Karara and Lochada (former pastoral estate now managed by DEC) within the WA rangelands
- the landscape scale within the northern jarrah forest, south-west WA
- a local scale at Dryandra Woodland and Tutanning Nature Reserve within the central WA wheatbelt
- a local scale at Lake Magenta and Dunn Rock nature reserves within the southern WA wheatbelt

Findings from the project will provide managers of conservation estate (in WA and elsewhere), and managers of privately owned estate managed for conservation purposes, with a better understanding of the implications of controlling, or not controlling, one or more predators and the importance and value of integrated control. The project will lead to a refinement of 'best practice' introduced predator management, and to an improved level of understanding of predator interactions. This will result in better 'on-ground' management of introduced predators. Refinements in the use of the cat bait Eradicat® and Probaits will result in decreased environmental impacts of foxes and feral cats. Trials are also assessing the non-target issues associated with use of the new Curiosity® cat bait. The field effectiveness of feral cat baits will be quantified and end-user training packages will be provided.

Associated with this project, PhD student Jennyfer Cruz-Bernal is assessing the demographic and behavioural effects of food and predation on koomal populations in the northern jarrah forest and to provide information on koomal's diet and home range dynamics.

Key achievements

- Demonstrated foxes and cats can be identified and genotyped (to individual) from DNA recovered from hair collected from both species through a single hair collection device.
- Demonstrated how this technique can be used to quantify sandplot data and derive estimates of abundance for both species.
- Demonstrated mesopredator release of cats in the presence of repeated use of baits for fox control.
- Demonstrated (through the use of the molecular techniques) that it is possible to identify the predator species and the individual predator responsible for predation events.
- Demonstrated, through the above, cats are a major predator of the woylie at an iconic conservation site which is baited for fox control.
- 'Best Practice' introduced predator management refined.
- Additional papers submitted/published and Jennyfer Cruz Bernal PhD conferred.

Project team

Dr Paul de Tores, Dr Dave Algar, Dr Nicky Marlow and Keith Morris (DEC), Dr Oliver Berry (ex University of WA now CSIRO), Dr Al Glen, Dr Duncan Sutherland, Robert Hill, Sean Garretson, (Invasive Animals CRC / DEC), John Angus, Neil Thomas, Andy Williams, Brian Macmahon, Brent Johnson, Bill Muir, Mike Onus, Neil Hamilton (DEC), Stephanie Hilmer (DEC), Dr Jennyfer Cruz-Bernal, Gillian Bryant, (PhD candidate, Murdoch).

Project partners

Invasive Animals CRC, WA Department of Environment and Conservation, Australian Wildlife Conservancy, University of WA, Murdoch University, Alcoa World Alumina Australia, Worsley Alumina.

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Responsible Cat Ownership

Project Leader: Margaret Kitchin and Sharon Lane, ACT Environment & Sustainable Development Directorate

Aim: *To understand community attitudes to fauna conservation, control of feral and stray cats, and containment of domestic cats, to smoothly implement conservation policies*

Project 10.T.10

Project duration	August 2010 – August 2011
Status	Completed

Project summary

In 2009 the ACT Government completed the construction of a cat, dog and fox proof fence around most of Mulligans Flat Nature Reserve to provide a sanctuary for native animals. The reserve contains approximately 400ha of critically endangered Yellow Box-Red Gum Grassy Woodland and a range of threatened species, mostly woodland birds. The sanctuary aims to provide a haven for wildlife, to restore woodland to its former pre-European condition, be an outdoor laboratory for researching woodland restoration and provide an avenue for raising community awareness and involvement in woodland conservation. The woodland-urban interface and the community's understanding of people's role in woodland conservation is a central element of the success of woodland restoration. This project on responsible cat ownership is an extension of the sanctuary project and one area where people could make a considerable contribution to bushland conservation generally.

It is necessary to understand the attitude of people to fauna conservation, control of feral and stray cats, and containment of domestic cats, in order to smoothly implement conservation policies related to cats, such as lethal control of feral or stray cats, trapping, micro-chipping, and cat containment.

The extension project achieved the following objectives:

- establish facts about husbandry practices in terms of domestic cats and gauge likely community response to expansion of cat containment in the ACT
- use survey data to inform scientific reports, inform policy development and implementation decisions around domestic cat ownership, fauna conservation, control of feral and stray cats,

  containment of cats, responsible management of cats and the identification and registration of pet cats
- produce a repeatable survey to monitor changing attitudes
- collate survey analysis for application to other jurisdictions.

A central element of this project involved a representative and statistically significant, random telephone survey of ACT residents to gain an understanding of community attitudes to a range of policies and management strategies for domestic and stray cats, and more specifically on cat containment.

The outcomes of this research will inform the development of future policy making and cat management approaches within the ACT and will also provide information relevant to other jurisdictions considering a range of cat management policies. In addition to the survey, the ANU (PhD student) is undertaking further research and analysis to produce a research paper that explores the human dimensions associated with cat management and wildlife conservation.

Key achievements

- PhD student Kathy Eyles engaged through ANU:
  - literature review for journal paper
  - community attitudes to managing cats and regulations
  - domestic cat predation and home range studies
  - evaluation/reviews of cat regulations
  - approaches to cat regulations including education and incentives
  - informants identified for qualitative research component
  - fieldwork commenced with piloting of questions for semi-structured interviews with cat owners, reserve managers and community groups.
- Survey developed, Micromex Research Pty Ltd engaged and survey conducted.
- 1,277 households successfully surveyed with 506 households representing cat owners. An additional 192 households from Forde and Bonner were also interviewed (current cat containment suburbs).
- Final report 'Responsible Cat Ownership' approved by steering committee.
- ACT Minister Corbell briefed of findings, report publicly released in conjunction with media release announcing the extension of cat containment areas and suburbs in Canberra.
- Cat containment extended by ACT Government to include five more suburban areas.
- Survey results provided to several state and local government organisations interested in extending cat containment:
  - Albury City Council
  - NSW Nature Conservation Trust
  - NSW Dept of Environment and Heritage
  - Bush on the Boundary Group (Gungahlin and Molonglo)
  - ACT Conservation Council
  - Molonglo and Ginninderra Catchment Groups (ACT)
- Article in NRM Notes newsletter September 2011, discussing survey findings.
- Presentation to the ACT NRM Advisory Committee.
- ANU discussion report submitted (expected end May 2012)

Project team

Sharon Lane, Kathy Eyles, Chris Lane, Jade Norris, Michael Linke, Simon Tadd, Michael Mulvaney, Don Fletcher, Rob Thorman, Felicity Grant (project manager) and Margaret Kitchin.

Project partners

Invasive Animals CRC, ACT Government: Conservation Planning and Research, Parks and Conservation Service, Environment and Sustainable Development Directorate (ESDD), Land Development Agency (LDA) and Economic Development Directorate (EDD), RSPCA Australia and ACT RSPCA.

Further information

Responsible cat ownership community research report:
www.environment.act.gov.au

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Goal 7: Integrated rabbit control

TARGET: Improved integration of existing biological, conventional and newly-developed control options for rabbits.

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
7.1	Biodiversity impacts of rabbits determined	2008	7.T.6, 7.T.7
7.2	The mechanisms behind the lack of effectiveness of RHD in higher rainfall areas understood	2011	7.T.3, 7.T.5, PhD (genetic resistance)
7.3	RHDV disease suspension product made available to end-users	2012	7.T.5
7.4	Knowledge on the potential of new RHDV strains to boost biocontrol of wild rabbits in Australia	2012	7.T.1, 7.T.9, 7.T.12 PhD (RHDV transmission)
7.5	Freeze-dried RHD bait-delivered product made available to end users	2011	7.T.5, 7.T.2
7.6	Rabbit warren pressure carbon monoxide fumigator	2011	10.U.14
7.7	Optimal strategy for bait-delivered RHDV	2011	7.T.1
7.8	Optimal strategies for conventional rabbit control	2012	7.T.4, 7.T.4a, 7.T.4b, 9.D.11
7.9	Strategies for optimal use of RHDV and conventional controls	2012	7.T.1, 7.T.4, .4a, .4b, 7.T.8e

* As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- Rabbit Impacts: Biodiversity and economic impacts of rabbits (7.T.6, 7.T.7– Completed)

Strategic control

- Review of RHDV (7.T.3 – Completed)
- RHDV genetic resistance (7.T.5 – Completed)
    - PhD: Development of genetic resistance to Rabbit haemorrhagic disease in wild rabbits *Oryctolagus cuniculus* (Peter Elsworth)
- Enhancing RHD effectiveness: Field study on the prevalence of different rabbit caliciviruses in south-east Australia (7.T.1, 7.T.9 – Completed)
    - PhD: Transmission and effectiveness of RHDV infections in rabbit populations at different spatial scales (Maija Marsh)
- RHD-Boost (7.T.12e – Current)

Tactical control

- Shelf-stable RHDV product (7.T.2 – Current)
- Carbon monoxide pressure fumigator (10.U.14 – Current)

Strategic control

- Improving efficiency of rabbit eradications on islands (9.D.11 – Completed)

Education and training

- Rabbit project manager (7.T.4, 7.T.4a, 7.T.4b, 7.T.8e – Completed)

Relevant projects included under other goals

Knowledge and tools

- Economic impact of feral animals (12.D.6 – Completed)
- Validating and refining risk assessment models (9.D.1 – Completed)
- Mapping invasive animals in Australia (includes rabbits) (12.D.1 – Completed)

Rabbit impact assessment

Project Leader: Dr Brian Cooke, Invasive Animals CRC

Aim: *To assess the impact of rabbits on biodiversity in pastoral lands and farmlands, including on road reserves, stock routes and public amenities*

Projects 7.T.6, 7.T.7

Project duration	November 2006 – June 2008
Status	Completed

Project summary

This project examined the impacts of rabbits on biodiversity. It looked beyond the impacts of rabbits on land that is used for wool and meat production and considered areas adjacent to farms such as roadside vegetation, water reserves and recreational areas of value to the broader community. It evaluated the likely long-term loss of trees and shrubs, damage to pasture and weed invasion and competition with native fauna. Results provided insights into the ways in which rabbits cause losses, including over-grazing pasture, digging or scratching, or selective grazing in summer.

The project provided a detailed review of the nature and severity of biodiversity losses and was instrumental in developing a simple method of scoring rabbit abundance for use by people contributing to pest management.

The project included:

- A literature review that documented the nature of rabbit impacts on biodiversity across a wide range of habitats in south-eastern Australia in different seasons.
- A survey of more than 200 field sites to assess rabbit presence and impact.
- These site surveys also provided a framework for developing a rapid method for estimating rabbit abundance that could be readily used by people who have no specific training or experience in rabbit management.
- The assessment tool was tested on nine sites with a range of rabbit infestations and levels of damage. At least four people from a range of background tested the tool on each site and despite different levels of experience with assessing rabbit problems, all participants arrived at similar conclusions.

Alongside this work, the project manager is providing input to another project to measure the direct and indirect impacts of pest animals. The project results enabled researchers to conduct an economic assessment of the costs of rabbits on agricultural producers, measuring the production losses from rabbits. The work contributes to estimating future losses that may occur as a result of the decline in effectiveness of current management strategies.

Key achievements

- Simple method of scoring rabbit abundance to estimate densities which are independent of seasonal variation in rabbit numbers or plant growth has been developed. A means of scoring biodiversity 'risk' using damage indices helped quantify the relationship between rabbit abundance and risk to natural biodiversity.
- A survey of 220 sites adjacent to farmlands in south-eastern Australia indicated that rabbits were present in 54% of sites visited and were causing noticeable vegetation damage in about half those infested.
- The project demonstrated that low numbers of rabbits (1-2/ha) are capable of removing all seedlings of the more palatable native tree and shrubs and exacerbating weed competition with native flora.
- 'Rabbits: A threat to conservation and natural resource management' provides a guide on how to rapidly assess a rabbit problem and take action.
- Both the method and the guide were applied in the 2009 community mapping survey, RabbitScan (www.rabbitscan.net.au)
- Rabbits were demonstrated as costing $206 million annually to agricultural producers in production loss alone.

Project partners

Invasive Animals CRC, Australian Wool Innovation, Victorian Department of Primary Industries.

Further information

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PestSmart Factsheet: Economic and environmental impacts of rabbits in Australia

www.invasiveanimals.com

Review of RHDV impact

Project Leader: Dr Brian Cooke, Invasive Animals CRC

Aim: *To review the impact of RHDV a decade after its release and assess its current status so that livestock industries are in the best possible strategic position if rabbits begin to build up again*

Project 7.T.3

Project duration	July 2006 – January 2008
Status	Completed

Project summary

The improved understanding of regional variations in the timing of outbreaks of RHD and its effectiveness enables recommendations for enhancing or prolonging its usefulness as a biological control agent and provides a framework for understanding the significance of data from related projects. Additionally, the work has provided insight into the likely importance of these viruses in different regions of Australia.

The project involved statistical analysis of field data and a literature review of RHD in Australia.

Statistical analyses, conducted at Gum Creek and Bacchus Marsh, estimates rabbit survival and allows complex covariate analysis to determine which factors, such as presence or absence of antibodies in rabbits, are important in determining the likely effectiveness of RHD in limiting rabbit populations.

An important objective of this research was the training of a biometrician in this important area of epidemiology that would have wider application in disease control and biosecurity as well as furthering our understanding of the epidemiology of RHD.

Information from the statistical review is further studied in the light of an extensive literature review. This literature review, including recently published information on RHD from both Australia and overseas, has helped to put the results in full context and advance our understanding of RHD.

This review enables recommendations for strategic release of RHD virus on baits and provides essential background in the development of shelf-stable RHD virus preparation for further release of virus by inoculation or on baits, and more broadly contributes to a national rabbit management strategy. It also underpins future decisions on the release of new virus variants that may be more effective than the Czech strain virus initially released.

Key achievements

- A literature review assessing suitability of RHDV for rabbit biocontrol in Australia, specifically relating to regional variations and implications for rabbit management.
- A biometrician was trained in the specific area of RHD epidemiology.
- The biometric analysis established key points in epidemiology of RHD at a high level of detail and with levels of statistical verification not previously achieved in epidemiological studies.

Project team

The project team, led by Brian Cooke, consisted of DPI Victoria's Steve McPhee, Ron Sinclair and Greg Mutze of DWLB SA and WA Agriculture's Dr Laurie Twigg.

Project partners

Invasive Animals CRC, Agriculture Services Victoria P/L, Department of Primary Industries and Department of Sustainability and Environment Victoria, APC Group SA Department of Water, Land and Biodiversity Conservation, WA Agriculture, Australian Wool Innovation.

Further information

Butler, K (2007) Review of RHD -10 years on: modelling rabbit population dynamics after the occurrence of rabbit haemorrhagic disease, Department of Primary Industries, Victoria.

Cooke, BD (2007) A review of rabbit haemorrhagic disease in Australia, Invasive Animals CRC (unpublished)

Cooke, BD, Yoon, H, McPhee, S and Butler, K (2007) Modelling Survival possibilities, Department of Primary Industries, Victoria.

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RHDV genetic resistance assessment

Project Leader: Dr Brian Cooke, Invasive Animals CRC

Aim: *To assess whether Rabbit Haemorrhagic Disease (RHD) will continue to be successful in keeping rabbit numbers low across Australia*

Project 7.T.5
PhD (genetic resistance)

Project duration	July 2006 – August 2007
Status	Completed

Project summary

This project provided crucial knowledge for development of future rabbit control plans control plans by establishing that wild rabbits in some populations showed resistance to RHD.

It involved testing wild rabbits from 12 sites across south-eastern Australia by challenge with a low dose of Czech 351 RHDV to detect changes in case mortality rate or survival time indicative of development of genetic resistance. This work was carried within an Invasive Animals CRC-supported PhD project by Mr Peter Elsworth whose final thesis has recently been submitted for examination.

Associated studies are carried out in South Australia by the Animal and Plant Control Group. They aim to determine whether the calicivirus is also changing genetically, possibly co-evolving in responses to changes in rabbit resistance and assess the effectiveness of making additional releases of RHDV. DNA samples from experimental rabbits are sent to Dr Nystrom at INSERM, Nantes France, while rabbit RNA was sent to Dr Nina Scwensow at the Institute for Zoo Research, Berlin, Germany, for analysis as a first step towards the identification of genes that may contribute to rabbit resistance.

Mr Elsworth has further compared the virulence of recent field virus strains against the initially released Czech-strain virus. Quantitative PCR results on virus titres in rabbit livers suggest that changes in virus genome sequence are reflected in virulence changes in resistant rabbits.

The final project outcome produced recommendations for maximising the benefits of rabbit control. These included not only actions that can be taken on individual farms or at a regional level but also addressed longer-term decisions on whether additional rabbit control methods (for example, new biological control agents) should be sought. The project directly relates to projects focusing on enhancing RHDV and RHD-Boost.

Key achievements

- Following on from the establishment that resistance is developing in rabbits to RHDV, challenge trials were performed to assess recent field strains of RHDV from the Turretfield region in South Australia. The three strains tested, collected in 2006, 2007 and 2009, appear to have performed better than the original release strain in that they heighten mortality rates and reduce survival times. The 2007 and 2009 strains appear to be maintaining a high level of virulence, in comparison to the original strain. This demonstrates that the virus is evolving with the rabbits and still providing some level of infection and control of rabbits in the field at this site.
- Publication and preparation of a number of journal articles will focus on the resistance of rabbits to the original release strain, theories on how this resistance may be acting and what this means for control, and virus virulence in the field and how this will impact on rabbit control. It is important to note that with the development of resistance, RHDV will decline, and additional control techniques need to be explored or highlighted.

Project team

Dr David Berman (Biosecurity Queensland), Mr Peter Elsworth, Ms Dallas Powell and John Kovaliski (SA DLWBC).

Project partners

Invasive Animals CRC, Australian Wool Innovation, Animal and Plant Control Group, SA Department of Land, Water and Biodiversity Conservation, Western Australian Department of Agriculture, NSW DPI, Victorian Department of Primary Industries, Queensland Department of Employment, Economic Development and Innovation, Biosecurity Queensland, IZS of Brescia, Italy (supplying monoclonal antibodies for ELISAs), INSERM, Nantes, France (analysing rabbit DNA samples).

Further information

Elsworth, PG, Kovaliski, J and Cooke, BD (2012) Rabbit haemorrhagic disease: are Australian rabbits (*Oryctolagus cuniculus*) evolving resistance to infection with Czech CAPM 351 RHDV? *Epidemiology and Infection* (e-publication only http://www.ncbi.nlm.nih.gov/pubmed/22244198)

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Richardson, BJ, Phillips, S, Hayes, R, Sindhe, S and Cooke, BD (2007) Aspects of the biology of the European rabbit (*Oryctolagus cuniculus*) and rabbit haemorrhagic disease virus (RHDV) in coastal eastern Australia, *Wildlife Research* 34/407.

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Enhancing RHDV effectiveness: avirulent caliciviruses

Project Leader: Dr Tanja Strive, CSIRO

Aim: *To develop a better understanding of the interaction between RHDV and avirulent caliciviruses to help inform decisions on effective management options*

Project 7.T.1

Project duration	October 2008 – October 2011
Status	Completed

Project summary

There is a need to understand the epidemiology of and the interaction between RHDV and avirulent caliciviruses in selected rabbit populations. This knowledge will provide the basis for further assisting land managers in reducing damage caused by rabbits.

Earlier studies have shown that RHD is generally more effective in arid regions and patchy or ineffective in wetter areas. This project investigated whether this is related to vector type and abundance, survival of the virus in wetter conditions, rabbit population dynamics, and/or the presence of other infectious agents.

The project was carried out in four phases:

- developing a method for detection of lagomorph caliciviruses in rabbits
- conducting a pilot study to determine the incidence of RHDV-like viruses in wild rabbits in the field
- determining the influence of RHDV-like virus on the epidemiology of RHDV
- providing advice to land managers.

Key achievements

- An evolutionary study was conducted analysing 36 different isolates of the benign Calicivirus RCV-A1. The study shows that RCV-A1 arrived in Australia together with the first rabbits 150 years ago. In addition, the evolutionary history of the virus reflects the recorded history of the rabbit host in Australia, in particular the two rabbit population bottlenecks induced by the two biocontrol agents, Myxoma Virus and Rabbit Haemorrhagic Disease virus.
- A series of serological tools for the detection of RCV-A1 was developed, including specific ELISAs for IgG, IgA and IgM antibodies as well as two different competition ELISAs. One of the competition ELISAs allows the specific detection of the benign calicivirus RCV-A1 and does not cross react with RHDV-antibodies.
- The other assays are sensitive tools that allow studying the infection dynamics of the benign virus RCV-A1. Studies are now underway using these tests to determine where in Australia the benign virus is present. Longitudinal samples from selected sites are also analysed to study potential seasonal dynamics of RCV-A1.
- Additional funding to extend the scope of the epidemiology study and include more different locations across Australia was obtained through the APARP program (DAFF). This one year project (ends March 2013) provided $40,000 of operating funds to produce a comprehensive distribution map of RCV-A1 across Australia, and study seasonality of RCV-A1 outbreaks on three selected sites.
- Two larger-scale infection studies were conducted to assess the extent of cross protection that RCV-A1 provides to lethal RHDV infection. Preliminary results indicate that the protection can be up to 40% but varies and may depend on a variety of factors such as challenge dose of RHDV, the particular strain of benign calicivirus used and most importantly, the time between infections with the two viruses.
- The latter finding is of particular importance as it indicates that the protection conveyed by RCV-A1 may be temporal and that there may be a window of opportunity for RHDV to be applied effectively in populations that carry the benign calicivirus.
- The project has resulted in five publications in peer reviewed international journals and one has been submitted. At least three more manuscripts are in preparation and are expected to be published in 2012–2013. Two book chapters were published, and a final project report was prepared and submitted to the Invasive Animals CRC.
- While the project was completed in October 2011, an APARP grant will allow the continuation of some of the work and produce a 'Calicivirus Map of Australia'. However, preliminary results indicate that more research is urgently needed to determine the seasonal occurrence of RCV-A1 in high production areas, in order to identify potential windows of opportunity for RDHV biocontrol, conventional as well as new RHD-Boost virus strains. The main challenge in 2012–13 is therefore to secure further funding for ongoing calicivirus monitoring and surveillance.
- Advice to land managers on the use of RHDV based on a knowledge of any interaction between avirulent rabbit caliciviruses and RHDV that would assist in reducing rabbit impacts
- Gained knowledge of the epidemiology of avirulent rabbit caliciviruses in Australian rabbits.

Results from the epidemiological studies and animal inoculation experiments should determine for any particular study site whether or not avirulent caliciviruses are influencing the effectiveness of RHDV. If they are, then means to reduce this influence would be sought for example by imposing RHDV on the population using baits at a time when avirulent caliciviruses are having the least effect. Other strategies could be devised depending on the results of the study.

The project outcomes directly relate to the RHD-Boost project, along with the development of strategic knowledge and application of best-practice management for rabbits, particularly optimal RHD bait delivery.

Project team

Dr Tanja Strive, Dr. June Liu, Dr Greg Mutze (SA DWLBC), Dr Glen Saunders (NSW Primary Industries) and technical officers John Kovaliski (SA DWLBC) and John Wright (CSIRO). Invasive Animals CRC-supported students Maija Marsh and Marlene Jahnke have also contributed to the outcomes of this work. The project receives support from Dr Brian Cooke (Invasive Animals CRC), Steve McPhee/Ivor Stuart (Victorian DPI), Dr Tarnya Cox (NSW Primary Industries), Ms Stephanie Habourie (CSIRO) and Dr Darren Kriticos (CSIRO).

Project partners

CSIRO Entomology, SA Department of Water, Land and Biodiversity Conservation and NSW DPI, Australian Wool Innovation, Victorian Department of Primary Industries.

Further information

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Enhancing RHDV effectiveness: RHDV genetic diversity

Project Leader: Greg Mutze, PIRSA

Aim: *To obtain completed sequences of RHDV to provide knowledge of Australian RHDV genetics*

Project 7.T.9

Project duration	April 2009 – March 2012
Status	Completed

Project summary

Rabbit populations around Australia have elevated levels of genetic resistance to RHDV infection and population levels are recovering from the impact of RHD. Research is currently under way through the RHD Boost program to test novel strains of RHDV from outside of Australia for improved effectiveness against RHD-resistant rabbit populations in Australia.

It is believed that increasing the genetic diversity of RHDV will increase its impact on rabbit populations through higher infection/mortality rates. However, prior to commencement of this project, we had little knowledge of changes in infection or mortality rates.

Our knowledge of the genetics of field strains of RHDV currently circulating in wild rabbits in Australia was limited to a small number of partial genetic sequences coding for part of the capsid protein. That was an inadequate basis on which to guide the choice of strains for release, or to monitor the establishment, spread and persistence of released strains. There was, therefore, an urgent need to obtain completed sequences of RHDV to provide knowledge of Australian RHDV genetics.

The project aimed to:

- Develop genetic information by sequencing samples from a bank of RHDV genetic material held by SA Department of Water, Land and Biodiversity Conservation and collected from field outbreaks of RHDV around Australia between 1995 and 2008 and from samples collected during the project's duration.
- Provide serological analyses for ongoing epidemiological field studies at Turretfield in SA. Turretfield is the only site where epidemiology of RHDV has been studied in detail before and during the period of emerging genetic resistance to RHD, has a high level of genetic resistance and offered potential for assessing the processes by which Australian rabbit populations are recovering, and where the releasing new strains of RHDV might be detected.

The project also provided serological support for:

- assessing field releases of RHDV on bait for project 7.T.1 'Enhancing RHD effectiveness'
- assessing studies of genetic resistance to RHDV through project 7.T.5 'RHD genetic resistance'
- ongoing epidemiological monitoring in the Flinders Ranges and the Coorong in South Australia.

Key achievements

- The work identified a virulent field strain for testing as part of RHD Boost evaluation.
- Genetic sequence analyses indicated that all sequences recovered in Australia so far are distinctly different from RHDVa strains under consideration for release through RHD Boost.

Genetics sequence analyses of RHDV

Liver samples were collected from carcasses of rabbits suspected to have died of RHD from:

- 76 rabbits in South Australia
- 39 rabbit liver samples were obtained from interstate collaborators.

Completed RHDV genetic sequences were obtained from:

- 9 samples from South Australia
- 12 sequences from samples from interstate.

Partial RHDV genetic sequences were obtained from:

- 19 samples from South Australia
- 28 sequences from samples from interstate.

Serological analyses of RHDV and myxoma antibodies - analyses were completed for:

- 3,103 rabbit sera from field samples for epidemiological field studies in South Australia
- 461 rabbit sera from field samples collected for Project 7.T.1 'Enhancing RHDV effectiveness'
- 568 rabbit sera from laboratory studies for Project 7.T.5 'RHD genetic resistance'
- 256 rabbit sera from new collaborative studies initiated with the German Liebniz Institute investigating enzyme activation in response to RHDV challenge.

RHDV genetic variation and impact at Turretfield

Analyses of serological data indicate that infection rates from RHDV vary significantly between years. Mortality rates were less variable although in the outbreak of 2008 mortality rates were lower than those in preceding or subsequent RHD outbreaks. Genetic analyses of viruses recovered during all years indicate that virus strains do not persist on the site from one year to another. A genetically distinct strain was present on the site in 2008, but not in preceding or subsequent outbreaks. These data point towards attenuation of RHDV as a contributor to the recovery in Australian rabbit populations.

Research initiatives arising from the work

Data arising from this project at the Turretfield site has become the focus of collaborative research initiatives in the new Invasive Animals CRC between Biosecurity SA and University of Adelaide, to study co-evolution between rabbits and RHDV. Dr Nina Schwensow of the Berlin Zoo's Liebniz Institute has obtained a three-year ARC DECRA research grant to study genetic co-evolution between rabbits and RHDV at the University of Adelaide, which began mid-2012.

Project team

Greg Mutze, Ron Sinclair, John Kovaliski and Dr David Peacock, each from Biosecurity SA, PIRSA.

Project partners

Department of Primary Industries and Regions SA, NSW Department of Primary Industries, CSIRO Entomology.

Further information

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PestSmart factsheet: Using RHDV for rabbit control

www.invasiveanimals.com

RHD Boost

Project Leader: Dr Glen Saunders, NSW Department of Primary Industries

Aim: *To identify new RHDV strains with high lethality to rabbits immune to endemic Australian Rabbit Calicivirus (RCV-A1) and rabbits resistant to infection with Czech 351 derived RHDV strains*

Project 7.T.12e

Project duration	July 2009 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

This project evaluates new strains of Rabbit Haemorrhagic Disease (RHDV). This includes screening to determine which candidate RHDV strains overcome rabbits with immunity to Czech 351 and research to confirm the competitive advantage of the new candidate RHDV strains.

A decision framework to optimise the impacts from releasing candidate RHDV strains will also be developed. RHD Boost is a strategic response to increasing genetic resistance of rabbits to the originally released RHDV Czech 351 strain and its limited effectiveness in temperate regions due to the protection offered by the endemic RCV-A1. In Europe, new RHDVa strains are out-competing the original RHDV strains in the field and are suppressing wild rabbit populations in cooler, wetter regions.

If successful, RHD Boost has a calculated Net Present Value to agricultural production of $1.4 Billion over 15 years and will substantially reduce the impacts of rabbits on Australian plant biodiversity over the 5.3 million square kilometres currently infested.

RHD Boost comprises eight key activities:

- selecting RHDV strains
- testing to ensure freedom from other agents
- producing virus stock and undertaking preliminary screening
- screening of virus strains for ability to overcome immunity to RCV-A1 and genetic resistance in wild rabbits
- screening of wild rabbits for ability to overcome immunity to RHDV
- demonstrating competitive advantage of selected strains
- optimising the efficiency of delivery
- developing a pre and post RHD Boost release monitoring and evaluation plan.

The three major outputs are:

- Up to 2 RHDV strains scientifically demonstrated to have a high lethality to wild rabbits immune to endemic Australian Rabbit Calicivirus (RCV-A1) and wild rabbits resistant to infection with Czech 351 derived RHDV strains, that perform well in both temperate and semi-arid Australia.
- A decision framework for optimising the release of candidate RHDV strain/s in terms of initial establishment and likely regional impact based on a model of the interaction between RHDV and RCV-A1.
- A pre- and post- RHD Boost release monitoring and evaluation plan to enable impact and performance to be robustly measured.

Key achievements

- Strains of RHDV have been imported from France, Spain and South Korea.
- Genetic and antigenic comparisons of imported RHDV strains have been conducted. Five candidate strains of RHDV have been selected.
- Master virus stocks for the candidate strains have been produced.
- A regime for testing for freedom from adventitious agents is under negotiation with Biosecurity Australia and AQIS.
- Real-time PCR assays for assessing virulent and benign rabbit caliciviruses have been developed.
- Real-time PCR assays have also been applied to Czech 351-derived field strains to assess virulence in resistant wild rabbits.
- Studies were conducted to assess the possibility of recombination between different caliciviruses.
- In vivo titration of candidate strains approaching completion.
- Completed in vivo comparisons of the candidate strains imported from France, Spain and South Korea for ability to overcome prior infection with benign RCV-A1.
- Completed in vivo comparisons of the candidate strains for ability to overcome prior infection with RDHV.
- Completed in vivo comparisons of the candidate strains using rabbits with genetic resistance.

Project team

Dr Peter Kirkland, Dr Andrew Read, Dr Peter Kerr, Dr Tanja Strive, Dr Markus Matthaei, Dr Tarnya Cox, Dr June Liu, John Wright, Stephanie Haboury, Chris Lane, John Tracey, Steve McPhee, Dr Brian Cooke and Dr Glen Saunders.

Project partners

Invasive Animals CRC, Meat & Livestock Australia, Australian Wool Innovation, Foundation for Rabbit Free Australia, NSW Department of Primary Industries and CSIRO.

Further information

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www.invasiveanimals.com

Freeze-dried RHDV bait

Project Leader: Dr Peter Kirkland, NSW Department of Primary Industries

Aim: *To develop a freeze-dried stock of RHDV that can be easily and safely transported*

Project 7.T.2

Project duration	July 2006 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

This project is developing a freeze-dried stock of RHDV that can be easily and safely transported without the need for dry ice, significantly enhancing convenience, reducing costs and the impediments to uptake. The product can be prepared for field distribution by mixing with carrots or oats.

Spreading RHDV by the oral route on treated carrots or grain is a much more practical delivery method compared to catching of wild rabbits and injection of RHDV prior to release. This project aims to overcome the need to transport the current form of the virus as a dangerous good and at low temperatures.

Studies at the Elizabeth Macarthur Agricultural Institute within NSW Department of Primary Industries involve a series of individual stages. These include:

- identifying the optimal conditions for freeze drying
- selection of an appropriate cryoprotectant
- preparation of a pilot batch of freeze-dried RHDV product
- determination of the shelf-life of freeze-dried RHDV product
- assessment of the infectivity of the freeze-dried RHDV product when presented on carrots or oats.|

Outputs of this project include:

- a freeze-dried stock of RHDV
- efficacy results from trials using freeze-dried RHDV
- stability study results for RHDV stored under real-time and accelerated conditions
- data packages compiled for Australian Pesticides and Veterinary Medicines Authority (APVMA) registration
- best-management code-of-practice for an integrated rabbit control strategy that incorporates the shelf-stable RHDV product and advocates a nil-tenure approach.
- promotion of the best-management Code of Practice strategy to stakeholders at a state and national level.

Key achievements

- Determination of the shelf-life of freeze-dried RHDV product have been completed. These studies indicate that at 4ºC RHDV freeze-dried preparations have an estimated degradation constant of 0.0939/month when calculated based on just the samples held at 4ºC or 0.942/month based on all data. Based on these data a preparation would require 40,506 RID50/ml at the time of production in order to contain 3,000 RID50/ml after storage at 4ºC for 12 months. For storage at -20ºC the estimated degradation constant is 0.0104, indicating that 3,999 RID50/ml at the time of production in order to contain 3,000 RID50/ml after storage at -20ºC for 12 months.
- Assessment of the infectivity of the freeze-dried RHDV product when presented on carrots or oats. Freeze-dried preparations containing approximately 3,000 RID50/ml have been administered to rabbits as oral baits. The preparations were prepared in a manner identical to the currently registered oral RHDV product. All rabbits fed either the carrot or oat preparation showed evidence of infection and that either preparation is suitable as a rabbit specific rodenticide.
- Final report into stability of freeze-dried RHDV prepared.
- Product registration to the APVMA submitted.

Project team

Dr Peter Kirkland, Dr Andrew Read and Dr Simon Humphrys.

Project partners

Invasive Animals CRC, NSW Department of Primary Industries.

Further information

www.invasiveanimals.com.au

Carbon monoxide pressure fumigator

Project Leader: Dr Simon Humphrys, Invasive Animals CRC

Aim: *To achieve a significant advance in the technology of warren fumigation for the integrated control of rabbits*

Project 10.U.14c

Project duration	July 2006 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

With the value of warren fumigation in integrated management of rabbits clearly identified, this project seeks to demonstrate an improved approach to warren fumigation with respect to efficacy, ease of use, fumigator portability, logistical use and the humaneness of the lethal outcome.

This project follows on from development work by the Victorian State Government Departments of Primary Industries and Sustainability and Environment and is supported by two Australian Government National Feral Animal Control Program grants so that carbon monoxide pressure fumigation is made available as a management technique that can be integrated into conventional control programs eg with ripping and baiting and used to control rabbits in situations where neither conventional controls are options.

Prototype CO pressure fumigators

Key achievements

- Manufacture and operational performance of several prototypes has been assessed.
- Registration application criteria and data packages discussed with the APVMA in preparation for submission.
- Five working prototypes manufactured based on the successful testing of the first prototype.
- Field testing of the five prototypes to determine efficacy.
- Submission of registration data packages (should the efficacy data warrant).
- Provision of the registration packages to overseas licensees for approval of the units outside of Australia to support international sales.

Project partners

Invasive Animals CRC, NSW Department of Primary Industries, ABARES, Victorian Department of Primary Industries, Victorian Department of Environment and Sustainability.

Further information

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www.invasiveanimals.com.au

Rabbit project management

Project Leader: Dr Brian Cooke, Invasive Animals CRC

Aim: *To provide practical experience in rabbit management enabling land managers to maintain low rabbits at low cost and effort to reduce impacts on agricultural production and native vegetation.*

Projects 7.T.4, 7.T.4a, 7.T.4b, 7.T.8e

Project duration	July 2009 – June 2012
Status	Completed

Project summary

This project encompassed a suite of projects under the Invasive Animals CRC strategic goal: Improved integration of existing biological, conventional and newly-developed control options for rabbits.

Initially the project was aimed at placing the wool and livestock industries in the strongest possible strategic position with respect to rabbit management and control throughout southern Australia. The aims were being carried out through initiatives such as support of the Rabbit Management Advisory Group, providing funding opportunities for research and development projects, increasing public awareness of the rabbit abundance assessment tool, and support other research projects funded by Australian Wool Innovation and Meat & Livestock Australia.

The focus was broadened to consider improved integration of existing biological, conventional and newly-developed control options for rabbits.

This project dealt with the growing rabbit problem in two ways:

1. Established demonstration sites to provide training and advice for dealing with the immediate problem of keeping rabbits down. This enabled:

- land managers to gain an understanding of the principles of rabbit control as well as gain practical experience in the use of the methods available
- land managers to evaluate the cost-effectiveness of methods used alone and in combination so that they can make general recommendations for the best combinations of methods for rabbit control for their district
- development of computer-based economic decision models based on the cost-effectiveness of each rabbit control method, singularly or in combination with others, that can be used to design the most efficient combination of techniques for rabbit control.
- extension of this information to others, such as individual farmers, park rangers and land-care groups NRM groups within their district who need advice for achieving effective rabbit control.

2. Developed desktop studies considering the long-term prospects for rabbit control, especially those that will facilitate control in the future such as new biological control agents. This involved:

- reviewing published information, current studies and discussions with people with responsibilities or interests in controlling rabbits to recommend ways of improving rabbit control
- reviewing, social barriers, legislative disincentives or the lack of skills inhibiting effective rabbit management
- investigating future benefits that could be obtained from evaluating more virulent strains of existing rabbit pathogens, or the importation of new biological control agents
- a peer-reviewed paper by people from all three States involved to make sure that conclusions are accurate and that recommendations reflect particular concerns and are feasible in terms of state policies and legislation.

A key outcome of the project has been the contributions made in developing the national rabbit management package, relating to the education and extension goal of end-user capacity building. Dr Cooke is contributing to the production of extension materials designed to enhance skills and knowledge to effectively delivery best-practice invasive animal management strategies.

Key achievements

- The results of economic model of rabbit control published in *Wildlife Research.*
- The landscape-scale rabbit management plan formulated and prepared for publication and distribution to Natural Resource Management Boards (this encompasses many of the issues impeding rabbit control as well as introducing new economic concepts).
- Decision-making framework and risk assessment for the release of new variants of RHDV under the RHD-Boost Program completed.
- Economic benefits of rabbit control with particular reference to RHD assessed.
- Supervised completion of PhD studies by Peter Elsworth on genetic resistance to RHDV in wild rabbits.
- Participated in supervision and training of Invasive Animals CRC postgraduate students.

Project team

Dr Cooke is working with project teams across all Invasive Animals CRC project relating to rabbits.

Project partners

Invasive Animals CRC, Australian Wool Innovation, Meat & Livestock Australia, Foundation for Rabbit Free Australia, NSW Department of Primary Industries, CSIRO, ABARES, Parks Victoria, SA Natural Resource Management Board.

Further information

Elsworth, PG, Kovaliski, J and Cooke, BD (2012 In Press) Rabbit haemorrhagic disease: are Australian rabbits (*Oryctolagus cuniculus*) evolving resistance to infection with Czech CAPM 351 RHDV? *Epidemiology and Infection*

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Enhancing rabbit eradication on islands

Project 9.D.11

Project Leader: Dr Elaine Murphy, NZ Department of Conservation

Aim: *To bring international rabbit experts together to update the best practice for rabbit eradications on islands, pool knowledge, discuss what has worked and not worked and agree on priority research that would help with future eradications.*

Project duration	September 2009 – June 2010
Status	Completed

Project summary

Rabbits have been nominated as among 100 of the World's Worst invaders (Global Invasive Species Database). They cause severe damage to the environment, contributing to the decline of threatened flora and fauna by overgrazing and destroying habitat. As prey, they support populations of introduced predators that also prey on native species. Worldwide, rabbits have been introduced to more than 800 islands with devastating impacts.

There have been at least 48 attempts to eradicate rabbits from islands with about a 95% success rate, but even on small islands eradicating rabbits is very difficult and often requires a combination of techniques.

The Invasive Animals Cooperative Research Centre hosted an international workshop in February 2010 to share and progress knowledge and experience of rabbit eradications, particularly on islands. The workshop was considered particularly timely in view of the planned eradication of rabbits and rodents on Macquarie Island. The workshop helped precipitate the idea of using rabbit hemorrhagic disease to reduce the deaths of non-target species (such as birds of prey consuming poisoned rabbits) on Macquarie Island.

Rabbit on Macquarie Island. Image by Mary Bomford.

Key achievements

This workshop brought together international rabbit experts to discuss ways to improve rabbit eradications on islands. Baiting techniques, bait type and quality, feed rate and toxin choice were discussed. Secondary measures to follow up poisoning were also discussed, including efficient use of dogs and traps.

The group suggested innovative methods that could be trialled in future, such as fibre optics and remote cameras, rabbit lures (eg pheromones), hair tubes, sticky traps and Judas rabbits.

The use of rabbit haemorrhagic virus, aerial shooting, directional netting/traps, water points in arid environments and mineral pegs in nutrient-deficient environments were also discussed.

Priorities for research that will help with future eradications were identified, focussing on developing techniques to be able to detect and kill rabbits at low densities, particularly after poison operations.

A better understanding of the biology and behaviour of surviving rabbits was also considered important. Research was recommended into bait stations for rabbits, kill traps or snares (preferably multiple-kill with automatic reset functions), new baits and lures, including pheromones.

New methods of toxin delivery that do not require bait should also be researched (eg a 'Tar Baby' technique). Called 'Tar Baby' after the efforts of Brer Fox to trap Brer Rabbit with tar, this technique devised by CSIRO researchers consists of laying a trail of greasy substance carrying a poison along the floor of a burrow. The rabbit naturally indulges in long bouts of meticulous grooming. The rabbit actively attempts to remove such foreign matter by licking or biting and pulling at it with the teeth and shaking the paws. Rabbits tread on the trail, then onto the soil, and ingest the poison when they clean their forepaws.

Search/detection models for validating the effectiveness of detecting survivors in the field are also needed. In the longer-term research should be conducted into rabbit genome sequencing to identify any potential weaknesses that could be exploited.

Project partners

NZ Department of Conservation; Tasmanian Department of Primary Industries, Water and Environment, University of Canberra.

Further information

Murphy, E, Crowell, M and Henderson, W (2010) Workshop Proceedings: Improving the Efficiency of Rabbit Eradications on Islands. 4–5 February 2010, Christchurch, New Zealand. Invasive Animals Cooperative Research Centre, Canberra.

'Best practice for rabbit eradications from islands' was published as an Appendix to this Workshop's Proceedings.

Enclosure against rabbits on Macquarie Island. Image by Mary Bomford.

Goal 8: Reducing expanding, overabundant and widespread invasive species impacts

TARGET: Deliver improved and humane approaches to reduce the production and biodiversity impacts of expanding or other overabundant and widespread pest species

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
8.1	Leadership role in implementing welfare based invasive animal control practices	2012	5.T.5e, 9.D.7e
8.2	A better understanding of the social impacts of animal invasions	2011	PhD (managing deer) PhD (wild dog impacts)
8.3	Management recommendations to reduce the impacts of Australia's pest birds	2011	9.T.2, 9.D.3, 9.D. PhD (bird management) PhD (removal of pest birds) PhD (invasive lizards)
8.4	Management packages for improved herbivore management	2012 9.T.1, 9.U.1	PhD (effects of GonaCon®)

*As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- PhD: People, pests and conflict: community participation in invasive deer management in Australia (Adriana Ford-Thompson)

- Improving the management of Australia's pest birds (9.T.2 – Completed)
  - PhD: Evaluating management strategies for pest birds of horticulture (John Tracey)
  - PhD: Removal of the pest bird – Indian Myna (*Acridotheres tristis*) and its impacts and implications for native Australian birds (Kate Grarock)

Tactical control

- The potential of avicide DRC-1339 for control of starlings (9.D.3 – Completed)

Strategic control

- Oral delivery systems for herbivore management (9.T.1 – Current)
  - PhD: Effects of vaccination against gonadotrophin releasing hormone (GnRH) on the behaviour and fertility of macropods (Melissa Snape)
  - PhD: GnRH constructs for oral delivery: affects on immune responses and reproductive function (Ian McDonald)
- Options for camel control in Australia (9.U.1 – Completed)

Tactical control

- Codes of practice and standard operating procedures for humane pest animal control (5.T.5e, 9.D.7e – Completed)

Relevant projects included under other goals

Knowledge and tools

- Socio-economic costs of invasive animals (12.D.6 – Completed)
- Community Awareness Surveys (10.D.12 – Completed)
- Public attitudes to invasive animals and their impacts (12.D.5 – Completed)
- Public attitudes to pest animal management and control (12.D.8 – Completed)
  - PhD: Loving nature, killing nature, and the crises of caring: An anthropological investigation of conflicts affecting feral pig management in Queensland (Carla Meurk)
- Starlings in Western Australia (9.T.4 – Completed)

PhD: social implications of managing deer

Dr Adriana Ford-Thompson

Aim: *To identify how social factors may inform invasive species management from social and ecological perspectives, with a particular reference to invasive deer for management decisions*

Project duration	January 2008 – February 2012
Status	Completed

Project summary

As stakeholder and public concerns surrounding invasive species have become increasingly recognised and better articulated, society has become more closely involved in invasive species management. This has resulted in the need to ensure that positive ecological outcomes, such as protecting native species and habitats and positive social outcomes, for example public support and improved stakeholder relationships, are both achieved as a result of management interventions.

Through identifying social factors affecting the relationship between conservation, society and invasive species, this research considers how both of these outcomes may be attained, in the context of invasive species management in Australia. This is done with particular reference to the management of invasive deer (with a focus on the Royal National Park in NSW), which are becoming an increasing issue of concern in Australia and a source of contention between stakeholders, particularly as deer are viewed as a hunting resource and charismatic, as well as an environmental and economic threat.

Three dimensions of this relationship were analysed- stakeholder participation, social and political mechanisms and context and public attitudes. This involved interview questionnaires, in-depth interviews, and postal surveys, respectively. The studies revealed three main social factors affecting the relationship–social associations with species, conflict over wildlife-related values, and conflicts between humans and invasive species.

Social associations were related predominantly to species characteristics and their position in the environment, and may affect policy and legislation. Conflicts over wildlife-related values were related to management approaches, animal rights and welfare, and were also revealed to be a legacy of political history.

The type of conflict between humans and invasive species was shown to affect management approaches. Stakeholder participation was shown to be essential in achieving both social and ecological outcomes, through conflict resolution, responsiveness to social factors, and justification of management approaches. This research provides a novel approach for analysing how social factors may influence both ecological and social outcomes of invasive species management.

Key achievements

- In her PhD 'Conservation, Society and Invasive Species', Adriana Ford-Thompson evaluated how managing people as well as invasive animals can be approached more effectively, so that both social and ecological goals can be met.
- The research first examined the way stakeholder participation is used in invasive vertebrate management programs across Australia, for example the motivations behind involving stakeholders, the participatory methods employed and how different features such as these link to the program outcomes.
- The research includes a number of recommendations for improving cooperation and collaboration, facilitating managers in their quest to manage invasive species in a way that is both socially and ecologically appropriate.
- Doctorate conferred February 2012.

Project partners

Invasive Animals CRC, Economic and Social Research Council (United Kingdom), NSW Department of Primary Industries and the University of York.

Further information

Ford-Thompson, AES (2012) PhD thesis 'People, pests and conflict: community participation in invasive deer management in Australia'.

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www.invasiveanimals.com

Improving management of Australia's pest birds

Project Leader: John Tracey, NSW Department of Primary Industries

Aim: *To estimate the impacts of birds to the horticultural industry, develop simple and efficient techniques for estimating damage, evaluate existing control methods, and provide tools for land managers to improve the management of pest birds*

Project 9.T.2
PhD (bird management)

Project duration	June 2006 – June 2012
Status	Completed

Project summary

Bird damage is a significant problem in Australia, with more than 100 species that can cause significant losses to fruit, nut, grain, rice and aquaculture industries, create conflicts in urban areas, damage infrastructure, reduce aesthetic values, and pose risks to the environment and to human health. The direct losses to horticulture alone are estimated at over $300 million, which is more than three times greater than direct losses attributed to any other pest animal. Pest bird managers are also faced with increasing social, environmental and legal issues that further restrict the techniques that can be used to reduce bird impacts. New types of horticultural crops are being grown, growing practices are changing, values for horticultural products are increasing and the geographical range of production is expanding. These factors often result in the expansion of the range and impact of pest birds.

There are many control techniques available, but they are often ineffective and expensive and little objective advice is available. For example, total costs of control in horticulture were estimated from a national survey at $18.6 million (average of $110.20 per hectare), with most techniques failing to adequately protect crops. To allow land managers to effectively manage pest birds, support is needed to estimate the extent and severity of damage, to evaluate management alternatives, to assist in economic decision-making and to improve the adoption of strategic management. This project has addressed these outcomes.

Brian Lukins, NSW DPI, estimating damage to crops

It is now widely accepted by the international animal health community that an understanding of the ecology of avian influenza viruses within the wild bird population is essential in assessing the risks to human health and production industries, and in demonstrating freedom from disease. However, broad-scale surveillance is logistically difficult and cost prohibitive due to a number of factors including the natural low prevalence of the virus. This project has used updated information on waterbird ecology and movements and avian influenza epidemiology to maximise the efficiency and relevance of surveillance for avian influenza in Australia's wild birds.

Alongside this work, a PhD project is also being conducted. John Tracey, NSW Primary Industries and University of York, has evaluated management strategies for pest birds using bio-economic models.

Key achievements

- Simple and efficient techniques for estimating bird impacts developed, with costs of pest bird impacts and control in horticulture estimated for Australia.
- Methods to reduce pest bird abundance and damage evaluated, with tools developed to improve pest bird management.
- 11 cases studies demonstrating effective local and regional control produced.
- National management guidelines for pest birds developed in cooperation with ABARES.
- Key national recommendations for future research and development produced with industry and government endorsement.
- National risk-based framework developed for the surveillance of avian influenza in wild birds.
- A simple tool developed to allow land managers to compare the costs and benefits of bird netting over time.

Key achievements

- Costs and benefits of management techniques for pest birds evaluated.
- Implementation of the national risk-based framework for the surveillance of avian influenza in wild birds.

Project team

John Tracey, Brian Lukins, Dr Glen Saunders and Randall Jones (NSW DPI).

Project partners

Invasive Animals CRC, ABARES, NSW Department of Primary Industries Wildlife and Exotic Diseases Preparedness Program, Avian Influenza Wild Bird Steering Group, SA Department of Water, Land and Biodiversity Conservation, University of York, Lord Howe Island Board.

Further information

Tracey, JP, Bomford, M, Hart, Q, Saunders, G and Sinclair, R (2007) Managing Bird Damage to Fruit and Other Horticultural Crops. Bureau of Rural Sciences, Canberra.

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Tracey JP (2009) Bird pests in: Crawford C (Ed) Vertebrate Pest Management Course Handbook. 23-27 March 2009, NSW Department of Primary Industries, Orange NSW.

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PhD: removal of the pest bird – Indian Myna

PhD Candidate: Kate Grarock

Aim: *To study removal of the pest bird Indian Myna (*Acridotheres tristis*) and its impacts and implications for native Australian birds*

Project duration	January 2008 – December 2012
Status	Current

Project summary

Assess the introduction, spread and impact of the Common Myna bird on native species. Using a composite 40-year dataset, the introduction and spread of the Common Myna in Canberra was mapped using GIS. The impact of the Common Myna on native bird abundance was then analysed using data prior to and after Common Myna establishment.

Monitoring nesting boxes using a 'lipstick' camera

Mynas displace native birds from nesting habitat

Transect survey data was also used to analyse the impact of both habitat and Common Myna abundance on native species.

A total of 450 nest boxes were built and erected to study nest box competition between the Common Myna and native cavity nesting species. Finally, the effectiveness of the community trapping program of Common Myna birds was assessed.

This project will build on existing work about the impact of the Common Myna on Australian native birds.

From this project, a scientific understanding of the impact of the Common Myna will be much clearer. Important species traits, such as spreading rate, will also significantly increase the understanding and management of the species. Finally, research on the effectiveness of the community trapping program will assist in making trapping more effective. The effectiveness of trapping in Canberra is essential knowledge as many areas around Australia are modelling trapping programs off this design.

Key achievements

- Six papers completed for submission and conferring of PhD.

Project partners

Invasive Animals CRC, Australian National University, Canberra Indian Myna Action Group (CIMAG).

Further information

Grarock K, Tidemann CR, Wood J, Lindenmayer DB (2012) Is it Benign or Is It a Pariah? Empirical Evidence for the Impact of the Common Myna (*Acridotheres tristis*) on Australian Birds. *PLoS ONE* 7(7): e40622. doi:10.1371/journal.pone.0040622

Tidemann, CR, Grarock, K & King, DH (2010) Euthanasia of pest sturnids in nestboxes. *Corella*, 35(2): 49-51.

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Avicide for control of starlings

Project leader: Dr David Dall, Pestat Pty Ltd

Aim: *To demonstrate the effectiveness of the poison DRC-1339 for lethal control of starlings under Australian field conditions*

Project: 9.D.3

Project duration	November 2006 – June 2009
Status	Completed

Project summary

Starlings are a significant invasive pest in Australia whose geographic range is continuing to expand. There are currently no effective methods for lethal control of this pest in Australia. Compound DRC-1339 (or 'Starlicide' as it is generically known, on the basis of its most common commercially-available product), is an acute toxin that causes irreversible kidney and heart damage in sensitive birds, resulting in a quiet and painless death, normally 1-3 days after ingestion (APHIS Tech Note). As a consequence of its extensive assessment and use in the USA, non-target susceptibilities to DRC-1339 have been well documented, providing estimates of median lethal dose (LD50) for more than 60 species of birds, as well as many mammals. Furthermore, in 36 years of widespread use in the USA Starlicide has not been responsible for any known secondary poisonings of mammalian or avian scavengers or predators, with the possible exception of a single crow.

Key project objectives were to:

- demonstrate the effectiveness of DRC-1339 for lethal control of starlings under Australian field conditions
- assemble a package of data that can be used to support local registration of the toxicant for lethal control of starlings.

Starlings flying above piggery shed at trial site.

Key achievements

- A package of data relating to Compound DRC-1339 was compiled, including public domain and unpublished confidential studies on the properties of the material.
- An application to import the compound was approved, and a protocol for field studies developed, resulting in field trials at a major piggery in SA.
- The field trials were not successful due to the inability to attract birds from the abundant amounts of available animal feed to the carrier bait. Multiple presentations of carrier bait were tested, however this inability to attract the pest birds to the carrier bait could not be resolved.
- Despite the unsuccessful trials, it is considered that the DRC-1339 agent still provides a potentially viable approach to starling control in Australia. Its use will need to be supported by development of a carrier bait and/or baiting strategies that will allow reliable delivery to these neophobic pests, which clearly show a high degree of fidelity to their usual local feeding sites and forms of food.

Project team and partners

Dr David Dall (Pestat Pty Ltd), Assoc. Prof Steven Lapidge (Invasive Animals CRC), Prof Joan Dawes (Pestat Pty Ltd), Dr Ron Sinclair (SA Department of Land, Water and Biodiversity Conservation) and Tina Bentz (Pestat Pty Ltd).

Further information

Sinclair, R, Dall, D, Lapidge, S and Bentz, T (2008) Failure to attract starlings to bait in Woolnough, A, Feare, C, Meier G (Eds) 2008. *Proceedings of the International Invasive Bird Conference*, Fremantle, Western Australia.

Lapidge, S, Dall, D, Dawes, J, Tracey, J, Sinclair, R. and Woolnough, A. (2005) STARLICIDE® The benefits, risks and industry need for DCR-1339 in Australia. *Australasian Vertebrate Pest Conference* 13: 235-238.

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Cost of starling incursion into Western Australia

Project Leader: John Roberts, ACIL Tasman

Aim: *To assess the likely cost of a starling incursion in Western Australia*

Project 9.T.4

Project duration	July 2006 – December 2006
Status	Completed

Project summary

The European or common starling (*Sturnus vulgaris*) is one of the world's worst invasive bird species. It originated in Europe and Asia and has become established in North America, South Africa and New Zealand.

ACIL Tasman was engaged by the Invasive Animals Cooperative Research Centre to undertake an analysis of the likely cost of a major starling incursion into Western Australia.

The report:

- describes the key uncertainties in relation to knowledge of starlings and their likely impact on Western Australia (importantly, some of the key uncertainties should be resolved by the currently funded research, surveillance and control exercise);
- sets out the approach and methodology used in estimating the cost of a starling incursion; and
- offers a summary and conclusion.

This report finds that in Western Australia, the potential habitat zone of starlings is around 1 million sq km, and under full infestation and with a conservatively estimated prevalence rate of 12.5 starlings per sq km, this would mean that the Western Australian habitat zone could support at least 12.5 million starlings.

Such a population of starlings could consume in excess of 110,000 tonnes of food in a year, of which two-thirds would come from commercially valuable sources such as horticulture and grains.

Starlings would account for a loss of 0.5% of the Western Australian grains crop, and 3% of the State's horticultural crop (grapes, apples, pears, etc). The annual damage caused on this basis has been valued at $21.2 million. The plausibility of these estimates has been corroborated using existing evidence on bird damage to crops.

A range of other costs, including management of urban roost situations, damage to property, clean-up costs, weed control, and the likely cost of recovery plans for displaced native birds, takes the estimate of annual damage done by starlings under a full infestation to at least $30 million per year. This estimate does not include less easily verifiable costs such as threatened existence values that the community might place on native birds.

Key achievements

- The final report highlights the need to maintain vigilance against a starling incursion, estimating the cost of controlling starlings at $3.8 million per annum in the first year, $3.6 million in years 2 and 3, and $1.5 million per annum thereafter.

Project partners

Invasive Animals CRC, ACIL Tasman.

Further information

Roberts J (2006) Starlings in Western Australia: assessing the likely cost of an incursion. ACIL Tasman, Perth.

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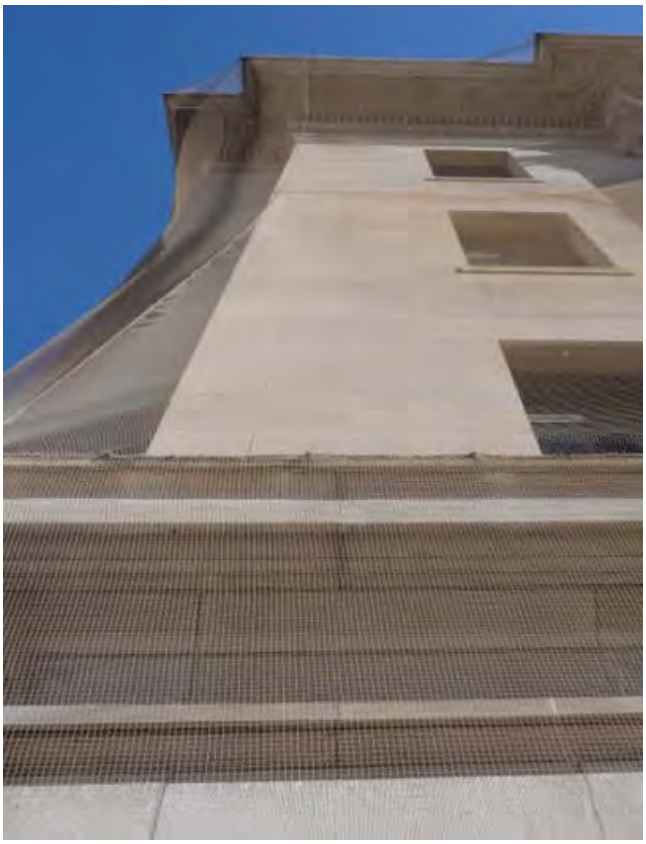

In the US, protecting amenities from starlings and other pest birds can incur high costs
Images courtesy of Ron Sinclair, SA DWLBC

Oral delivery systems for herbivore management

Project Leader: Dr Lyn Hinds, CSIRO

Aim: *To develop oral delivery systems for control agents which could be used to manage herbivores, such as wallabies, kangaroos, horses and camels in the Australian environment*

Project 9.T.1
PhD (vaccination effects)

Project duration	March 2006 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

In Australia, native herbivores, particularly kangaroos and wallabies, have become pest species in pastoral, agricultural and forestry production areas. Efforts to manage their impact include shooting, trapping, exclusion and poisoning. More humane alternatives for management are required. This project is exploring options for oral delivery of agents which will affect reproductive success. No methods are currently available for landscape scale application of fertility control and modelling may show that it is not appropriate for all species even though the methods may work in individual animals. This project has been focussing on assessment of immuno-contraceptive vaccines (single shot GonaCon®) with the view to oral delivery to herbivores.

Recently a modification of the GnRH vaccine approach has become available via collaborating colleagues at USDA National Wildlife Research Center. One agent, known as the Talwar protein, is a potentially orally active recombinant protein construct which incorporates the GnRH peptide and a number of T-cell epitopes. It is currently being prepared for oral testing. Over the last 12 months, delivery of alternative GnRH constructs has been assessed directly and within selected formulations for their efficacy in laboratory mice. If results are positive then the next phase will comprise captive studies using wallabies to assess efficacy of the oral agent for a herbivore. The scale of this testing will depend on funding availability and its source.

This project specifically aimed to deliver:

- refined oral delivery formulations for control agents such as fertility control or toxic agents
- modelling of population dynamics to determine the potential of oral fertility control for different test species
- product for strategic use in the management of overabundant herbivores
- product for use in commercial domestic livestock production.

The project was conducted to achieve improved understanding and assessment of the efficacy of orally deliverable fertility control agents for management of pest herbivores and improved domestic livestock production. Major outcomes included having Gonacon®— a first-generation injectable immuno-contraceptive for over-abundant large herbivores — tested in Australia. PhD student Melissa Snape is associated with this research on GonaCon® and PhD student Ian McDonald is undertaken research on oral delivery assessing silica nanoparticles and GnRH constructs.

Key achievements

- Group sizes in the tammar wallaby GonaCon® fertility trials have declined due to a major orbivirus infection in wallaby colony between November 2010 and March 2011. Animal monitoring continues to provide valuable information on the longevity of infertility following vaccination against GnRH.
- Adult female wallabies vaccinated once or twice with GonaCon® in March 2007 remain infertile to July 2012.
- Juvenile male tammars were vaccinated intramuscularly 4.5 years ago at or before the onset of puberty. In a few treated animals the testis volume has been slowly increasing in the last 18 months.
- One animal vaccinated once only became fertile during the 2010 breeding season. No further animals in this group have shown signs of sexual behaviour or return to fertility during the 2012 breeding season.
- Adult male tammars vaccinated in March 2009 showed a very rapid decrease in testis volume – these decreases were reflected in decreases in serum testosterone concentrations and increases in the production of GnRH antibodies after vaccination. These males were not fertile during 2010 breeding season, though one adult male given a single vaccination recovered its fertility by the 2011 breeding season. During fertility assessments in 2012, one adult male, vaccinated twice, showed sexual behaviours but no successful mating was recorded.
- Eastern grey kangaroos vaccinated intramuscularly with a single shot of GonaCon® (n=15) in May 2008 have not produced a pouch young in the breeding seasons of 2009, 2010 or 2011. All control females (n=9) have produced young since 2010.
- Delivery of GnRH constructs: We have completed the planned experimental components of two studies in mice using different formulations of a reproductive hormone construct (GnRH conjugated to larger proteins) to which we have added additional immune adjuvants. Analysis of serum immune responses and of the histology of the reproductive tissues is in progress. An abstract has been submitted for consideration for oral presentation at the 7th International Conference on Fertility Control for Wildlife to be held in Wyoming, USA in late August 2012.
- Trials assessing the efficacy of silica nanoparticles as carriers for oral delivery of immunogenic proteins have been undertaken. Variable immune responses after oral delivery of a non-reproductive immunogen (tetanus toxoid) using these particles have been observed in mice. These results have also been included in a second abstract to be presented at the above mentioned conference.
- PhD theses from Melissa Snape and Ian McDonald expect to be submitted during 2012. Manuscripts submitted for publication where possible.

Project team

Dr Lyn Hinds, Dr Sameer Sharma, Steve Henry, Stephanie Haboury, Ian McDonald, Melissa Snape, Dr Lowell Miller (USDA NWRC).

Project partners

Invasive Animals CRC, CSIRO, NSW Department of Primary Industries, USDA National Wildlife Research Centre, Australian National University, University of Queensland.

Further information

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Hinds, LA. (2011) Fertility control for invasive pest mammals – are we making progress? (Invited Plenary Presentation) 8th European Vertebrate Pest Management Conference, Berlin, Germany. ISBN: 978-3-930037-82-7 Page 15.

PhD: GnRH oral construct

PhD Candidate: Ian McDonald, CSIRO

Aim: *To determine the efficacy of oral delivery of constructs of GnRH using rats as a model*

Project duration	March 2007 – June 2012
Status	Completed

Project summary

This project aimed to determine the efficacy of oral delivery of constructs of GnRH using rats as a model. The two main objectives were to assess the immunogenicity of GnRH constructs when delivered intranasally or orally, and determine if this immune response affects reproductive function.

Fertility control has the potential to offer benign, long-term, humane approaches to managing the impacts of overabundant wildlife populations. Contraception methods are considered an ethically more acceptable alternative to culling or translocation when dealing with population control of large mammals, particularly for overabundant native species such as kangaroos.

Current fertility control techniques require the capture and treatment of individual animals which can be stressful for the animals during the capture process and expensive when used on large populations (example: kangaroo populations). For practical use an orally delivered form of fertility control which could be applied strategically to populations in the wild would have broader application and the potential for reducing overabundant wildlife in specific areas.

The initial experiments for this project assessed the immune responses to a range of constructs of GnRH delivered orally to lab rats. A range of protein and/or carbohydrate and lipid constructs which have been designed to stimulate immune responses when given orally, will be tested. Those constructs which induce a significant immune response were assessed for their effects on reproductive function.

Key achievements

- Results from a GnRH injectable vaccine trial have been promising in reducing fertility in both males and females of a range of mammal species. The GnRH vaccine induces the development of antibodies to GnRH and thereafter disrupts reproduction in both sexes. The duration of the effect is often correlated with circulating antibody titres.
- PhD project papers to be submitted and PhD to be conferred.

Project team

Lyn Hinds (CSIRO Entomology), Michael D'Occhio (UQ), Helle Bielefeldt-Ohmann (UQ), Peter Murray (UQ), Andrew Tribe (UQ).

Project partners

Invasive Animals CRC, University of Queensland, CSIRO.

Further information

McDonald, I (2009) Fertility control in macropods – effects on behaviour and welfare. Oral paper at Australian College of Veterinary Scientists Science Week, Gold Coast International Hotel, Gold Coast, Queensland.

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McDonald, I, Tribe, A, Murray, P, Phillips, C (2008) Behavioural and welfare effects of the population management plan of Eastern Grey Kangaroos (Macropus giganteus) at the 'Pines' Golf Course Sanctuary Cove. Paper presented at the 6th International Conference on Fertility Control in Wildlife, York, UK. p 46 (abstract published online).

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Options for camel control in Australia

Project leader: Assoc. Prof Steven Lapidge, Invasive Animals CRC

Aim: *To identify and compare all potential methods of chemical, fertility and biological control for the camel in Australia*

Project: 9.U.1e

Project duration	January 2007 – June 2008
Status	Completed

Project summary

This review, provided to the Desert Knowledge CRC, identified and compared all potential methods of chemical, fertility and biological control for the camel in Australia. The review also provided suggestions for potential landscape-scale delivery options for any promising actives identified. A review of current control methods, namely trapping and shooting, was not undertaken.

An estimated minimum of 750,000 feral camels currently roam over 40% of the Australian mainland. The species is already having significant impacts on Australia's fragile desert ecosystems, with such damage only set to increase as the population swells by 6-10% each year. To curb the current population growth at least 10% of the entire population, or 75,000 individual camels, must be removed each year. Despite some significant effort this is not currently occurring, with commercial harvesting (5,000 animals per annum) and aerial and ground shooting falling short. The only realistic solution to the current problem is some form of species-specific and humane lethal chemical, fertility or biological control. To this point, the Invasive Animals CRC undertook a search for potential actives for the Desert Knowledge CRC as part of their larger camel management project.

Feral camel herd in the Australian outback

Key achievements

- The Invasive Animals CRC submitted report for the Desert Knowledge CRC to use as a foundation for identifying future research and development options for the control of camels in Australia. The report was accompanied by a hard copy of all references used in the review.
- An examination of the literature on camel diseases, such as camel pox virus, contagious ecthyma and papillomatosis, indicates that the infections generally result in high morbidity but not necessarily mortality and this alone may not justify their consideration for use in Australia.
- Key findings from the review published.

Project team

A/Prof Steven Lapidge and Dr Simon Humphrys (Invasive Animals CRC), Charlie Eason (Connovation Ltd NZ), Dr Robert Henzell (Animal and Plant Group SA Department of Water, Land and Biodiversity Conservation).

Project partners

Invasive Animals CRC, Connovation Ltd (New Zealand), Animal and Plant Group SA Department of Water, Land and Biodiversity Conservation.

Further information

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www.feralcamels.com.au
Desert Knowledge CRC Feral Camel Project website

www.invasiveanimals.com

Codes of practice and standard operating procedures for humane invasive animal control

Project 8.T.1

Project Leader: Trudy Sharp, NSW Department of Primary Industries

Aim: *To systematically evaluate the humaneness of currently used invasive animal control techniques using a recently developed assessment model and review and update the existing COPs and SOPs*

Project duration	March 2007 – June 2012
Status	Completed

Project summary

When determining the most appropriate method for managing the impact of an invasive animal, several factors need to be considered. These include efficacy, cost-effectiveness, practicality, target specificity, operator safety and also humaneness (or animal welfare impact).

A model has been developed to allow an assessment of humaneness using a systematic, comprehensive and transparent process that helps to generate consensus among diverse stakeholders. The next logical step is to use this model to assess the humaneness of existing control methods and make this information available to all those involved in invasive animal management. Additionally, the existing Codes of Practice (COPs) and Standard Operating Procedures (SOPs) for the humane control of invasive animals, originally written in 2004–05, are being updated and a system is being implemented to allow periodic review and modification. It is proposed to publish these animal welfare documents and incorporate results into the pest animal control kits.

This project specifically aims to deliver:

- systematic, comprehensive and accessible humaneness assessments of commonly used invasive animal control methods based on a nationally accepted ranking model
- a review and modification of existing COPs and SOPs, establishment of a base for the documents on a suitable website and development of a system to allow periodic review.

It is anticipated that the information gained from the humaneness assessments could be used in a range of invasive animal management applications eg when drafting management plans, during crisis management situations, to support funding proposals, to identify unacceptable methods, to resolve issues where the humaneness of a technique is questioned. Additionally it is expected that access to current national COPs and SOPs will promote and encourage Australia-wide 'best practice' invasive animal management.

Key achievements

- The resulting COP and SOP documents are technically sound, well presented and widely accepted by the target audience. Pest animal practitioners are frequently referred to the COPs and SOPs and several government agencies have made adherence to the documents a condition of funding or of their internal operations.
- All States and Territories have now agreed to the adoption of the COPs and to the phasing out of several techniques categorised in the codes as 'unacceptable'.
- During 2009, the humaneness assessment model was used by an expert panel to assess the relative humaneness of currently used control pest animal control methods in Australia. The SOPs were used as the best practice methods during this process. The report for this project has been prepared and has been published on the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) website.

  The model has also been applied in a project to assess the humaneness of control methods used in New Zealand and is currently being used to assess pest control methods in the UK.
- The model has been formally endorsed by the Vertebrate Pests Committee, the Australian Animal Welfare Strategy Wild Animals Working Group, DAFF and RSPCA Australia. It is currently under consideration by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for incorporation in their product registration process.
- The final report for the project to assess the humaneness of commonly used invasive animal control methods has been published as a hardcover document and on the website: http://www.daff.gov.au/animal-plant-health/welfare/aaws/humaneness-of-pest-animal-control-methods
- The majority of the humaneness assessments of currently used pest animal control methods have now been published on the www.feral.org.au website. The final two species to go up (rodents and deer) will be finalised and published by December 2012.
- A review of the current COPs and SOPs (Sharp & Saunders, 2005) is underway with more than 30 SOPs already reviewed. As well as revising the current 2005 versions, new COPs and SOPs have been written for a range of species including cane toads, rodents, camels and donkeys. The revised COPs and SOPs along with the new documents will be published on the www.feral.org.au website by December 2012.

Project partners

Invasive Animals CRC, NSW Department of Primary Industries, ABARES, Australian Animal Welfare Strategy (AAWS), RSPCA Australia, University of Sydney, Department of Sustainability, Environment, Water, Population and Communities.

Further information

Sharp, T and Saunders, G (2011) A model for assessing the relative humaneness of pest animal control methods (Second edition). (Department of Agriculture Fisheries and Forestry: Canberra, ACT). http://www.daff.gov.au/animal-plant-health/welfare/aaws/humaneness-of-pest-animal-control-methods

Sharp, T and Saunders, G (2008) A model for assessing the relative humaneness of pest animal control methods. (Australian Government Department of Agriculture, Fisheries and Forestry: Canberra, ACT).

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Feasibility of humane non-surgical sterilisation of female mammals

Project 9.T.6

Project Leader: Professor R John Aitken, University of Newcastle

Aim: *To engineer reagents for non-surgical sterilisation of female mammals*

Project duration	August 2010 – May 2012
Status	Completed

Project summary

The purpose of this project is to engineer reagents for the non-surgical sterilisation of female mammals. The reagents incorporate a targeting peptide, generated using random peptide phage display, coupled through a reducible chemical linkage to xenobiotics that will eradicate the target cells through a redox cycling mechanism.

Project outcomes are to:

- deliver an optimised strategy to the Invasive Animals CRC for the non-surgical sterilisation of male and female mammals coupled with proof-of-concept data in laboratory animals (rats, mice)
- deliver reagents that have been specifically developed for use in rabbits.

The University of Newcastle possesses the necessary know-how in the areas of germ cell biology, phage display technology and medicinal chemistry to deliver on this approach. Coupled with the Invasive Animals CRC's expertise in the management of invasive animal populations, there is the potential to achieve a major new technology for pest animal control.

Using the mouse and rabbit as model species the hypothesis will be tested by targeting the primordial follicle population with phage-xenobiotic constructs which will lead to a state of permanent sterility in the treated animals.

The approach is based on two fundamental concepts:

1. The use of random peptide phage display libraries to develop reagents that specifically target the germ line.
2. The use of redox-cycling thiolated xenobiotics that are coupled to the targeting peptide via a disulphide bond that once cleaved at the surface of the germ line by protein disulphide isomerases (PDI) will release the xenobiotic to the interior of the cell.

This redox cycling strategy will:

a) result in a rapid amplification of the cytoxic effect (one molecule of a quinone xenobiotic would, for example, generate many thousand molecules of reactive oxygen)
b) utilise the fact that both male and female germ cells are unusual in possessing PDIs on their outer surface
c) capitalise on the unique susceptibility of male and female germ cells to oxidative stress.

Key achievements

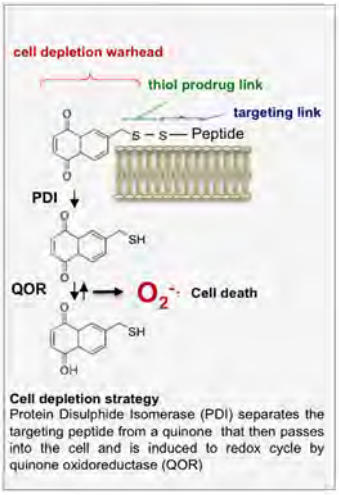
- Library of bacteriophage clones targeting the primordial follicle populations of target species including mouse, rat and rabbit generated.
- Bacteriophage clones against contraceptive targets in the male mouse including Sertoli cells and spermatogonia generated.
- Bacteriophage targeting primordial follicles shown to deplete the ovarian reserve by more than 90% in vivo.
- Extensive screening of chemical libraries has succeeded in isolating a cohort of chemicals that are selectively cytotoxic towards our target cell types. All of these chemicals have demonstrated selective cytotoxity in vitro and some have had their activity confirmed in vivo.
- These results herald a new chapter in the development of highly selective reagents for the non-surgical sterilisation of pest animal species. Provisional patents have been filed to protect this IP.

Project team

Prof R John Aitken, Prof Eileen McLaughlin

Project partners

Invasive Animals CRC and University of Newcastle.



Cell depletion strategy
Protein Disulphide Isomerase (PDI) separates the targeting peptide from a quinone that then passes into the cell and is induced to redox cycle by quinone oxidoreductase (QOR)

Further information

Edina, KA, Hennery, CC, Aitken, RJ Selection of peptides targeting the human sperm surface using random peptide phage display identity ligands homologous to ZP3. *Biol Reprod* (November 2000) 63(5):1396-1402

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Goal 9: Forecasting and responding to potential, new, expanding or emerging invasive pests

TARGET: Reduced risks of economic losses, environmental damage and social stress by forecasting and responding to potential, new or emerging invasive animal problems

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
9.1	Information systems that improve coordination and evaluation of effort on a national, regional and local level	2012	12.D.1
9.2	Validated risk models, systems and assessments	2011	9.D.1, 9.D.9. PhD (monitoring tools)
9.3	Cost-effective early warning detection and response options to restrict introductions or the range of invasive animals	2011	9.D.2, 8.D.4, 9D9b, 9.T.4, 9.D.10
9.4	Delivery of improved technical and strategic packages for managing invasive species that are hosts for pathogens that threaten humans, livestock or native fauna	2012	8.D.1, 8.D.3, 8.D.4, 9.D.9b
9.5	Management recommendations for endemic and exotic diseases of invasive animals	2011	8.D.3, 8.D.4, 12.D.7

* As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- Validating and refining risk-assessment models (9.D.1, 9.D.9 – Completed)
  - PhD: Optimal decision-making in conservation: management, uncertainty and monitoring (Eve McDonald-Madden – Completed)
- Development of a national pest animal genotyping facility (9.D.2 – Completed)
- Developing a toolbox of early detection and rapid response options for new or spreading pest invasions (9.D.10 – Completed)
- Incursions and interceptions of exotic vertebrates in Australia (9.D.9b – Completed)
- Identifying high-risk exotic disease sites (8.D.4 – Completed)
  - PhD: understanding and mitigating domestic pig and wildlife interactions (Hayley Pearson – Completed)
- Starlings in Western Australia (9.T.4 – Completed)
- Pathogens in vertebrate pests of Australia (8.D.3 – Completed)

Tactical control

- Cyanide pig and fox baits for monitoring(8.D.1 – Completed)

Relevant projects included under other goals

Knowledge and tools

- Mapping invasive animals of Australia (Project 12.D.1 – Completed)
- Predict the distribution of key vertebrate pest species in 2020 under a future climate scenario (12.D.7 – Completed)
  - PhD: Invasive Species, endemic species and geographic distributions. Ecology behaviour and physiology of the highly invasive lizard, *Lamphropholis delicata* (Scott van Barneveld – Completed)

Validating and refining risk assessment models

Project Leader: Dr Mary Bomford, ABARES

Aim: *To develop validated risk models to enable more accurate border and post-border risk assessment.*

Projects 9.D.1 and 9.D.9a

Project duration	February 2006 – May 2009
Status	Completed

Project summary

The goal of this project was to establish a validated system to assess and prioritise the risk of establishment and pest potential for invasive animals existing in Australia and those that could potentially be imported.

This project had four main components:

1. developing risk assessment models for exotic vertebrates (ABARES)
2. validating these models and assessing a wide range of exotic animal species (Department of Agriculture and Food WA)
3. developing web-enabled software for climate matching for use in risk assessments (BRS)
4. a workshop to review government risk assessment processes for the import and keeping of exotic vertebrates in Australia.

The Bomford risk assessment models and CLIMATCH software were developed and refined. DAFWA further explored the ability of these models to predict public safety, establishment and pest risks across a full range of species and risk levels. The variety of species included animals that have not yet entered Australia, animals currently kept in Australia as pets, livestock or in zoos and animals that are already widely established in the wild here. Livestock species assessed were chital, red and fallow deer, domestic sheep and ostrich.

Key achievements

- Dr Bomford's models for establishment of exotic vertebrates were published by the Invasive Animals CRC as Risk Assessment Models for Establishment of Exotic Vertebrates in Australia and New Zealand.
- DAFWA's risk assessments testing the new Bomford models were officially endorsed by the VPC. A final report was published by the Invasive Animals CRC as Assessment and Prioritisation of Risk for 40 Exotic Animal Species.
- State and Commonwealth agencies use the risk assessments in policy development and legal prosecutions. For example, the red-eared slider assessment was used in the successful prosecution of a pet shop owner in South Australia illegally selling sliders.
- CLIMATCH, a web-based version of the CLIMATE software, was produced and enables access by state, national and international experts, thereby increasing the consistency and transparency of risk assessments for invasive animals and other pests. The software predicts the likely range of an exotic species using a simple matching algorithm to compare the climate in known locations with that in an invaded country.
- A national workshop was held in 2009 in Canberra addressing risk assessment protocols and issues. Proceedings were published, including recommendations for a national community of expertise and an improved system for regulating the import and keeping of exotic animals in Australia, to ensure we are adequately protected from new pest incursions.

Project team

Dr Mary Bomford, Dr Greg Hood and Joe Crombie (ABARES), Marion Massam, Win Kirkpatrick and Amanda Page (DAFWA) and Dr Wendy Henderson (Invasive Animals CRC).

Project partners

Invasive Animals CRC, ABARES, Department of Agriculture and Food WA.

Further information

Bomford, M, Barry, S, Lawrence, E (2010) Predicting establishment success for introduced freshwater fishes: a role for climate matching. *Biological Invasions*, Volume 12, Number 8, pp. 2559-2571.

Massam M, Kirkpatrick, W and Page, A (2010) Assessment and prioritisation of risk for 40 exotic animal species, Invasive Animals CRC, Canberra.

Bomford, M, Kraus, F, Barry, SC and Lawrence, E (2009) Predicting establishment success for alien reptiles and amphibians: a role for climate matching. *Biological Invasions* 11, 713–724.

Bomford, M, Darbyshire, RO and Randall, L (2009) Determinants of establishment success for introduced exotic mammals. *Wildlife Research* 36, 192–202.

Henderson WR (2009) Workshop Proceedings: Risk assessment processes for import and keeping of exotic vertebrates in Australia. 25-26 February 2009, Canberra. Invasive Animals CRC, Canberra.

An interface for running climate-matching algorithms (September 2009) http://adl.brs.gov.au:8080/Climatch/

Bomford, M (2008) Risk assessment models for establishment of exotic vertebrates in Australia and New Zealand. Invasive Animals Cooperative Research Centre, Canberra.

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PhD: ecology and physiology of invasive lizards

Dr Scott van Barneveld

Aim: *To study the ecology, behaviour and physiology of the highly invasive lizard,* Lamphropholis delicata

Project duration	January 2007 – December 2011
Status	Completed

Project summary

The rainbow or plague skink *Lampropholis delicata* is a very common and familiar garden lizard along the east coast of Australia. It is an Australian native lizard that has become invasive overseas. It was introduced to Hawaii in 1900, New Zealand in the 1960s and most recently to Lord Howe Island in the 1980s.

Lampropholis delicata is extensively established, highly abundant and spreading throughout these islands. It is believed that the lizard is causing significant ecological damage in NZ, Hawaii and on Lord Howe Island, particularly via the displacement of endemic lizards and predation upon endemic invertebrates.

The invasive *Lampropholis delicata* has been identified as a key threatening process to Lord Howe Island's biodiversity and value as a World Heritage Area.

Predicting which species may become successful invaders is a central theme of invasion biology. Lampropholis skinks provide an excellent model to investigate the differences between invasive species and non-invaders, because the genus Lampropholis contains not only the invasive rainbow skink, but also some very rare species.

Looking into the differences between these species provides insight into traits of invasive species, and helps predict which species may pose a greater risk of invasion.

The research will provide data to be applied to risk assessment models to predict the invasion potential of other species.

Key achievements

- Completed data collection and presently have several draft papers in review.
- Up to four international peer-reviewed journal articles to be published from this research. The first manuscript has been submitted for review and is currently being amended for resubmission.
- PhD conferred.

Project partners

Invasive Animals CRC, University of Sydney, NZ Department of Conservation.

Lampropholis delicata eating another L. delicata by J. Luke.

Further information

van Barneveld, S (2012) PhD thesis 'Invasive Species, endemic species and geographic distributions'.

www.invasiveanimals.com

PhD: decision-making in conservation: management, monitoring and evaluation

Dr Eve McDonald-Madden

Aim: *To devise tools for detecting change in pest animal populations and the threatened species being protected, reliably and cost effectively, and placing monitoring within a robust management framework*

Project duration	January 2005 – December 2008
Status	Completed

Project summary

This idea of integrating monitoring into a decision theory approach for management is a relatively new innovation in conservation management and provides a unique opportunity for the application of this work to both the management of pests in other countries, for example New Zealand, and utilisation for other management scenarios.

This project developed new theory and mathematical methods to incorporate optimal monitoring scenarios and economic information into a decision theory approach for the management of pest species in Australia. The work was based on existing datasets on overabundant species.

Key achievements

- Working at the cross-roads of statistical and mathematical analysis and ecology, to improve conservation decisions eg deciding how much money to invest in fox control when it is unknown how foxes will respond to management or how their prey will benefit.
- To aid better decision-making in these situations, use of a suite of analysis techniques that are largely novel to conservation and pest control including:
  - 'Decision Theory', a concept initially used to maximise the effectiveness of scarce military resources while dealing with the uncertainties always present in war.
  - Artificial Intelligence (AI), the science of making intelligent machines to efficiently search for optimal conservation strategies.
  - Cross-pollination of ideas from Ecology, Decision Theory and AI has enabled exploration of complex ecological systems and provided novel and practical management solutions.
- Publications in internationally-renowned journals such as *Nature*, *Science*, *Nature Climate Change*, Proceedings of the National Academy of Science and *Trends in Ecology and Evolution*.

Project Partners

Invasive Animals CRC, University of Queensland.

Further information

McDonald-Madden, E (2009) PhD thesis 'Optimal decision-making in conservation: management, uncertainty and monitoring'.

Game, E, Bode, M, McDonald-Madden, E, Grantham, HS, Possingham, HP (2009) Dynamic marine protected areas can improve the resilience of coral reefs. *Ecology Letters* 12: 1-11.

McDonald-Madden, E, Gordon, A, Wintle, B, Grantham, H, Walker, S, Carvalho, S, Bottrill, M, Joseph, M, Ponce, R, Stewart, R, Possingham, HP (2009) 'True' conservation progress. *Science* 323: 43-44.

McDonald-Madden, E, Baxter, PWJ, Possingham, HP (2008) Making robust decisions for conservation with restricted money and knowledge. *Journal of Applied Ecology* 45: 1360-1638.

McDonald-Madden, E, Bode, M, Game, ET, Grantham, H, Possingham, HP (2008) The need for speed: informed land acquisitions for conservation in a dynamic property market. *Ecology Letters* 11: 1169-1177.

McDonald-Madden, E, Baxter, PWJ, Possingham, HP (2008) Subpopulation triage: How to allocate conservation effort among populations. *Conservation Biology* 22: 656-665.

Chadès, I, McDonald-Madden, E, McCarthy, MA, Wintle, B, Linkie, M, and Possingham, HP (2008) When to stop managing or surveying cryptic threatened species. Proceeding of the National Academy of Sciences 105: 13936-13940.

Game, ET, McDonald-Madden, E, Puotinen, ML and Possingham, HP (2008) Should we protect the weak or the strong? Risk, resilience and the selection of marine protected areas. *Conservation Biology* 22: 1619-1629.

Bottrill, M, Joseph, LN, Carwardine, J, Bode, M, Cook, C, Game, ET, Grantham, H, Kark, S, Linke, S, McDonald-Madden, E, Pressey, RL, Walker, S, Wilson, KA and Possingham, HP (2008) Is conservation triage just smart decision-making? *Trends in Ecology and Evolution* 23: 649-654.

National pest animal genotyping facility

Project Leader: Prof Stephen Sarre, University of Canberra

Aim: *To establish a genotyping facility that will provide a service to management agencies for small and large-scale population genetic analyses of pest animals in Australia*

Project 9.D.2

Project duration	May 2006 – December 2011
Status	Completed

Project summary

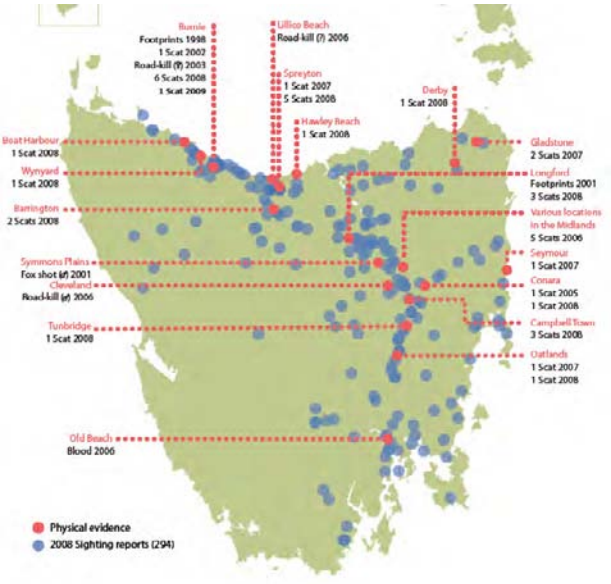
This project established a national facility using cutting-edge DNA technology to identify and genetically characterise key invasive species from tissue or trace samples collected in the field. The applications for this technology include detection of cryptic species, defining units of control, determining barriers to dispersal, estimating population size and other population-level studies for management purposes.

The focus was on the development of DNA markers for two of the CRC's target vertebrate pests, cats and pigs, the improvement of technologies for foxes and deer, and the development of processing approaches that will enable genotyping of those animals to be applied to real control situations in a cost effective and efficient manner.

Currently, the application of molecular approaches to wildlife analysis in Australia is piece-meal, dependent on specific project funding, and often reliant upon post-graduate students for method development and sample analysis. Commonwealth and state agencies would use such technologies but find it difficult to fund the initial development or to obtain ongoing access to the technology.

Population genetic analyses using DNA can provide essential ecological information for the management of pest animals. They are now being applied to the sampling and location of low density and cryptic animals, the analysis of mating systems and dispersal characteristics, population censusing, determining the degree of connectedness among sub-populations as units of eradication or control, assessing species distributions, and predator dietary analysis. Given this range of application, the strength that molecular approaches could add to target control more effectively is substantial.

This project relates to demonstration sites throughout goals one to eight.



Genotyping helps identify and genetically characterise key invasive species
(image: Tasmanian Department of Primary Industries, Parks, Water and Environment)

Key achievements

- Multiplex microsatellite genotyping for foxes, cats, fallow deer and pigs has been developed and/or optimised. These DNA technologies have been used to analyse feral pigs and fallow deer on Kangaroo Island in South Australia and feral pig populations in the Blue Mountains, NSW.
- The team provides ongoing support to the Tasmanian fox eradication project through technical advice, DNA primer development, project direction, facility development, project direction, facility acquisition and sample storage. More than 5,000 scats have been screened for fox DNA as part of this project. Of those, 61 have been identified as fox-positive and 10 have yielded identifiable and unique genotypes. Results will be used to define management units, estimate dispersal among mainland foxes, and assign possible points of origin for Tasmanian foxes (see also Goal 1 summaries).
- Large-scale sampling of cats across the continent is continuing with the recruitment of approximately 100 recreational hunters and Government officers to submit feral cat tissues collected as part of their normal activities. To date, more than 220 tissue samples have been received from 20 sites.
- Short course in genetic applications to wildlife management targeting developed specifically for wildlife managers in government agencies. The first course was run in October 2011.
- Publications for Tasmanian fox study completed.
- Sample collection and analysis of genetic variation for cats across Australia completed.
- Population genetics publications for cat DNA population genetics study completed.

Project team

Prof Stephen Sarre, Niccy Aitken, Anna MacDonald, Nancy FitzSimmons (UC), Dr Oliver Berry (UWA).

Project partners

Invasive Animals CRC, University of Canberra, University of Western Australia.

Further information

MacDonald, AJ and Sarre, SD (2011) Genetic Species Identification and Microsatellite Genotyping of a Putative Fox Skull and Fox-Positive Scats Collected in Tasmania. Report to the Department of Primary Industries, Parks, Water and Environment, Tasmania.

MacDonald, AJ and Sarre, SD (2011) DNA Species Identification and Microsatellite Profiling of Fox Scats Collected Pre- and Post-Control in Rubicon State Forest, Victoria. Report to the Arthur Rylah Institute for Environmental Research.

Berry, O and Kirkwood, R (2010) Measuring recruitment in an invasive species to determine eradication potential. *Journal of Wildlife Management* 74:1661-1670.

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Early detection and social response to incursions

Project Leader: Prof Stephen Sarre, Prof Deborah Blackman, University of Canberra

Aim: *To develop techniques and strategies for the early detection and monitoring of key invasive vertebrates (including DNA approaches)*

9.D.10

Project duration	July 2010 – June 2012
Status	Completed

Project summary

The study of the response to the appearance of foxes in Tasmania has highlighted many issues which directly affect the likelihood that the eradication of foxes can be achieved in that State. A number of strategies to define and contain the threat of foxes in Tasmania have been attempted over the past 10 years, with the key issues being the difficulty in detecting foxes at low densities and the inability to carry out a sufficiently broad and intense search for foxes and/ or baiting program due to limited resources.

The fox issue is highly contentious in Tasmania and this has impacted on the amount of community and political support that the program receives. One of the biggest issues looking forward is that there is currently no exit strategy for the eradication program. An insight gained from the data is that the creation of an exit strategy is more likely to be informed by the lack of political support or lack of funding than because the scientific evidence dictates that either eradication has been achieved or that the program needs to move to one of control rather than eradication. We note that the recent creation of a new Invasive Species Branch incorporates the Fox Eradication Program as one of its programs was one of the key recommendations arising from our work as the basis for greater support within the Department.

These changes have formed part of the ongoing discussions between Prof Blackman and the Fox Eradication Program.

This project was aimed at identifying the key elements of the response to the fox incursion in Tasmania that have improved or held back the program and develop a toolbox of approaches for future incursions in other locations based on the lessons learnt from the case study of this particular incursion. One of our first steps in analysing the data gained from the interviews we have conducted has been to identify important turning points in the attempt to eradicate foxes. These include changes in the management and focus of the program, the involvement of the Invasive Animals CRC and their application of DNA technologies to the detection problem, the completion of a key independent review that recommended a more strategic approach to baiting and the adoption of this baiting program.

We have begun writing up our findings focusing on that role science and scientists have played in this situation and how governance has influenced the program. Key findings are being written up for publication on topics which include problem identification, risk management and preparedness, community engagement, human resource management and doubting.

Key achievements

- Event timeline and identification of key decision points created.
- Presentation to Fox Eradication Program Steering Committee (22 August 2012) discussing key findings.
- Advice given on the development of the recent community engagement survey undertaken by the newly created Invasive Species Branch.
- Discussions between the team and the Fox Eradication Program are ongoing.
- A new project has emerged exploring policy development issues in more depth. This project is underpinned by the 'toolbox' project findings and the combined research output are of great interest to the new branch management.

Project team

Prof Stephen Sarre, Prof Deborah Blackman, Amy Corcoran (University of Canberra), Dr Glen Saunders (NSW Department of Primary Industries)

Project partners

Invasive Animals CRC, NSW Department of Primary Industries, Western Australian Department of Agriculture and Food, University of Auckland, University of Canberra.

Further information

Saunders, G, Lane, C, Harris, S and Dickman, C (2006) Foxes in Tasmania: A report on the incursion of an invasive species. Invasive Animals CRC, Canberra.

Invited keynote speech – 'To hunt or to analyse: that was the question' – delivered at Queensland Pest Animal Symposium (2 August 2012).

Workshop entitled 'Influencing conversations: understanding power to effect change' developed for Invasive Animals CRC students.

Publications in progress:

'Tasmanian foxes: where does the doubt emerge? Will be presented but not published at the Australian and New Zealand Academy of Management conference 5-7 December 2012.

'How identifying and managing stakeholder expectations supports effective feral pest eradication'.

'The role of effective governance in feral pest invasion: lessons from Tasmania'.

'When Management and Science fail to meet: The Fox Eradication Program in Tasmania'.

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Incursions and interceptions of exotic pests

Project Leader: Dr Wendy Henderson, Invasive Animals CRC

Aim: *To report on recent incursion and interception events (from the past decade) in terms of what species have been detected, how many, where they were and how they were dealt with*

Project 9.D.9b

Project duration	January 2010 – July 2011
Status	Completed

Project summary

Data on recent incursions of invasive animal species into Australia have not been previously collated on a national scale. The aim of this project was to report on recent incursion and interception events (from the past decade) in terms of what species have been detected, how many, where they were and how they were dealt with. Data from the Australian Government and each relevant state and territory agency is being collated to give a national picture of what vertebrate species have been detected both pre- and post-border. Species detected and intercepted at the border include cargo/transport stowaways and smuggled animals. Information on post-border species detected includes animals in the wild, in pet shops, seized from private keeping, stolen from zoos or translocated on transport vehicles. Information on incursion responses has also been collected including how agencies dealt with the animals, follow-up prosecutions, public awareness campaigns and so on. This project is a progression from Project 9.D.9a, which looked at risk assessment processes in Australia, particularly regarding assessing exotic animals proposed for importation. It should help inform biosecurity policy by providing critical information on exotic vertebrate species and their potential pathways for entry into the Australian environment.

Two tiny black-spined toads (Bufo melanostictus) were detected by Cairns port stevedores and dealt with by the Australian Quarantine and Inspection Service in 2011 (image courtesy of AQIS)

Key achievements

- National collation of incursion data, including different entry pathways, from state/territory agencies, AQIS and Customs, analysed and published.
- Proceedings published from a national workshop on incursion/interception information sharing and management.
- Inclusion on the VPC Incursions Working group to co-develop a national incursions response plan.
- Secure website set up to allow inter-agency information sharing on incursions and interceptions.

Project team

Dr Wendy Henderson, Dr Mary Bomford and Dr Phill Cassey.

Project partners

Invasive Animals CRC, University of Adelaide, State and Territory agencies and Vertebrate Pest Committee.

Further information

Henderson, W and Bomford, M (2011) Detecting and preventing new incursions of exotic animals in Australia. Invasive Animals Cooperative Research Centre, Canberra.

Henderson, W, Bomford, M and Cassey, P (2011) Managing the risk of exotic vertebrate incursions in Australia. *Wildlife Research* 38: 501–508.

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Identifying high-risk exotic disease sites

Project Leader: Peter West, NSW Department of Primary Industries

Aim: *To map high-risk sites of exotic disease outbreak in feral populations*

Project 8.D.4

Project duration	December 2008 – June 2009
Status	Completed

Project summary

Feral and wild animals are potential hosts for the maintenance and transmission of many exotic diseases in Australia. There is uncertainty regarding the level of contact between feral animal populations and sites of exotic disease incursion, which might result in poor decision making in the event of an exotic disease emergency, and affect the size and severity of an exotic disease outbreak.

Current populations of feral animals (namely feral pigs, feral goats, feral deer, foxes and wild dogs) were identified that may become exposed to exotic livestock diseases if introduced to Australia. Sites of possible disease introduction and spread at the national level were then identified using existing datasets for disease hosts, including feral animals (and livestock where available).

This project presented a novel approach to examining spatial datasets on sites of disease risk with regard to potential feral and wild animal disease hosts. As improved datasets are made available, there should be further examination of potential exposure groups and sites of possible disease introduction/detection.

The inclusion of other possible disease risk sites from domestic activities, such as carcass disposal locations, livestock transport routes and livestock movement patterns may also add value to the assessment, providing additional information for prioritisation of disease surveillance and improvements to feral animal control practices.

The project has contributed to mapping projects under Goal 12.

Key achievements

- Database of potential exotic disease incursion sites in Australia based on import risk analysis documents for animals and animal products established.
- Data on locations of these potential disease introduction sites with existing data on invasive animals assessed.
- Final report to the Wildlife Exotic Disease Preparedness Program identifying sites of potential disease introduction with recommendations for targeted exotic disease surveillance, improved management of feral animals, and improved data accessibility.

Project partners

Invasive Animals CRC, Wildlife Exotic Disease Preparedness Program – Department of Agriculture, Fisheries and Forestry, NSW Department of Primary Industries.

Further information

West P (2009) Feral animals as hosts of exotic disease incursion. Final report to WEDPP, NSW DPI (unpublished).

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PhD: understanding and mitigating domestic pig and wildlife interactions

PhD candidate: Hayley Pearson

Aim: *To provide detailed information on the risks to the pig industry posed by wildlife.*

PhD (feral pig management)

Project duration	February 2007 – February 2011
Status	Completed

Project summary

The project, funded by Australian Pork Limited (APL), aimed to provide detailed information on the risks to the pig industry posed by wildlife. This was achieved through assessing the level of interactions occurring between domestic pigs and a number of invasive species (including the European starling, feral pigs, rodents and feral cats), as well as obtaining samples from captured wildlife to analyse for specific diseases of concern to the pork industry. Some of the diseases to be monitored, including Salmonella and Campylobacter, are a human health risk, either directly from the animal or through infected pork consumption. Findings will provide an assessment of risk for each wild animal species targeted to determine the hazard posed to the commercial pig industry based on disease status and movement data. The project resulted in refined strategies for control and eradication of diseases on pig farms and likely the addition of strategic pest control to currently accepted farm protocols.

A flock of starlings at a piggery

Key achievements

- Large-scale postal survey of APL members to assess key wildlife species and diseases of concern completed. The survey results have since been prepared for publication.
- European starling disease surveys — Salmonella, E. Coli Camplobacter, West Nile Virus and Newcastle Disease Virus — completed in key South Australian piggeries.
- Majority of the disease sampling has been completed, including disease surveys in rodents inhabiting Victorian and South Australian piggeries.
- PhD submitted March 2012.

Project team

Hayley Pearson, A/Prof Jenny-Ann Toribio (U Syd), Dr Marta Hernandez-Jover (U Syd/CSU), A/Prof Steven Lapidge (Invasive Animals CRC) and Dr Pat Mitchell (APL).

Project partners

Invasive Animals CRC, University of Sydney, Australian Pork Limited.

Further information

Pearson, HE (2012) Understanding and mitigating the risk of pathogen transmission from wild animals to domestic pigs in Australia. Unpublished PhD thesis. Faculty of Veterinary Science, The University of Sydney

Pearson, HE, Lapidge, SJ, Hernández-Jover, M and Toribio, JA. (in review) Producer reported wildlife incursions on commercial piggeries. *Australian Veterinary Journal.*

www.invasiveanimals.com

Pathogens in vertebrate pests of Australia

Project Leader: Dr Wendy Henderson, Invasive Animals CRC

Project 8.D.3

Aim: *To identify significant pathogens potentially being carried by feral animals in Australia*

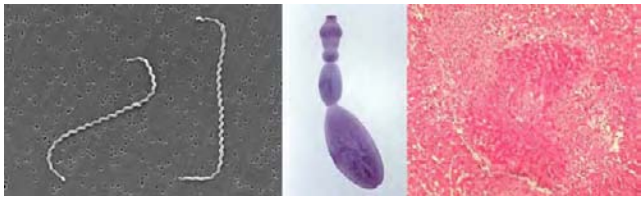
Project duration December 2008 – June 2009
Status Completed

Project summary

This project involved a literature review of published articles on pathogens or disease identified in the vertebrate pest species of interest to the CRC, namely, cane toads, carp, feral cats, feral goats, feral pigs, foxes, rabbits, rodents and wild dogs. Australian research published between 1990 and 2009 was reviewed.

A range of bacterial, viral, fungal, helminth and protozoan pathogens have been identified: many of these have broad host specificity, so could affect a wide range of species. Pathogens that could significantly impact on native species include *Toxoplasma gondii* (causing toxoplasmosis), *Echinococcus granulosus* (causing cystic hydatidosis) and Asian fish tapeworm *Bothriocephalus acheilognathi*. Pathogens with serious zoonotic potential include Salmonella, *Coxiella burnetti* (causing Q fever), *Brucella* (causing brucellosis), Leptospira (causing leptospirosis), Murray Valley encephalitis virus and *Angiostrongylus cantonensis* (causing neurological disease). Pathogens particularly significant to livestock include *Neospora caninum*, porcine parvovirus, *T. gondii* and *Brucella* (all causing reproductive failure) and E. granulosus.

While the greatest potential threat of disease from vertebrate pests may be from future exotic outbreaks such as foot-and-mouth disease, it is clear many other pathogens of concern currently occur in feral populations. The occurrence of such a wide range of pathogens emphasises the need to effectively monitor and manage populations of vertebrate pests to avoid the spread of disease into livestock, native species or humans.



Key achievements

- CRC technical report on pathogens in invasive animals published.

Project partners

Invasive Animals CRC, University of Canberra.

Further information

Henderson W (2009). Pathogens of vertebrate pests in Australia. Invasive Animals CRC, Canberra.

www.invasiveanimals.com

Cyanide pig and fox baits for monitoring

Project Leader: Dr Matt Gentle, Queensland DAFF

Aim: *To reduce risk of disease transfer from invasive animals to livestock and humans*

Project 8.D.1

Project duration	March 2007 – June 2011
Status	Completed

Project summary

This project contributes to management recommendations for endemic and exotic diseases of invasive animals.

Connovation Ltd and Queensland Department of Agriculture, Fisheries and Forestry trialled cyanide baits for suitability for use with pigs and/or foxes in the field. Cyanide baits may be useful in a disease outbreak, restricting dispersal of animals from the baiting site, and allowing a method of monitoring animals for disease.

Pen trials were done on feral pigs using a variety of bait packages and cyanide formulations (powder, paste and liquid). Although cyanide has been shown to kill anaesthetised pigs in less than 20 minutes, the results with pigs not anaesthetised indicated that, with current encapsulation technology and at 'pig-size' doses, it appears difficult to disguise the cues associated with cyanide, given its distinctive smell and taste. Given these difficulties, it was decided to cease testing any further cyanide packages on feral pigs until these issues can be overcome.

The project then focussed on using cyanide baits with foxes. Early results indicated that when baits are consumed, foxes are highly susceptible to cyanide. However, subsequent work showed that despite free-feed baits being readily consumed, baits were largely rejected by foxes following the addition of cyanide. Observations indicate that the detectability, environmental stability, and desiccation/contamination of the paste from the surrounding soil reduced the palatability and effective delivery of cyanide to foxes. Odour cues were surmised to be largely responsible for foxes detecting and rejecting cyanide baits.

Key achievements

- Pen trials with pigs were done using a variety of bait packages, ejectors and cyanide formulations (powder, paste and liquid). Despite considerable successes, the results indicated that the distinctive smell and taste of cyanide deters pigs from consuming lethal doses.
- Lab emissions testing, and pen and field trials with foxes were completed, using several bait-cyanide combinations. As with pigs, it was concluded that cyanide emissions may be deterring foxes from consuming baits. Future research should include further modifications to improve cyanide encapsulation either physically or chemically.
- Final report submitted on applicability of cyanide for use in the field with pigs and foxes.
- Final CRC technical report published and posted on web: http://www.feral.org.au/development-of-cyanide-for-feral-pig-and-fox-control/

Project team

Dr Matt Gentle (Qld DAFF), Duncan MacMorran, Prof Charlie Eason (Connovation Ltd).

Project partners

Invasive Animals CRC, Queensland Department of Agriculture, Fisheries and Forestry, Connovation Ltd.

Further information

Gentle, M, Eason, C, MacMorran, D, Aylett, P and Aster, D (2011) Development of cyanide for feral pig and fox control. Invasive Animals Cooperative Research Centre, Canberra.

Aster, D, Boot, S and Gentle, M (2009) Development of cyanide bait for rapid disease sampling and surveillance of wild animals Supplementary Report to WEDPP (unpublished).

Aster, D, Boot, S and Gentle, M (2008) Can we develop a cyanide bait for foxes? 2nd Queensland Pest Animal Symposium, Cairns, 19–22 October 2008 (unpublished).

www.invasiveanimals.com

Goal 10: Growth in invasive animal control industries

TARGET: Growth in Australian invasive animal control industries

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
10.1	A registration, marketing, export and community uptake package for reducing the impacts of invasive pest animals	2011	10.U.14, 10.U.14c, 2.U.1, 2.U.5e, 2.U.2e, 2.U.3e, 2.U.4e, 6.U.1, 10.U.2, 7.T.2, 7.T.12e.

* As per contract variation approved by DIISRTE

Projects

Overarching project

- Commercialisation management (10.U.14 – Current)

Relevant projects included under other goals

Tactical control

- Foxecute® and Dogabate® fox and wild dog bait (1.T.3 – Current)
- Blue Healer® antidote (10.U.14 – Current)
- New feral pig toxins, baits and delivery systems (2.U.1, 2.U.5e, 2.U.2e, 2.U.3e and 2.U.4e – Current)
- Feral cat bait uptake in eastern Australia (6.U.1, 10.U.2 – Completed)
- Fertility control projects (9.T.1 – Current)
- Shelf-stable RHDV product (7.T.2 – Current)
- Carbon monoxide pressure fumigator (10.U.14c – Current)

Commercialisation management

Project 10.U.14

Project Leader: Dr Simon Humphrys, Invasive Animals CRC

Aim: *To accelerate end-user-adoption of Invasive Animals CRC's research*

Project duration	September 2005 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

The commercialisation management project's aim is to accelerate the transfer of Invasive Animals CRC's research outputs into marketable outcomes and their adoption by end-users. It will achieve this by strategically directing resources toward critical research development and technology transfer bottlenecks.

To advance the adoption of Invasive Animals CRC research outputs and outcomes, this project's objectives are to:

- attract additional grant funds leveraging CRC resources
- professionally negotiate research and commercial agreements and contracts
- effectively manage projects, regulatory work and intellectual property, and
- provide market analysis (barriers and drivers) and business development/management expertise.

These objectives will result in:

- value adding to Invasive Animals CRC and participant intellectual property
- coordinated national and international registrations that reduce research replication
- more efficient commercialisation, market delivery and uptake of Invasive Animals CRC products, and
- the implementation of social and economic instruments that promote regional scale coordinated and integrated invasive animals management.

This project will contribute positively toward a primary aim of the Invasive Animals CRC, which is to deliver new, innovative, market researched products that meet a market need and have been demonstrated in practice with scientific rigour to be welcomed additional tools in reducing the impacts of invasive animals.

Key achievements

- More than $2 million in external grants attracted.
- More than $5 million worth of projects managed, aimed at delivering eight new products to land managers and producers.
- All regulatory trials for five new products successfully managed to completion.
- APVMA begins the assessment of the new active approval application for PAPP and two new PAPP bait product applications.
- Two new treatments (vet only and dog owner) in development for PAPP accidental poisoning and seeing the vet only product used successfully to save working dogs in PAPP field trials.
- Identified and developed new opportunities for commercial participants.
- Seeing the new products make a material improvement to the growth of the invasive animal industry in Australia.
- Exporting our expertise, products and IP.
- Chair of the national mouse management working group (2011–2012)

Project team

Dr Simon Humphrys, Assoc. Prof Steven Lapidge, Dr Glen Saunders, Andreas Glanznig.

Project partners

Australian Wool Innovation, Meat & Livestock Australia, Grains Research and Development Corporation, Animal Control Technologies (Australia) P/L, Connovation Ltd (New Zealand), Pestat Pty Ltd, SenesTech, Bioquiv, University of Sydney, University of Newcastle, CSIRO, NSW Department of Primary Industries, NSW Livestock Health and Pest Authorities, Queensland Department of Agriculture, Fisheries and Forestry, Victorian Department of Primary Industries, Victorian Department of Sustainability and Environment, ABARES, United States Department of Agriculture (USDA), Food and Environmental Research Agency (UK).

Further information

Eason, CT, Fagerstone, KA, Eisemann, JD, Humphrys, ST, O'Hare, JR and Lapidge, SJ (2010)) A review of existing and potential New World and Australasian vertebrate pesticides with a rationale for linking use patterns to registration requirements. *International Journal of Pest Management* 56: 109-125.

Humphrys, S and Lapidge, SJ (2008) A review of delivering and registering species-tailored oral anti-fertility products. *Wildlife Research* 35: 578-585.

Lapidge, SJ, Humphrys, S and Dall, D (2007) Global harmonisation in the field of invasive species management product development. *Proceedings of the Managing Vertebrate Invasive Species Symposium*, Ft Collins, Colorado pp 34-42.

Saunders, G, Lapidge, S, Fulton, W, Murphy, E, Sarre, S, Buller, C and Peacock, T (2007) The Invasive Animals CRC: a new research initiative for managing some old problems. *Pest or Guest: the zoology of overabundance.* Royal Zoological Society of NSW, Mosman, NSW, Australia pp 88-93.

Lapidge, S, Dall, D, Hunt, R, Cowled, B, Smith, M and Staples, L (2006) A review of the impact of sheep predators in Australia and new control methods. *Australasian Vertebrate Pest Conference* 22: 258-263.

Fleming, PJS, Allen, LR, Lapidge, SJ, Robley, A, Saunders, GR and Thomson, PC (2006) A strategic approach to mitigating the impacts of wild canids: proposed activities of the Invasive Animals Cooperative Research Centre. *Australian Journal of Experimental Agriculture* 46: 753-762.

www.invasiveanimals.com

Goal 11: Professional and practical skills in invasive animal management

TARGET: Increased professional and practical skills-base for invasive animal management through education, training and community awareness

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
11.1	Postgraduate training (PhD and Honours students) in support of CRC goals – Balanced Scientist Program	2012	11.E.1, 11.E.2, 11.E.3, 11.E.4, 11.E.5, 11.E.9
11.2	Manager and field officer training (PestPlan: diploma-level training course in strategic invasive animal management and conservation and land management).	2012	11.E.6, 11.E.10
11.3	Enhanced professional skill development for partner agencies	2012	11.E.6, 11.E.10
11.4	End-user capacity building: increased knowledge and skills (PestSmart Stage 1 – social research) and Online learning and information: www.feral.org.au	2012	11.D.1, 11.E.7
	PestSmart Stage 2 – Toolkits and Roadshow)	2012	11.U.1, 11.U.2, 11.U.3e (MLA). 11.U.4e (AWI), 11.U.5e (MDBA).
11.5	Increased stakeholder and community awareness (NRM Liaison Officer)	2012	11.T.1, 10.U.10
	Pest management instructional DVD and Technical Guide for Camera Trap Use	2012	11.T.4, 11.T.5

*As per contract variation approved by DIISRTE

Projects

Education and training

- PestSmart toolkit, stage 2 (11.D.1 – Current)
- Postgraduate training (PhD and Honours students) supporting CRC goals (11.E.1, 11.E.2, 11.E.3, 11.E.4, 11.E.9 – Completed)
- Stakeholder training in conservation and land management (certificate II to IV and diploma-level courses) (11.E.10, 11.E.6 – Completed)
- Online learning and information: www.feral.org.au (11.E.7 – Completed)
    - Feral Focus, secondary school education resource (11.E.7 – Completed)
- NRM liaison officer (11.T.1 – Current)

Demonstration Site

- Demonstration Site: Mulligan's Flat, ACT (10.U.10 – Completed)

Balanced Scientist Program

Project Leader: Prof Stephen Sarre, University of Canberra

Aim: *To produce better, more 'balanced' scientists that are attractive to employers and will make a substantial contribution to ecosystem and invasive animal management*

Projects 11.E.1, 11.E.2, 11.E.3, 11.E.4, 11.E.5, 11.E.9

Project duration	July 2005 – June 2012
Status	Completed

Project summary

The Balanced Scientist program prepares graduates for leadership roles in the invasive animal management industry by providing postgraduate education opportunities for students to participate in some of Australia's most significant environmental issues.

A critical component of the education program is the placement of students within industry, where industry includes education institutions, government and non-government conservation and land-management agencies. The PhD program is complemented by an Honours research program. Students work in projects that contribute to the goals of the Invasive Animals CRC. They each learn to conceive, plan and carry out to completion a substantial piece of original research in a specialised area of academic study, under the supervision of at least one industry professional, and a primary supervisor from a CRC-affiliated university. Students receive training in leadership, management, business and entrepreneurial skills.

These skills complement sound research training in ecosystem and invasive animal management. Each student participates in an 80-day training program across a four-year learning plan. The skill-set will help students:

- better prepare for the industry workplace
- develop networks before graduation
- improve employment prospects
- match research efforts with industry priorities.

Program targets include:

- 24 PhD students graduating from an 80-day training program across a four-year learning plan
- delivering an intensive professional development training camp each year, supplemented by short-courses and conference opportunities
- recognition of student achievements through the annual student awards.

Key achievements

Four cohorts of students inducted with 29 students enrolled.
Delivery of the fifth intensive professional development training camp (June 2011) with customised courses, workshops and sessions which have so far included 'Science Journal Article Writing and Publishing', 'Grant Application Writing and Strategic Career Development' and 'Commercialisation Management'.

- 27 of 29 PhD students have completed the additional training requirements of the Balanced Scientist Program and have been awarded the Certificate of Achievement in Research Leadership and Management.
- Cohort 1: All students have submitted, 11 out of 12 Cohort 1 PhDs accepted or conferred.
- Cohort 2: Six of 11 students have submitted their thesis for marking with four of six PhDs accepted or conferred
- Cohort 3: Two of six students have submitted theses with one having their doctorate conferred. The remaining four students are progressing strongly towards completion with three of four intending to submit by the end of June 2012
- Masters Cohort: All Masters students have submitted theses and have had their award conferred
- The guidelines for the Balanced Scientist Program were published under the PestSmart banner in November 2011.
- The first phase survey for the review of the Balanced Scientist Program was completed and interim results were presented at the Vertebrate Pest Conference in Monterey, California in March 2012.
- Intensive training courses (PhD camp), held in semester two of 2011.
- Balanced Scientist Program Manual completed, published and launched.
- First phase of Balanced Scientist Program longitudinal survey of PhD graduates conducted and results analysed for publication in refereed journal.

Project partners

Invasive Animals CRC, University of Canberra, University of Newcastle, University of Queensland, University of Sydney, University of Western Australia, project partners included under specific research programs under other goals.

Further information

Sarre, S, Buckmaster, T and Dimond, W (2012) The Balanced Scientist Program - Training PhD candidates beyond research. Proceedings of the Vertebrate Pest Conference, Monterey, California.

Dimond, W. and Sarre, S. (2011) Guidelines for the Balanced Scientist Program: A unique PhD program to address a major environmental problem, Invasive Animals CRC, Canberra.

www.invasiveanimals.com

PestPlan management training

Project Leader: Adj. Prof Mike Braysher, David Walter and Dr Tony Buckmaster, University of Canberra

Aim: *To increase the capacity of people involved in planning and implementing strategic and cooperative invasive animal management*

Projects 11.E.10, 11.E.6

Project duration	July 2005 – June 2012
Status	Completed

Project summary

The Invasive Animals CRC developed a Vocational Education and Training Diploma in Conservation and Land Management (specialising in pest management). The courses have been developed and nationally approved under the Australian Qualifications Framework.

Participants from the PestPlan pilot course

The Diploma gives pest managers the capacity to develop and implement best-practice pest management, thereby supporting a key Invasive Animals CRC objective of significantly reducing damage due to pests.

Key factors in developing the course included addressing:

- poor awareness and adoption of the nationally-endorsed best-practice approach to pest management
- contraction in state-based training in pest animal management
- increasing tendency of state agencies to contract onground management to the private sector.
- a loss of skill base due to retirement of experienced pest managers
- establishment of NRM regions – key new players in pest management.

The course is primarily on-line and can be completed by participants at their own pace in the workplace. It is supplemented by two residentials and each student develops a pest management plan as part of the course. A graduate certificate version of the course has also been developed.

Key achievements

- Successful development and national accreditation of the Diploma course.
- Delivery of the course since 2008, with 40 students having completed or undertaking the course.
- Development of an electronic-based marketing program to identify markets and to promote both the VET Diploma course and the Graduate Certificate in Wildlife Management (Strategic Pest Management).
- Development and University Accreditation of a Graduate Certificate and preparation of the Diploma and MSc version of PestPlan course encompassing weeds as well as pest animals. Short-course version of the strategic pest management course delivered to 15 biosecurity officers from Department Agriculture and Food WA in 2011.
- Graduate Certificate course presented to Vertebrate Pests Conference, May 2010.
- Paper on the range of pest management training courses presented at 2011 AVPC conference in Sydney.
- Workshop held to develop a strategy to address key recommendations of the Brown and Munckton report (2010) 'A scoping study: training and capacity building in vertebrate pest management', Invasive Animals CRC, Canberra.
- Review of competencies for the VET certificate II, IV and Diploma accepted by Agrifood Skills Australia under its continuous improvement program. 11 Diploma graduates attended the 2011 AVPC Conference and five presented papers – an indication of the capacity-building impact in national pest-management through trickle-down effect.
- Paper on the 'Principles underpinning Best Practice' and another paper on the 'Strategic pest management training courses available online' was presented at the Vertebrate Pest Conference in Monterey, March 2012.
- Visited USDA offices in Fort Collins (Colorado) and Logan (Utah) in 2012 to discuss joint training opportunities in strategic pest management.
- Best Practice pest management presented at each of the PestSmart Roadshows.
- Continued delivery of PestPlan diploma course.
- Commencement of the Graduate Certificate in Wildlife Management (strategic pest management). In liaison with Agrifood Skills Australia, revision of the VET pest animal training was added to the continuous improvement scope of the Agrifood Skills program.
- Groundwork completed for Agrifood Skills Australia to develop the project brief for reviewing the competencies and training packages for the VET Diploma and certificate II and IV courses.
- Commence review of competencies in cooperation with Agrifood Skills Australia, TOCAL Agricultural College, NSW DPI and Vertebrate Pests Committee.

Project partners

Invasive Animals CRC, Australian Bureau of Agriculture and Resource Economics and Sciences, University of Canberra, NSW Department of Primary Industries, National Vertebrate Pests Committee and AgriFood Skills Australia.

Further information

Buckmaster T and Braysher M (2012) Strategic vertebrate pest management training in Australia. Proceedings of the Vertebrate Pest Conference, Monterey, California

Project Leader: Professorial Fellow Mike Braysher <mike.braysher@canberra.edu.au>.

www.invasiveanimals.com

PestSmart - Stage 1 (Social research)

Project Leader: Dr Lisa Robins, Robins Consulting

Aim: *To examine the information needs of regional-level natural resource management (NRM) managers and pest animal controllers and the efficacy of a suite of options for building their capacity to manage the impacts of pest animals at the regional scale*

Project 11.D.1

Project duration	February 2010 – June 2010
Status	Completed

Project summary

The 1990s coincided with the production of numerous pest animal information products (eg BRS guides, CDs and handbooks) funded under the Natural Heritage Trust. While there is anecdotal evidence that many of these products have been useful, the efficacy of these products has not been robustly evaluated. It also coincided with a limited body of social research on the dynamics, drivers and barriers to the adoption of pest animal management practices by land managers.

The Invasive Animals CRC applies an end-user centred approach to output design and development. This initially involved formative research to identify end-user needs to drive the design of an applied R&D program and later market and social research to inform the design and development of adoption pathways, including suitable information products.

The PestSmart toolkit consolidated and packaged information from the Invasive Animals CRC's seven-year research program findings into practical planning and control actions to improve pest animal control, and reduce their impacts both at the property and regional levels.

The focus for stage one was regional end-users, namely natural resource management (NRM) managers and pest animal controllers that work at the regional level. The research aims to better understand the requirements of these end-users in terms of their information requirements and preferred pathways for communication and capacity building.

The research was conducted over a five-month period from February to June 2010, and focuses on three case study regions in NSW (Lachlan), Queensland (Desert Channels) and South Australia (Kangaroo Island).

Key achievements

- Options paper on capacity building for pest animal control, for focus groups prepared.
- Three focus groups held (Lachlan NSW (Forbes), Desert Channels Queensland (Longreach) and Kangaroo Island, SA (Kingscote).
- Invasive Aniamls CRC occasional report 'Enabling Regional Pest Animal Control' published.
- Findings and conclusions of the stage 1 market research informed the structuring, articulation and extension of the PestSmart toolkit.

Project partners

Invasive Animals CRC, ABARES.

Further information

Robins, L (2010) Enabling regional pest animal control, Invasive Animals CRC, Canberra.

www.invasiveanimals.com

PestSmart - Stage 2 (Toolkits & Roadshow)

Project Leaders: Keryn Lapidge / Assoc. Prof. Steven Lapidge

Aim: *To ensure that existing and new Invasive Animals CRC-developed information on key pest species is readily available PestSmart information toolkits and that the toolkits and new Invasive Animals CRC products are promoted through a national PestSmart Roadshow*

Projects 11.U.1, 11.U.2, 11.U.3e (MLA), 11.U.4e (AWI), 11.U.5e (MDBA)

Project duration February 2010 – June 2012
Status Completed

Project summary

The PestSmart toolkit consolidates and packages information from the Invasive Animals CRC's seven-year research program findings into practical planning and control information to improve pest animal control and reduce pest impacts both at the property and regional levels.

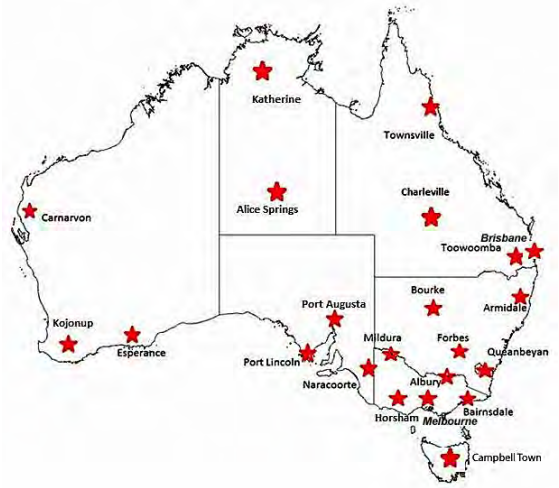
Some 70 PestSmart Toolkit publications across several pest species are now live on www.feral.org.au/pestsmart and content continues to be developed. Toolkit publications have also been distributed at PestSmart Roadshows, CMA/NRM forums, agricultural field days and direct mail upon request with very strong positive feedback. Demand has been strong with some materials re-printed up to three times. Several requests have been received for bulk quantities of PestSmart toolkit materials. Landcare and NRM groups have ordered publications for participants in their own pest control programs. Print files of the Wild dog Glovebox guide were provided to AWI to do their own print run of 3,000 copies.

Two DVDs (*Introduction to using foot hold traps for the capture of wild dogs and foxes* and *Guide to Practical Pest Animal Management*) have been produced and distributed across Australia. All video clips from both DVDs are now on a PestSmart YouTube channel (www.youtube.com/PestSmart). The Queensland Department of Education, Training and Employment has been granted permission to use a video clip produced as part of the feral pig PestSmart Toolkit in material they are developing for the Australian Curriculum for primary and secondary schools.

Promotion of toolkits is also ongoing and continues to encourage uptake. PestSmart account on social media clients (Facebook: https://www.facebook.com/PestSmart and Twitter: https://twitter.com/PestSmartCRC) are proving to be valuable communication channels. Website traffic on feral.org.au has also increased since the launch of the PestSmart project.

The PestSmart Roadshow format and content was road tested at the 2011 AWMS Conference in November 2011 ahead of its 30 January 2012 launch in Queanbeyan. The Roadshow then visited another 19 regional venues across all States and Territories in Australia between February and June. Two national pest fish Forums on European carp and tilapia were also held.

Near 1,500 people subsequently attended the PestSmart Roadshow events, with thousands more seeing, hearing or reading about the events in the associated radio, television and newspaper articles.



From all reports the Invasive Animals CRC's PestSmart Toolkit and Roadshow have been a resounding success. Feedback has been overwhelmingly positive and every event had an extremely positive and collegial feel to it. That some individuals travelled to multiple shows (up to five for one individual), people drove or flew more than 1,200km each way to attend events, and that multiple NRM Boards have offered to pay $20,000 for the Roadshow to come to their town indicates the strong public support the extension effort had.

Key achievements

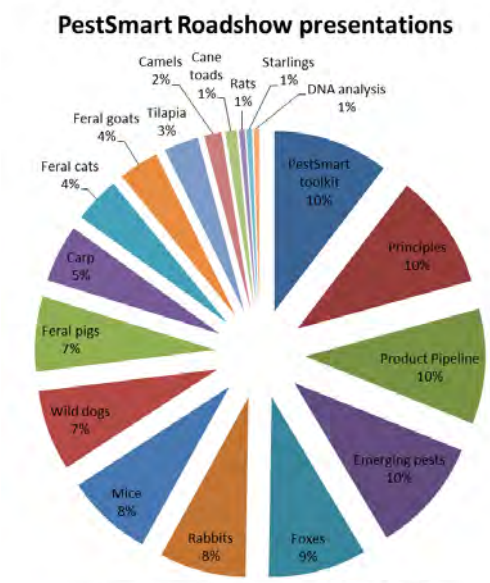
- The PestSmart Toolkit (www.feral.org.au/pestsmart) is now Australia's one-stop-shop for pest animal information. With more than 70 specifically written factsheets, case-studies, glovebox guides, technical manuals and scientific reports produced, the site contains the most up-to-date information on Australian pest animals. An additional 50 PestSmart Toolkit products are currently in production and should be available by the end of 2012.
- A PestSmart YouTube Channel has been established - http://www.youtube.com/PestSmart – which now contains 67 original videos shot by the Invasive Animals CRC that demonstrate practical pest management, pest ecology and pest impacts, including interviews with farmers and species experts.

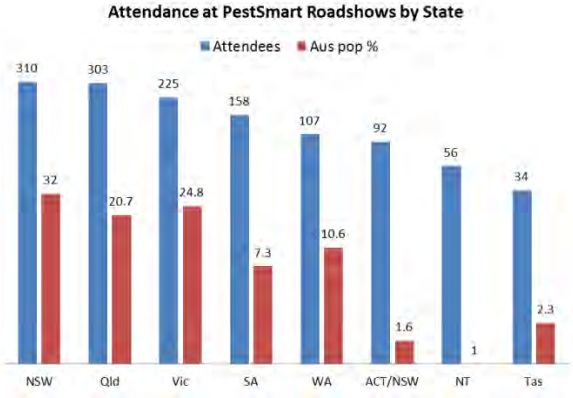
Whether indicated through increasing usage of the PestSmart Toolkit website and You Tube channel, direct attendee feedback at Roadshow events, community support, increased product sales or calls for more Roadshow events, the PestSmart project has been a resounding success. This is in part due to the financial and physical support received for the project from Meat & Livestock Australia Ltd, Australia Wool Innovation Ltd, the Australian Bureau of Agricultural and Resource Economics and Sciences, the Murray-Darling Basin Authority and Animal Control Technologies (Australia) Pty Ltd. For this the Invasive Animals CRC is sincerely grateful.

Project partners

Invasive Animals CRC, ABARES, MLA, AWI, MDBA, ACTA, NSW DPI, Vic DPI, Pestat / Australian Pest Animal Strategy and the University of Canberra.

Welcome address being provided by Blair Brice (Meat & Livestock Australia) at the Toowoomba PestSmart Roadshow, March 2012.





Further information

Lapidge, SJ, Balogh, S and Lapidge, KL (in Press) PestSmart: An information toolkit for practical pest animal control. *Vertebrate Pests Conference* 25.

Robins L (2010) Enabling regional pest animal control. Invasive Animals Cooperative Research Centre, Canberra.

www.feral.org.au/pestsmart/

"The PestSmart Roadshow set a new standard in the area of adoption of research results, targeting as it did, not primarily the end users, but the consultants, advisors and extension officers who would carry the message further."

Dr Johann Schröder, Meat & Livestock Australia

Online learning and information: www.feral.org.au

Project Leader: Prof Stephen Sarre, University of Canberra

Aim: *To improve the availability of feral animal management information to landholders, pest control practitioners and researchers, to assist them in strategically managing pests to achieve both their production and conservation outcome*

Project 11.E.7

Project duration	January 2005 – July 2012
Status	Completed

Project summary

www.feral.org.au was developed in 2004 by the then Pest Animal Control CRC as a joint initiative with the University of Canberra and with funding from the then Bureau of Rural Sciences (now ABARES). The project consisted of three elements:

- a comprehensive website to provide feral animal management information
- a forum for interactive participation
- delivery of educational products to schools and the community (Feral Focus).

The www.feral.org.au website covers a broad range and amount of information that is currently available on pest animals, management and educational resources. This is the first time a dedicated 'home' for invasive pest research and management data has been developed and maintained. The site is integrated with a categorised database, which makes specific searches possible (for example, by species, common-name, location, author, or keyword), and returns a variety of data (for example, images, scientific papers, pest-distribution maps and hard-to-access grey literature).

Forum use has diminished due to technological advances, for example in more sophisticated social networking websites. Redevelopment to integrate with some of these high-traffic sites will not only improve user experience, but would significantly help promote the broader www.feral.org.au site to users who may not be aware of its existence.

The Feral Focus resource has been developed for high school students. A list of activities, interactive scenarios and detailed research projects present teachers with strong links to current curriculum profiles. To reinforce student understanding, each activity comes with a list of further reading points and relevant websites which provide up-to-date information and allows the student to be fully informed when undertaking the activity.

Teachers examined the Feral Focus secondary schools resource.

The kit provides teachers with a completed and up to date resource which addresses the complexities of effective pest animal management. This resource dispels the myth that a feral animal should be eradicated at any cost using any means available. Instead, students learn and appreciate the complexities involved in addressing pest problem issues. They are brought to an understanding that the aim of pest animal management is to reduce pest damage to an acceptable level using an economically sustainable approach and employing animal welfare and environmentally sensitive techniques.

The www.feral.org.au site will continue to be a central portal for individuals and groups needing to access information on pest animals and their management.

Key achievements

- The site has undergone several rebuilds to enhance usability, including the migration of the site from the Cold Fusion platform, the inclusion of a new search function to enhance the search quality and speed, and the addition of an image gallery containing more than 200 images and sort options for search results.
- www.feral.org.au has around 8,000 records, including web-links, maps, manuals, guides, scientific papers, grey literature and images) and averages around 9,000 visits per month.
- The Feral Focus and secondary school teachers' resource pack has been complemented with Pest Tales, the primary school teacher and student online resource. Both are now linked to from the feral.org site and have stand-alone domain names.
- Continued promotion of Feral Focus and Pest Tales to primary and secondary school education.
- Scoping www.feral.org.au for migration to web 2.0 platform for increased communications functionality (eg integration with image sharing, mapping functionality, blogs, wiki capability) in accordance with end-user need.
- Legacy planning for housing www.feral.org.au beyond the life of the Invasive Animals CRC.

Project team

Prof Stephen Sarre, Keryn Lapidge, Joanne Keogh, Adj. Prof Mike Braysher.

Project partners

Invasive Animals CRC, Institute for Applied Ecology, University of Canberra, ABARES.

Further information

www.feral.org.au

Feral animal information website.

www.pestales.org.au / www.feralfocus.org.au

Teacher student resource sites for primary and secondary levels.

NRM liaison officer

Project Leader: Jessica Marsh, NSW Department of Primary Industries

Aim: *To provide specialist invasive animal advice to NRM agencies on pest species impact, improved capabilities for best-practice, regional management of invasive animal impacts and monitoring natural resource responses to pest control*

Project 11.T.1

Project duration	January 2008 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

This project involves bringing public and private land managers together to cooperatively manage the impacts of invasive animals with best practice methods. Planning for the management of invasive animals will be in accordance with the established PestPlan process – with a strong emphasis on capacity building outcomes for participants in each PestPlan workshop. Out of necessity, the impacts on agricultural production and conservation outcomes will be addressed together within regions (because invasive animals rapidly re-colonise areas from neighbouring properties).

There are a range of invasive animal pests which have a serious and ongoing affect on the natural resources across Australia. The Australian NRM regions tend to be at various stages of planning and/or implementation of pest animal management programs. Several have recently sought technical assistance from the Invasive Animals CRC and state agencies on how to best manage invasive animals.

In some cases, as a consequence of the variation in priorities over time, skill level, competition from other catchment priorities and limited available resources, most NRMs lack the expertise and resources to develop and implement specific pest management plans according to current 'best practice' principles, even when invasive pests are identified as a priority issue.

A more effective and coordinated process is required for interacting with NRM groups and to provide access to expertise and strategies for managing invasive animals and their impacts. This need for more widespread expertise and training has highlighted a gap in the process of information transfer of scientific information and best practice methods to those working at a regional level in managerial and/or onground positions.

The development of the NRM Liaison Project enables the Invasive Animals CRC to maintain a Liaison Officer who will provide specialist support to NRMs nationally to develop a consistent integrated approach to reducing the impact invasive animals have on natural resources. The Liaison Officer is involved with bringing public and private land managers together within NRM groups to cooperatively and collaboratively manage the impacts of invasive animals with best practice methods.

The primary objective of this project is to provide specialist invasive animal advice to NRMs on:

- pest species having greatest impact on natural resources ie land, water and biodiversity
- improved capabilities for best-practice, regional management of invasive animal impacts
- stakeholder management
- monitoring natural resource responses to pest control.

The NRM Liaison Officer is creating a more effective and coordinated approach to communicate with NRM groups and to provide information on the most relevant and up-to-date strategies for managing invasive animals and their impacts.

Key achievements

- Various pest management plans have been assessed and comments have been provided to the following NRM regions/ agencies- Territory NRM, Murrumbidgee CMA, ACT NRM, and North Central CMA (Victoria).
- The 'Feral Photos' photography competition was launched at the AVPC in Sydney, June 2011. The competition was developed with aim to increase awareness of pest animals and the impacts they have and to also build a database of images that will be used in educational and scientific publications. The competition was a great success with more than 200 entries received from all over the country, with many different species of pest animal being photographed. It is hoped that the competition can continue each year, gain attention from sponsors and start to attract more entries.
- The NRM Liaison Officer has been instrumental in developing, launching and distributing PestSmart toolkit information to public land managers, government officers, farmers, graziers, Landcare groups, NRM regions as well as teachers and school groups across Australia.
- A 'Ferals in the Classroom' workshop was held for primary and secondary teachers in Dubbo at the Taronga Park Zoo education centre to demonstrate the online resources, 'Feral Focus' and 'Pest Tales'.
- NSW CMA CAP Upgrades have been happening across the state and where possible the NRM Liaison and Invasive Animals CRC have been involved in this process to guide investment for these groups for the next 5-10 years.
- Two weeks were spent in March to visit and engage with all Western Australian NRM groups: Perth region NRM, the Northern Agricultural Catchment Council (NACC), South West NRM, the Wheatbelt and South Coast NRM were all included in the visit in addition to some local pest management/ action groups. In addition to the NRM groups, some 15 Department of Agriculture staff were receiving a week of training on strategic pest management, in which the NRM Liaison Officer gave examples of strategic management in other areas and worked with the group to increase their understanding of the issues and also what services and resources could be provided to them from the Invasive Animals CRC.
- The Invasive Animals CRC initiated an adoption steering group (ASG) to help guide the delivery of outcomes from their past seven years of research and education to individuals and groups on the ground, across the country. Being part of this group has ensured the best delivery to regional groups and communities as the group has been able to take advantage of the skills, knowledge and contacts acquired over the past few years. This group organised the Invasive Animals CRC PestSmart Roadshows and the NRM Liaison officer presented on best practice pest animal management.

- NRM Notes, a specific invasive species newsletter was again distributed to all Australian NRM regions and other landholders, agencies and cooperatives. It was distributed in March, June, and September & December in 2011 and is due to be distributed again throughout 2012–2017.
- NRM Notes is also available on the internet via www.feral.org.au and the Invasive Animals CRC website www.invasiveanimals.com The interest in NRM Notes is again increasing with the subscription lists increasing with each issue.
- Assist with implementing best practice invasive animal management through strategic planning, prioritisation of actions, knowledge transfer and training.
- Continuation of the Feral Photos competition on an annual basis.
- Progression towards an NRM working group to identify needs and resources available and possible avenues for future onground work.
- Education extension work with workshops and education packs to assist in the implementation of best practice pest management.
- Attend, present and service a trade display at the National NRM Knowledge Fair and other relevant events.

- Assist NRMs in the development of regional pest management plans ensuring that they are structured to suit regional conditions and complement existing national, state and local plans and strategies.
- Establish a searchable database that is easily accessible by NRMs and pest groups as a platform for project reporting, promotion and knowledge.
- Maintain the established network of contacts between Invasive Animals CRC and NRM regions, Commonwealth officers and relevant state agencies.
- Assist in the development and application of funding under Caring for our Country to address invasive animal priorities within NRM regions.
- Ensure that management recommendations and funding proposals are integrated with existing planning documents eg CAPs and TAPs etc.
- Facilitate the rollout of products which will be an immediate requirement that will include the Invasive Animals CRC's PestSmart toolkits.
- Develop and deliver information packages appropriate to individual or group needs.
- Maintain and expand newsletter distribution and published material distribution at essential times.
- Assistance with the delivery of the goals and objectives within the AUSTRALIAN PEST ANIMAL STRATEGY and various State/ Territory Invasive Species Plans.

Project team

Jessica Marsh, Annette Brown, Chris Lane, Dr Glen Saunders, Jonathan Lawson, Ron Beazley, Adj. Prof Mike Braysher, LHPA, NRM and CMA staff.

Project partners

Invasive Animals CRC, Caring For Our Country–Department of Agriculture, Fisheries and Forestry, NSW Department of Primary Industries, Border Rivers-Gwydir Catchment Management Authority, University of Canberra, NSW Livestock Health and Pest Authorities, NRMs and CMAs across Australia.

Further information

Marsh, J, NRM Extension Pack (Resource DVD) (March 2011) Hard copy only.

Robins, L (2010) Enabling regional pest animal control. Invasive Animals Cooperative Research Centre, Canberra.

Marsh, J (2010) Border Rivers- Gwydir Catchment Management Authority Invasive Species Management Plan. Invasive Animals Cooperative Research Centre, Orange. www.feral.org.au/invasive-species-managment-plan-brg

NRM Notes Newsletters www.invasiveanimals.com/research/goals/goal-11/11t1/

www.invasiveanimals.com

Pest management instructional DVD

Project Leader: Paul Meek, Invasive Animals CRC

Project 11.T.4

Aim: To provide an instructional DVD of vertebrate pest control methods, products and monitoring techniques

Project duration	March 2011 – March 2012
Status	Completed

Project summary

Training in vertebrate pest management skills has been recently reviewed by Brown (2010). This review highlighted a number of issues including:

- significant national variation in content and modes of delivery
- need for greater emphasis on strategic management with a stronger practical component than is currently available
- need to give special consideration to the high-risk areas of vertebrate pest training, particularly regarding the use of firearms, poisons and actions which may draw in unnecessary media attention
- need to be complementary to existing state initiatives but realistic regarding the continuing capacity of the state jurisdictions to undertake training given limited resources
- training both public and private personnel, particularly where vertebrate pest control may be outsourced to private sector land management organisations.

While face to face content remains an essential component especially for training the trainers and other specialist groups, more accessible and cheaper instruction is needed by end users.

The development of on-line pest management resources will overcome some of these issues and assist end users to become competent and more confident in the use of nationally approved vertebrate pest management and monitoring techniques. On-line pest management resources are intended as tools that can be uploaded from the Internet and disseminated via training courses conducted by NRM groups, government agencies and industry groups.

Discussions with landholders attending wild dog training days revealed that many simply forget the techniques they are taught if they do not implement them soon after any face-to-face instruction and would rarely take the time to read a course booklet to refresh their memory.

They did however agree that it would be more useful to have short film clips outlining the techniques they learnt and that they would in fact be more inclined to watch a film clip before undertaking a technique rather than reading a training booklet. Similar comments have been received from landholders and stakeholders from both the private sector and government agencies from around Australia.

Key achievements

- Set of two instructional DVDs and suite of clips on YouTube on vertebrate pest control methods, products and monitoring techniques produced.
- 3,000 DVDs disseminated throughout Australia via the PestSmart Roadshows and NSW Vertebrate Pest Management Courses.
- 15 Balanced Scientists PhD interviews on DVD produced promoting the Invasive Animals CRC education program.

Project team

Paul Meek, Chris Lane, Dr Glen Saunders, Adj. Prof Mike Braysher.

Project partners

Invasive Animals CRC, NSW Department of Primary Industries.

Further Information

PestSmart DVD: DVD Guide to Practical Pest Animal Management

Brown (2010): Scoping Study on Training and Capacity Building in Vertebrate Pest Management).

http://www.youtube.com/PestSmart

www.invasiveanimals.com

Technical guide for camera trap use

Project Leader: Paul Meek, Invasive Animals CRC

Project 11.T.5

Aim: *To produce a technical guide to improve and enhance remote camera use for pest management in Australia*

Project duration	July 2011 – December 2011
Status	Completed

Project summary

Camera traps are being used extensively in Australia as a means of detecting a range of invasive species and other wildlife. Their potential benefits include detecting and surveying cryptic species as well as reducing field time and associated expenses.

In addition to the many models and brands (with a significant variety of functions that have not been tested for accuracy in order to allow informed / appropriate use) there is a paucity of information available regarding species-specific strategies for deployment in monitoring situations.

This document will be a detailed technical guide on how to choose the right models and functions that are fit for purpose, how to use the equipment effectively and the technical limitations of major models.

It will also introduce standard conventions for use to encourage consistency in design and analysis of data throughout Australia. A specific focus will be pest animal detection and monitoring.

This type of guide has not been produced in Australia and will be a widely utilised tool by agencies, land managers and students dealing with invasive animals and their impacts.

Camera traps are increasingly being used in invasive animal and native species management although there is limited information available on techniques and constraints.

This project will produce a technical guide based on experience, literature and contemporary research to improve and enhance camera trap use in Australia.

The tool will provide guidance on standardised protocols/standards for survey design, methods and data collection as well as providing advice to assist in "right choice" decision making.

The guide will become a valuable tool for Registered Training Organisations.

Key achievements

- Produced a technical guide currently in review–Principles, Methods and Standards: Camera Trapping for Pest and Wildlife Management in Australia. This guide summarises the current knowledge on camera traps, equipment, methods and analysis tools, and given the fast and evolving nature of this field of science, the guide will be a web based live document that can be updated as new information is produced.
- Produced a standardised data sheet for site recording.
- Produced and upload a camera trap site data base on www.feral.org.au
- Completed a Churchill Fellowship study tour and Final Report on camera trap technology.
- Completed research trials on several key aspects of camera traps and methods, several manuscripts have been written or are in draft include:

1. Meek, Zewe and Falzon Temporal activity patterns of the swamp rat *(Rattus lutreolus)* and other rodents in north-eastern NSW, Australia. *Australian Mammalogy*
2. Meek, Ballard and Fleming. Research Note: A Permanent Security Post for Camera Trapping *Australian Mammalogy* (accepted)
3. Meek, PD, Ballard, G, Fleming, PJ, Falzon, G, Schaefer, M, Williams, W, Stewart, G, Howe, R and Padgett, CM. Potential Acoustic and Infra-red Interference to Animal Behaviour using Camera Traps for Wildlife Monitoring. Wildlife Research, in prep
4. Meek, Ballard and Fleming. How do dogs (*Canis lupus*), cats (*Felis catus*) and foxes (Vulpes vulpes) respond to acoustic outputs and/or see infra-red light emitted from camera traps? Wildlife Research in prep
5. Meek and Pettit. User based design specifications for the ultimate camera trap design for wildlife research. Emerging Technology
6. Meek. P. A History of Camera Trapping in Australia and a Critique of Applications in Wildlife Research, Australian Mammalogy or Wildlife Research

Paul Meek and Dr Guy Ballard set up remote camera

Project team

Paul Meek, Dr Peter Fleming, Dr Guy Ballard

Project partners

Invasive Animals CRC, NSW Department of Primary Industries

Further information

Meek, PD, Ballard, G and Fleming, P (2012) An Introduction to Camera Trapping for Wildlife Surveys in Australia. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia. Online at: www.feral.org.au/camera-trapping-for-wildlife-surveys

www.invasiveanimals.com

Goal 12: Benchmarks for invasive animal impact, density and distribution

TARGET: Establish national and local benchmarks for invasive animal impact, density and distribution from which performance on delivery of all outcomes can be assessed

Commonwealth Agreement Outputs*

Output		Due Date	Project/s to Deliver Output
12.1	Assessment of the overall impact of the Invasive Animals CRC throughout its life and recommend directions and requirements into the future.	2012	12.D.1, 12.D.7 12.D.8, 10.D.12, 12.D.6

* As per contract variation approved by DIISRTE

Projects

Knowledge and tools

- Mapping invasive animals of Australia (Project 12.D.1 – Completed)
- Scoping current invasive fish measuring and reporting methods (9.D.5 – Completed)
- Predict the distribution of key vertebrate pest species in 2020 under a future climate scenario (12.D.7 – Completed)
- Community Awareness Surveys (10.D.12 – Completed)
- Public attitudes to invasive animals, and their management and control (12.D.5, 12.D.8 – Completed)
- Socio-economic costs of invasive animals (12.D.6 – Completed)

Mapping invasive animals of Australia

Projects 12.D.1, 9.D.5, 12.D.11

Project Leader: Peter West, NSW Department of Primary Industries

Aim: To obtain agreed benchmarks for invasive animal impacts, density and distribution in Australia

Project duration Phase 1 July 2005 to 30 June 2012
Status Completed

Project summary

This project:

- improved monitoring, data entry, collation and reporting tools, techniques and protocols for significant invasive vertebrate pests and improved existing national databases and national information system infrastructure
- surveyed key established species, new and emerging species, and alien fish species at finer resolution to present national maps of occurrence, distribution and relative abundance
- developed and delivered meaningful information products to relevant stakeholders (including NRMs) to support management planning, surveillance, control, and biosecurity activities.

The major project outputs included the production of national, state and NRM region maps that show the distribution and abundance of 10 key pest animal species (feral pigs, feral goats, wild rabbits, foxes, feral cats, wild dogs / dingoes, carp, starlings, cane toads and feral deer). These maps and case studies of pest animal impacts were published as a joint NLWRA / Invasive Animals CRC report 'Assessing Invasive animals of Australia' 2008. The project has also resulted in the first set of a nationally-agreed, standardised protocols for monitoring and reporting on invasive animals.

Phase 2 of this project will value-add to achievements of phase 1, building on the momentum of the project with monitoring, mapping and reporting of invasive animals at state and national levels. It will identify and target data gaps, priorities and fundamental information needs for ongoing monitoring and reporting of invasive animals throughout Australia.

With a nationally endorsed proven method for monitoring and reporting of invasive animals, this project will build on existing datasets to deliver more detailed information for a wider range of established species, new and emerging species, pest birds and alien fish. This project will make improvements to tools, techniques, procedures, products, and information management, and deliver vital information to decision-makers at all levels. On completion, this project will provide the Invasive Animals CRC with national maps for nationally significant pest species (including birds mammals, fish and amphibians), as a benchmark for prioritising research, and assessing programs, funding and investment, management actions, and national policy. Further collaboration will be sought with states and territories, Australian Government and NRM regional groups to coordinate ongoing monitoring and reporting activities. Further collaboration with NSW will facilitate development of data infrastructure and web-based data capture tools for invasive animals essential for national information systems infrastructure.

The project delivered:

- improved procedures for monitoring, evaluation and reporting at regional, state and national levels for significant invasive animals in Australia
- nationally consistent national-scale datasets for species occurrence, distribution and abundance
- series of pest species mapping information products for relevant stakeholders including NRM regional groups, local government, state/territory pest management authorities and VPC
- data capture tools and techniques for national databases and information systems
- pest animal information resources for decision support for respective jurisdictional management authorities.

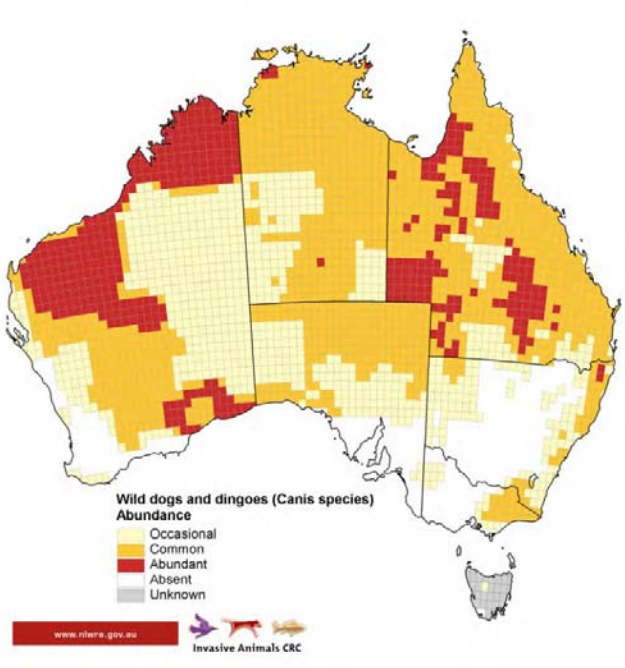
Key achievements

- 'Assessing Invasive Animals of Australia' report and accompanying information booklet 'Significant invasive species– Status of information for reporting' published.
- Series of information products (maps) established and delivered to relevant state/territory and Australian Government agencies, and regional NRM groups. These maps are also available on the PestMaps website in www.feral.org.au and data are available through the Australian Natural Resources Data Library.
- Existing national data reviewed and a series of information gaps and issues identified to support development of updated pest species information to support government decision making.
- Multi-scale invasive animals database including data across all states/territories updated and further developed for reporting on species extent, distribution and abundance.
- Workshops held to re-evaluate monitoring and reporting information needs of the state/territories and Australian Government and identify changes required to current monitoring protocols and priority species lists.
- National and state/territory recommendations for improving invasive species datasets across all jurisdictions developed through a series of state/territory workshops — supplied to VPC and associated working groups.
- Published book chapter: 'Mapping actual and predicted distribution of weeds and pest animals in Australia', in GIS Applications in Agriculture: Volume three: Invasive Species.
- National database of invasive animal records and data aggregations at multiple data scales updated for reporting the extent, abundance and distribution of species.
- Series of information products defining the extent and abundance of nationally significant pest species (mammals, birds, fish and amphibians) produced.

- Further progress on nationally agreed monitoring and reporting protocols (through VPC working group).
- Series of invasive animals mapping outputs at relevant scales published on priority pest species for decision makers.
- Final report to Invasive Animals CRC and partners containing updated datasets and information products.

Project team

Peter West (NSW Dept of Primary Industries)



Project partners

State and Territory government agencies, National Vertebrate Pests Committee, Commonwealth Department of Agriculture, Fisheries and Forestry and Department of Sustainability, Environment, Water, Population and Communities.

Further information

West, P (2008) Assessing Invasive Animals in Australia 2008. National Land and Water Resources Audit and Invasive Animals Cooperative Research Centre, Canberra.

West, P (2008) Significant invasive species (vertebrate pests) — Status of information for reporting against indicators under the National Natural Resource Management Monitoring and Evaluation Framework. National Land and Water Resources Audit and Invasive Animals Cooperative Research Centre, Canberra.

Gibson, J, and West, P (2006) Summary of state/ territory invasive animal distribution and abundance monitoring. Invasive Animals CRC, Canberra.

West, P and Saunders, G (2006) Pest Animal Survey: A review of the distribution, impacts and control of invasive animals throughout NSW and the ACT. NSW Department of Primary Industries and Invasive Animals Cooperative Research Centre, Canberra.

West P, Auricht, CM, Franco, M and Alexandra, J (2006) National Weeds and Invasive Animals Information Workshop: a report on workshop outcomes. Invasive Animals Cooperative Research Centre, Canberra.

Maps

Current maps cover cane toads, wild dogs, feral cats, wild rabbit, feral pigs, feral goats, carp, foxes, deer and starlings.

FeralScan: web-based community mapping

Project 12.D.11

Project Leader: Peter West, NSW Department of Primary Industries

Aim: *To create a web-based community reporting, education and extension tool for landholder and community groups*

Project duration	July 2010 – December 2012
Status	Current (Ongoing under the new extension Invasive Animals CRC)

Project summary

This project will establish a community web-based reporting (and two-way communication tool) specifically for landholders, community groups, schools, indigenous groups and non-government agencies to report on a range of nationally significant pest animals and their impacts throughout Australia. This will be coupled with education and extension material to support best-practice pest animal management. This project:

- Developed FeralScan (based on the successful RabbitScan model) as a web-enabled tool to allow community groups and landholders to directly enter information on the occurrence and density of pest species and importantly their impacts to agricultural and environmental values with pinpoint accuracy. FeralScan will maintain the momentum of RabbitScan and build on its success and achievements.
- Established FeralScan specifically as a landholder and community-group surveillance tool for a range of nationally significant pest animal species (including established and new species) in support of concurrent government initiatives.
- Integrated information from existing community-based databases wherever possible (such as Kimberley Toad Busters, Indian Myna action groups, Birds Australia, and state-based Atlas systems) to aid detection, reporting and management of incursions and the spread of established species.
- Developed education and extension material for community groups and landholders to support strategic management of pests and their impacts and communicate project outcomes via a series of newsletters and media campaigns. Material will also be published and distributed where possible.
- Evaluated community information to maintain accuracy against established field monitoring sites and existing datasets collected through independent programs.
- Reported outcomes of FeralScan (with regular newsletter and progress reports) to all relevant and participating land management agencies (at all levels of government), the VPC, APAMP, community/public, and industry/corporate groups.
- Sought external and ongoing funding sources from a range of long-term industry, corporate and government partners, such as relevant research and development corporations, technology providers and non-government agencies – and formalise agreements for investment/funding.
- Sought a long-term custodian for web-hosted services and accompanying project database, such as Landcare Australia.
- Delivered advice on control techniques and best-practice methods for use by landholders and peri-urban, urban, school, community group, sport clubs and other community organisations.

Key achievements

- FeralScan websites for rabbits, foxes, feral camels , feral pigs, wild dogs, cane toads, feral goats, common starlings, feral deer and common mynas developed, launched and promoted.
- Range of facilities for site users including bulk data importing, year and month filtering, data exporting, map creation and printing, image uploading and real-time reporting of species sightings, damage and control data developed.
- Independent datasets defining the known extent of species (eg known max range of pest) integrated.
- Engagement with key national advisory groups, including National Wild Dog Management Advisory Group and Cane Toad Advisory Group and former Rabbit Management Advisory Group members.
- Uploading templates for bulk data for public participants and importing of records from key community action areas, such as Clarence Valley created.
- Reporting on project developments and outcomes via a media and communications campaign reaching 80 external newsletters, websites and circulars from NRM, CMA, state government, local government and community action groups.
- More than 7,000 community data records for four species, as well as damage and impacts data not available to general public, collected and collated.
- Examination of data against known information sources including independent data sources such as Atlas databases.
- Series of national-scale mapping layers covering community and government data sets for projection in online mapping tools produced.
- Presentation of FeralScan project developments and outcomes at Invasive Animals CRC workshop, NSW Livestock Health and Pest Authorities meetings, National Wild Dog Management Advisory Group and Australasian Vertebrate Pest Conference.
- Series of real-time mapping outputs and information products tailored for user groups and end-user needs provided.
- Customised facilities for local government, NRM regions, local community action groups and community for data capture, recording and mapping provided within FeralScan.
- Suite of data querying and analytical tools developed for public use.
- Best available independent pest animal data sets to accompany FeralScan data layers in KLM format integrated.

Project team

Peter West, Chris Lane, Jessica Marsh, Brian Lukins (NSW Dept of Primary Industries), Dr Wendy Henderson, Alex Bagnara, Glenn Conroy, Dr Elaine Murphy, Tracey Lianos, Dr Glen Saunders, David Berman and Jenny Quealy

Project partners

Department of Agriculture, Fisheries and Forestry (ABARES via APARP grant), NSW Department of Primary Industries, Woolworths, Landcare Australia, Toshiba, Australian Broadcasting Commission, Western CMA (NSW), Canberra Indian Myna Action Group, Australia Feral Camel Management Project, Australian public.

Further information

www.feralscan.org.au

Invasive fish monitoring scoping study

Project Leader: Peter West, NSW Department of Primary Industries

Aim: *To review current techniques, research programs and management activities for measuring and monitoring pest fish distribution, abundance, and impacts*

Project 9.D.5

Project duration	April 2007 – June 2007
Status	Completed

Project summary

Information on the potential threats posed by invasive exotic fish to agricultural industries (and the freshwater systems they depend on), the environment, biodiversity, and ecosystem services was largely unclear at the onset of this project. There are many introduced and wild-living fish species that have been identified as presenting a risk to aquatic ecosystems, and many are known to cause adverse impacts to aquatic ecosystems. There are many more species (particularly within the ornamental fish keeping trade) that are considered threats – with the potential to significantly impact upon river systems and their health.

The Vertebrate Pests Committee (VPC) recently became responsible for providing coordinated policy and planning solutions for exotic fish. Under the former government, the National Land and Water Resources Audit previously developed various indicators and standards for monitoring resource condition, as part of the National Monitoring and Evaluation Framework. The VPC recommended that fish be included in the Invasive Species theme of the framework, and the Audit Advisory Council, agreed to produce a scoping study to identify issues and recommendations for monitoring and measurement procedures for fish distribution, abundance and impacts. It was essential to identify whether the recommended monitoring, evaluation and reporting protocols for introduced vertebrate pests (terrestrial) could be directly applied to exotic fish.

Key achievements

- An Invasive Animals CRC report 'Review of Alien Fish Monitoring Techniques, Indicators and Protocols: Implications for National Monitoring of Australia's Inland River Systems' published in August 2007. It outlined:
  - the pest fish species of importance throughout Australia, and the regions they are known to occur
  - review of the techniques used to detect and monitor populations and the techniques used to measure the impacts of pest fish
  - a list of management programs/strategies/activities being undertaken throughout Australia
  - a statement of recommendations for monitoring of pest fish species under the NM&EF for NLWRA and VPC, including recommendations for developing national pest fish species datasets.

Project team

Peter West, Annette Brown (NSW Department of Primary Industries), and Kylie Hall (Vic Department of Primary Industries).

Project partners

Invasive Animals CRC, NSW DPI.

Further information

West, P, Brown, H and Hall, K (2007) Review of Alien Fish Monitoring Techniques, Indicators and Protocols: Implications for national monitoring of Australia's inland river systems. Invasive Animals CRC, Canberra.

www.invasiveanimals.com

Predicting pest distribution in 2050

Project Leader: Dr Greg Hood, ABARES

Aim: *To predict the distribution of key vertebrate pest species in 2020 under a future climate scenario*

Project 12.D.7

Project duration	April 2008 – June 2011
Status	Completed

Project summary

Climate change has the potential to allow new and existing pests to establish and expand their ranges, increasing the threat they pose to biodiversity. To respond to these threats, we need to know the current extent and impacts of pest animals, how the distribution of pests is affected by climate and habitat, and how climate and habitats will change in the future.

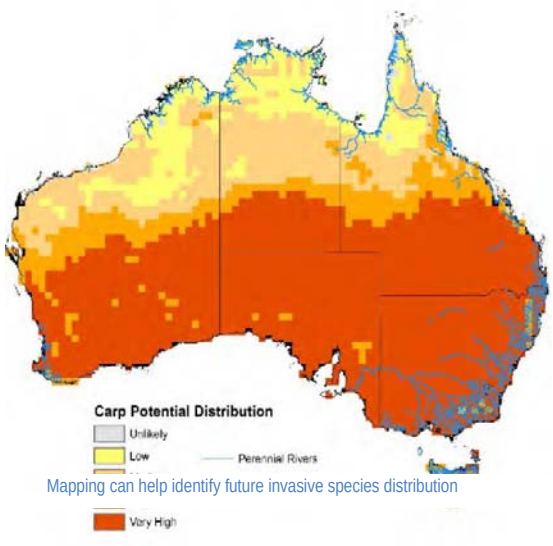
The project used statistical models to predict the distribution of key vertebrate pest species in NSW under a future climate scenario for the year 2050. In addition to climate, a range of biophysical variables were also used in the models where it was believed they may influence the distribution and abundance of the pest species. The study used four different global climate models to gauge variation in the predicted response of pest species distributions. The species analysed were: cane toads, feral cats, feral goats, feral pigs, foxes, Indian mynas, rabbits, starlings, wild dogs and wild deer.

Results showed that, as expected under a warmer climate, cane toads are predicted to expand their range considerably (four-fold). Predictions varied more for temperate species. Rabbits are predicted to generally decline in distribution and abundance, and foxes to increase in density in some areas and decrease in others. Feral cats are predicted to have a slight decrease in abundance, but to maintain a similar range. The current distributions of some species, such as feral pigs, wild dogs and feral goats, are affected by land use, particularly the intensity of agriculture. The ability of the models to predict distributions for starlings was poor.

Maps of predicted distributions generated by the modelling will help government agencies and the community plan for pest control activities in the future.

Key achievements

- Four different climate models on 10 pest species tested.
- Predicted land-use patterns analysed and results incorporated into species distribution models.



Mapping can help identify future invasive species distribution

- Maps of predicted distributions generated.
- Final Invasive Animals CRC technical report submitted.
- Invasive Animals CRC technical modelling report 'Modelling the distribution of vertebrate pests in NSW under climate change' published.

Project team

Benjamin Russell, Andrew Leys, Dr Paul Downey (NSW DECCW), Dr Jeanine Baker, Dr Greg Hood, Leane Brown, Hilary Johnson, Raphael, Phillip Tennant, Peter Caley (ABARES).

Project partners

Invasive Animals CRC, ABARES, NSW Office of Environment and Heritage.

Further Information

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Socio-economic costs of pest animals

Project Leader: Dr Randall Jones, NSW Primary Industries

Aim: *To measure the environmental, economic and social costs of vertebrate pests*

Projects 12.D.6

Project duration November 2006 – November 2009
Status Completed

Project summary

This project assessed a range of impacts attributable to vertebrate pest animals throughout Australia.

Economic costs: The concept of economic welfare was used to estimate costs of production losses. Government and landholder expenditure on pest control and research were also included. Direct costs of foxes, rabbits, wild dogs, feral pigs, birds and mice were examined.

The overall direct economic impact of the pest animals was conservatively estimated at $740 million annually. This comprised $620 million in agricultural losses and $120 million in expenditure on research, management and administration.

Pest	$m
Birds	313.1
Rabbits	206.0
Wild dogs	48.5
Mice	22.8
Foxes	21.2
Feral Pigs	9.2
Total	**620.8**

Production impacts were broken down by industry (beef, wool, lamb, grains and horticulture industries) and by key pest animal. Horticulture and beef industries were the most impacted industries. Rabbits and birds (combined species) incurred the greatest losses to production. The agricultural loss versus current expenditure by governments and landholders on pests suggests that too little money is being spent on pest animal research and control. A benefit-cost analysis of a range of scenarios concerning investment in research and management to better control pests was also done, showing that the benefits of further research exceed the costs.

Environmental impacts: The cost of invasive animals on the environment was analysed by estimating the loss of one environmental asset class, listed threatened species, in NSW. A scientific article on this research is being prepared.

Social impacts: A social costs case study in the Upper Hunter Valley of NSW has been written up and published ('Assessing the Social Impact of Invasive Animals in Australia'). The report shows social impacts flow from economic and environmental impacts, although direct social impacts also occur, such as distress from wild dog attacks on stock, or personal injuries from vehicle collisions with feral animals. Conflicts within communities can result from differing opinions on pest control programs, in the context of changing land-use patterns and the migration into rural communities of people with different sets of values.

The information obtained from these impact analyses will allow a better understanding of the range of impacts vertebrate pests have on our economy, people and biodiversity. The reports will also provide tools for leveraging for further resources for pest management.

This project also contributes to Output 9.1: The development of information systems that will improve coordination and evaluation of effort on a national, regional and local level.

Key achievements

- Final social report assessing the Social Impact of Invasive Animals in Australia published.
- The final economics report 'The Economic Impacts of Vertebrate Pests in Australia' was launched in August, 2009 by Minister Burke at Parliament House and was responsible for increasing Invasive Animals CRC media coverage by approximately 50% over the related reporting period.

Project team

Dr Wendy Gong, Prof Jack Sinden, Adj Prof Mike Braysher, Dr Randall Jones, Gerard Fitzgerald, Roger Wilkinson and Dr Wendy Henderson.

Project partners

Invasive Animals CRC, NSW DPI, University of New England, University of Canberra, ABARES, Victorian Department of Primary Industries, Fitzgerald Applied Sociology.

Further information

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Evaluation of the impacts from alien pest animals on threatened biodiversity in NSW

Project Leader: Dr Paul Downey, Department of Environment & Climate Change NSW

Project 12.D.3

Aim: *To identify the specific threat posed by alien pest animals to threatened biodiversity in New South Wales*

Project duration	January 2006 to June 2007
Status	Completed

Project summary

This project quantified, for the first time in Australia, the impact of invasive animals on biodiversity in NSW and shows that they are a major cause of biodiversity decline in the State.

It illustrates the problem's scale in terms of the number and range of native species at risk.

The report assessed threats to 972 species, populations and ecological communities listed under NSW legislation for threatened species. About half of these threatened species are also listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*.

The threatened species list spans a broad range of mammals, birds, fish, insects, plants, fungi and algae.

- Pest animals threaten 40% of the threatened biodiversity in New South Wales.
- 388 threatened species are at risk, including 186 animals, 154 plants, 17 endangered populations and 31 endangered ecological communities.
- 29 different pest animal species were identified as threatening biodiversity.
- Feral cats, foxes and wild dogs are the worst pest predators.
- Feral goats, rabbits and feral pigs are the worst pest herbivores.
- Gambusia, redfin perch and European carp are the main pest fish threatening biodiversity.

The threat posed to biodiversity by invasive animals (as a single factor) was ranked fourth after land clearing, altered fire regimes and weeds. Pest animals also ranked highly when compared with broader processes threatening biodiversity, such as the destruction and modification of native vegetation.

Key achievements

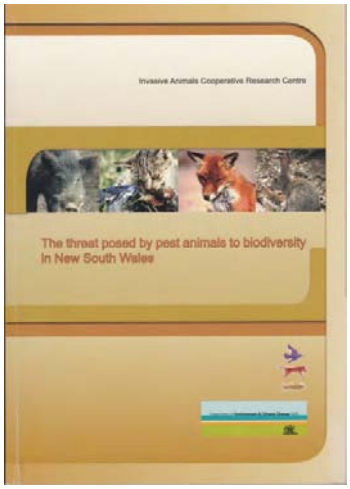
- This study provided a long-overdue baseline on invasive animals that can be used to make informed management and policy decisions into the future.
- It should also help stimulate discussion on the description of threats, which is currently not standardised.
- The new approach used to assess impacts on threatened species could be used in other jurisdictions to give a national picture of biodiversity threats posed by invasive animals.
- Addressing the impacts of species such as the feral cat, fox, feral pig and European carp are high on the list of priorities for the Invasive Animals CRC.
- This study gives further weight to the urgent need to reduce the threats posed by invasive animals.

Project team

Dr Paul Downey, Aaron Coutts-Smith, Paul Mahon, Mike Letnic

Project partners

Invasive Animals CRC, NSW Department of Environment & Climate Change and NSW Department of Primary Industries.



Further information

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Public attitudes to pests and methods for their control

Project Leader: Gerald Fitzgerald, Fitzgerald Applied Sociology
Aim: *Improved understanding among Invasive Animals CRC Participants and public decision makers of community and public attitudes towards, and understanding of, invasive animals, their impacts and methods for their control.*

Projects 12.D.5, 12.D.8

Project duration	1 June 2006 – 30 June 2009
Status	Completed

Project summary

Social research on attitudes to invasive animals and current and proposed forms of pest animal control were reviewed.

In particular, they identified the Australasian and relevant international research literature on public attitudes towards, and understanding of, invasive animals and their social impacts.

The reviews found that little primary research has been done on attitudes and perceptions of invasive animals in Australia. Studies to date have generally been reactive and not well informed by previous work.

The geographical coverage is patchy, and no national Australian picture for pest animals was available.

Animals covered include: foxes, wild dogs and dingoes, rabbits, horses, pigs, cats, deer, goats, water buffalo, kangaroos, wallabies, possums, stoats and flying foxes. Coyotes, wolves and elk are also briefly discussed.

In general, the research shows that attitudes towards invasive animals vary with age, gender, residential patterns, species of animal, situation and interest group.

The reviews serve as an information resource for those involved in researching and managing the impacts of animal pests in Australia and New Zealand

Key achievements

The research shows that attitudes towards pest animals and their control methods vary according to the:

- characteristics of the person or group — their gender, urban or rural residence, culture and value orientation
- perceptions of the pest animal and its impacts — its size, predation on livestock or other valued species, physical threat to people, impact on people's livelihood and aesthetic appeal
- environment being impacted — its proximity, accessibility, aesthetic and utilitarian appeal, public or private ownership
- features of the control strategy — safety, specificity, effectiveness, humaneness and cost.

Decisions about pest controls need to be made on a case-by-case basis and be informed by systematic assessments, recognising social and physical context. It is recommended that public and stakeholder involvement in decision making be accompanied by well-designed, balanced information.

An EndNote database of the references is available from authors.

Project team

Gerard Fitzgerald, Roger Wilkinson, Carl Davidson, Nic Fitzgerald and Elaine Murphy

Project partners

Invasive Animals CRC, Fitzgerald Applied Sociology, Victorian Department of Primary Industries and NZ Department of Conservation

Further information

Fitzgerald, G and Wilkinson, R (2009) Assessing the social impact of invasive animals in Australia. Invasive Animals Cooperative Research Centre, Canberra.

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www.invasiveanimals.com

Community awareness survey

Project Leader: *Dr Nicholas Fisher*, ValueMetrics Australia

Aim: *To determine ongoing community awareness of, and attitudes to, pest animal issues*

Project 10.D.12

Project duration	July 2007 – June 2011
Status	Completed

Project summary

This project used an internet-based survey to determine community awareness of and attitudes to invasive animals issues. It aimed to provide an ongoing community assessment and help the Invasive Animals CRC to fine tune its communication strategy by identifying community concerns.

The survey ran for two and a half years and showed that Australians are generally well aware of the threat posed by introduced pests and strongly support the development of improved methods for controlling them.

Main findings of the survey are:

- The 'top five' invasive animals are cane toads, feral cats, rabbits, carp and feral pigs followed by foxes and Indian mynah birds.
- Cane toads are ranked one of the worst pests by over 80% of respondents, feral cats are ranked one of the worst by two thirds of respondents and rabbits are ranked one of the worst by almost half of respondents — these three have been consistently ranked as Australia's three worst invasive animals.
- Issues of concern to members of the public regarding the control of pest animals include humaneness, ethics of 'right to kill' and non-target effects.

On average, 90% of women and 80% of men agree on the importance of developing effective, safe and humane controls for Australia's pest animals. Fertility control remains the public's number one choice as the preferred method for controlling feral animals (supported by 90%); this method is especially favoured among women.

The survey highlighted contrasting attitudes towards pests between different groups in the Australian community. For example: older people are far more likely than young Australians to regard cats, camels, cane toads, carp, mynas, starlings and feral pigs as serious pests. Young people are far more likely to regard introduced mice, rats, gambusia and pigeons as serious pests. These results suggest that young Australians should be provided with objective information about invasive animals and the damage they cause.

Key achievements

- Quarterly survey report for November 2007 to June 2010.
- Invasive Animals CRC project report published.
- Four peer-reviewed journal articles published.

Project team

Dr Nicholas Fisher and Prof Julian Cribb.

Project partners

Invasive Animals CRC, ValueMetrics Australia and Julian Cribb and Associates.

Further information

Fisher, NI, Lee, AJ and Cribb, JHJ (2012) Will the community accept our science? Monitoring the community's view about managing pest animals in Australia. Invasive Animals Cooperative Research Centre, Canberra.

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