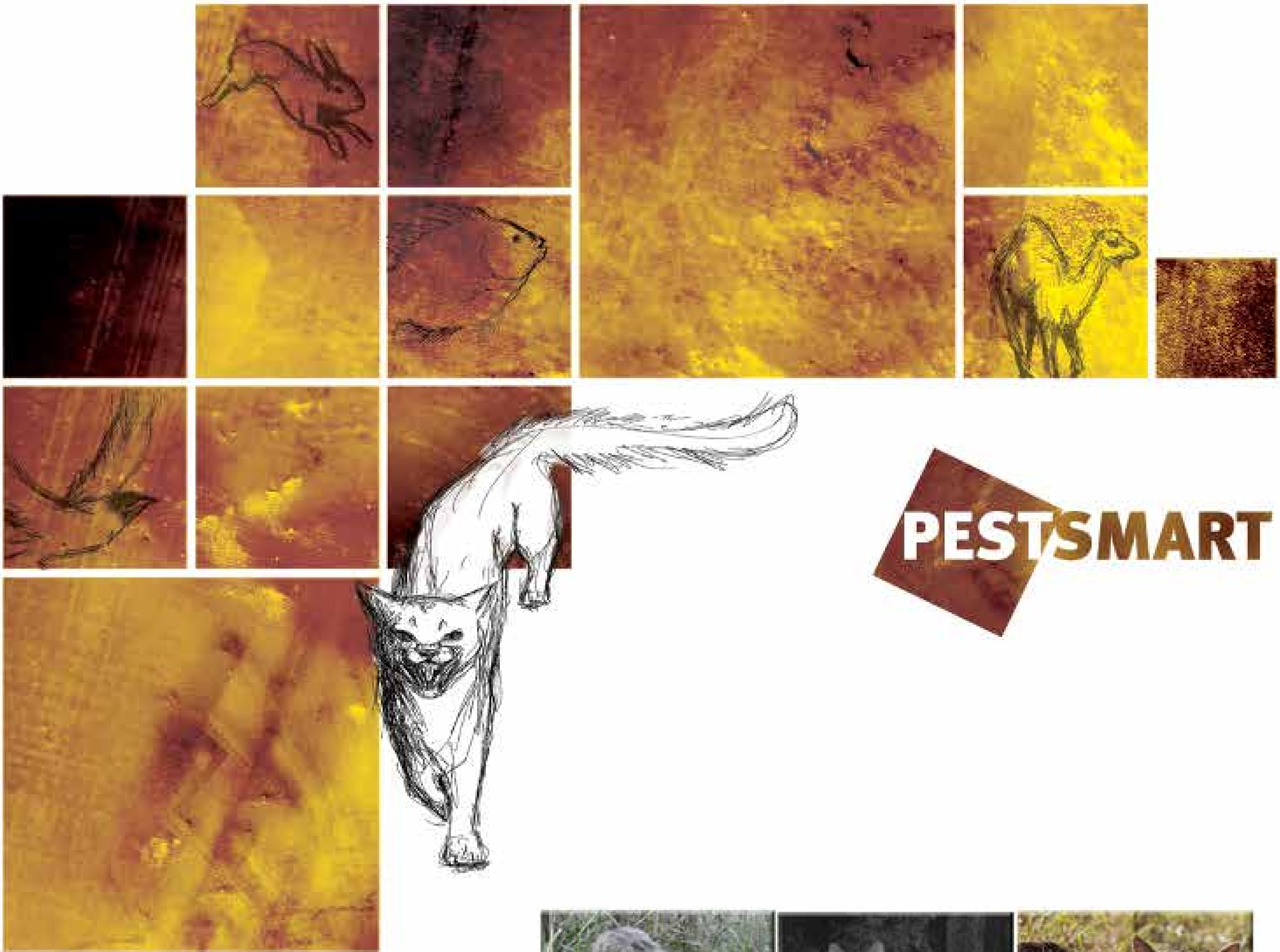

PESTSMART

2015 National Feral Cat Management Workshop Proceedings

University of Canberra, Australia
21-22 April, 2015

J Tracey, C Lane, P Fleming, C Dickman,
J Quinn, T Buckmaster & S McMahon (Eds)

Australian Government
Department of Industry and Science

Business
Cooperative Research
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Front cover photos: Phil Redpath, Joe Scanlan, Marika Maxwell

Contents

Summary

Feral cats (*Felis catus*) are widespread across Australia and New Zealand, occupying most habitats. They are a significant predator of mammals, birds and reptiles (Doherty et al 2015) and are identified as a major threat to endangered fauna, particularly on islands (Medina et al. 2011). Consequently predation by feral cats has been listed as a key threatening process in Australia under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). However, feral cat management and legislation is highly variable across Australia, and investment in research to seek longer term solutions has been *ad hoc* with limited national coordination. This workshop was held to address these issues, and to guide national strategies and actions under the *Threat abatement plan for predation by feral cats*.

These proceedings outline high impact research and innovation priorities and national actions for feral cats within five key areas: impacts, monitoring, control tools, management strategies and community engagement. A collection of papers is also provided that outline the strategic direction and review the most current research and innovation initiatives for feral cats and their management in Australia.

The workshop and review identified significant gaps in knowledge that must be addressed to effectively manage feral cats in Australia. Better information on impacts is required, in particular, on how impacts vary between prey species and across the landscape. We also require improved monitoring tools and use of technology, including the improved collection, automation and analysis of large data sets for predators and prey. Further development of traps and baiting tools is recommended, including, grooming traps, implants, lethal collars and kill traps; and standard operating procedures and support tools to ensure the animal welfare and effective adoption of these methods. Management should focus on eradication of feral cats on priority islands and fenced reserves, and on understanding the influence and role of predators, baiting, fire, grazing and rabbits on widespread feral cat populations. A national engagement strategy and facilitator, knowledge sharing, alternative funding models and improved ways to engage with communities are also identified as priorities.

It is hoped that these proceedings will assist key groups, particularly the Commonwealth and State governments and Ministers, the Threatened Species Commissioner, the Invasive Plants and Animals Committee, the Invasive Animals Cooperative Research Centre, universities and conservation and community groups to prioritise funding and resources to reduce the impacts of cats. Outcomes will also be used in the preparation of an updated *Threat abatement plan for predation by feral cats,* and a national *Threatened Species Strategy*.

Priorities identified for future work

The workshop used open theme-based and follow-up focussed discussions to identify and prioritise areas of future work to improve the management of feral cats, with consideration of the benefits, costs, feasibility and time frame.

Those areas considered of highest priority were:

Impacts

1. Quantify impacts of feral cats on other species, especially natives
2. Better understand spatial variations in cat impacts
3. Conduct studies on predation rates by cats, including the development of improved camera collars to discover kill rates
4. Review disease-related impact of cats on people and livestock (e.g. sarcocystis, toxoplasmosis)
5. Assess overall economic impacts of cats (including impacts on agriculture and tourism)
6. Explore Aboriginal cultural approaches to managing impacts

Monitoring

1. Develop guiding principles for feral cat and threatened species monitoring (including TAP targets)
2. Design and implement a national monitoring network for cats and threatened species
3. Review cat monitoring methods, and establish standards
4. Develop improved monitoring tools, including automated recognition, improved use of cameras, and improved management and analysis of data (e.g. Bayesian approaches, a package of analytical techniques)
5. Investigate the use of eDNA as a monitoring technique for predators and prey
6. Develop detection probabilities for established and commonly used monitoring methods (including camera traps, spotlighting)

Control tools

1. Develop a grooming trap for feral cats
2. Review the feasibility of biocontrol agents for cats (including gene drive technology and technical, ecological, and social considerations)
3. Develop improved baiting tools and strategies, including implants, lethal collars, kill traps, and national registration and adoption
4. Update Standard Operating Procedures (animal welfare) for cat control methods
5. Develop support tools (improved adoption, multimedia, decision support tools)

Management

1. Develop a long term national management strategy to build collaboration across different approaches in different environments
2. Eradicate cats from priority islands
3. Eradicate cats from fenced enclosures on mainland Australia
4. Improve management of cats in open landscapes, including integration and improved understanding of the role and influence of predators, baiting, fire, grazing and rabbits

Community engagement

1. Conduct community-needs research, identify institutional barriers, understand community perceptions and barriers to effective management
2. Build a collaborative approach through the development of a national stakeholder engagement strategy and appointment of a national feral cat facilitator
3. Facilitate knowledge sharing through social media, marketing, Feral Cat Scan
4. Explore alternative funding models, including crowdsourcing, philanthropies, community programs (who’s for cats) etc.

Recommended national targets

The following targets were recommended by participants for consideration by the Australian Government in its review of the *Threat Abatement Plan for predation by feral cats* and the development of the *Threatened Species Strategy*.

1. Effective evidence – based cat management has been implemented in six sites of high priority for native species imperilled by cats by 2020.
2. An effective national monitoring network developed (with sufficient precision) to detect trends in 40 key threatened species, and cats, by 2016.
3. New data management and analysis techniques used by X% practioners to assess the effectiveness of cat management by 2016.
4. By 2018, low cost and readily available tools based on existing and novel technologies for both broad-scale and localised intensive monitoring effectiveness of cat management.
5. Two new tools targeting feral cats within 3 years (to boost current control).
6. Ten year research program into gene drive technology to stop feral cats breeding (biocontrol, new emerging technology).
7. New feral cat bait available for landscape-scale delivery in 2 years.

1) Cats eradicated from 5 new islands (offshore).
2) Ten new fenced areas, each greater than 25 km^2 with cats eradicated.
3) In open landscapes:
    A) 20,000 km^2 of commonwealth land with strategic cat control
    B) Ten open-landscape sites each greater than 10,000 ha with strategic cat control, prioritised by
        - Extant threatened or high priority species
        - Recent species loss that is reversible.

8. National Feral Cat Management Initiative implemented.
9. Increase in support for the National Feral Cat Management Initiative by key stakeholder groups by X% by 2017
    a. Partners/ states sign onto national plan
    b. Community groups using Feral Cat Scan
10. Increase in collaborative engagement for NFCMI by stakeholders by X% by 2017
    a. Involvement in database, linkages to investors, Community groups using Feral Cat Scan.
11. Announce a National Feral Cat Facilitator by July 2015 (summit).
12. 20% of National Landcare Program (NRM) competitive funding (up to 5 years) tied to address key priorities identified for feral cats.

Background information

Steering Committee

Panel

John Tracey (Chair) - NSW Department of Primary Industries - Invasive Animals CRC
Julie Quinn - Department of the Environment
Chris Dickman - University of Sydney
Stuart McMahon - NSW Office of Environment and Heritage

Administrative assistance

Chris Lane - Invasive Animals CRC
Peter Fleming - NSW Department of Primary Industries
Tony Buckmaster – Institute for Applied Ecology, University of Canberra
Julie McGuiness – Invasive Animals CRC
Dorothee Scholl – Invasive Animals CRC
Keryn Lapidge – Invasive Animals CRC

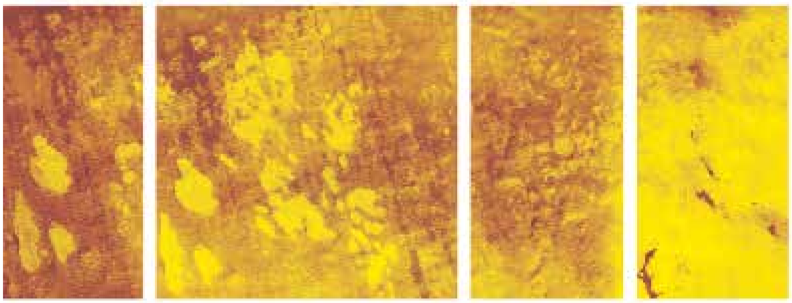
Context

Key guiding documents include:

- *Action Plan for Australian Mammals 2012*
- *Threat abatement plan for predation by feral cats*
- Policy and regulatory framework
    - Legal status across states
    - TAP/s
    - EPBC Act
- Identification of sites of high conservation priority impacted by feral cats (Dickman et al. 2010)
- Previous national feral cat workshop proceedings convened by the Invasive Animals CRC in 2010.

Aim:

To identify national actions and priorities for research and innovation to improve feral cat management in Australia in the short, medium and long term.



Objectives:

Specifically the workshop will:

1. Review existing knowledge of impacts, monitoring, control tools, management strategies and community engagement for feral cats in Australia,
2. Review current feral cat research and innovation projects, their objectives and progress,
3. Identify future actions and research and management priorities that have the potential to make feral cat management more effective and efficient, and
4. Strengthen collaborations between governments, universities, conservation and welfare organisations and the community to jointly address agreed priorities and achieve national action for feral cats.

In addressing these objectives consideration was given to:

- Integration of cat management into broader conservation objectives and existing research and management of other predators,
- Setting innovation and management priorities with consideration of benefits, costs, feasibility and timeframe (short, medium, long-term), and
- Building community approaches and collaborations between key stakeholders.

Attendees:

Experienced representatives from research and management agencies from Australian States and Territories, and New Zealand. A list of attendees is shown on page 159.

Location:

INSPIRE Centre, Building 25, University of Canberra, Pantowora Street, Bruce, ACT.

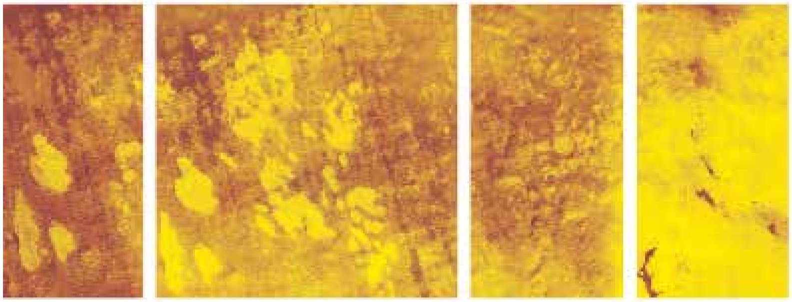
Date:

21- 22 April 2015.

Agenda

Tuesday 21st April 2015

10:00	Welcome	Andreas Glanznig, Chief Executive IACRC
10:05	Workshop aims and approach	Stuart McMahon- Facilitator, NSW Office of Environment & Heritage
Why are we here?- context and opportunities		
10:20	Opening address	Gregory Andrews, Threatened Species Commissioner, Department of the Environment
10:35	Strategic direction - policy and regulatory framework	Julie Quinn, Department of the Environment
10:45	Draft national targets for feral cat management	John Woinarski, Charles Darwin University
Impacts		
11:10	Introduction	Peter Fleming, NSW DPI
11:15	Environmental	Chris Dickman, Uni of Sydney
11:25	Impacts of cats on agriculture	Pip Masters, SA Govt
11:35	How to prioritise impacts	Chris Dickman, Uni of Sydney Tony Buckmaster, Uni of Canberra
11:45	Panel Discussion	All
12:25	Lunch	
Monitoring		
13:30	Introduction	Graeme Gillespie, NT Dept Land Resource Management
13:35	Quantifying cats: How many are there and do we need to know?	Tony Buckmaster, Uni of Canberra
13:45	Methods to monitor cats	Paul Meek, NSW DPI
13:55	Sampling designs for effective monitoring and evaluation	Peter Caley, CSIRO
14:05	Panel Discussion	All



Control Tools		
14:45	Afternoon Tea	
15:00	Introduction	Tony Pople, Biosecurity Qld
15:10	Review of cat control methods	Andrew Bengsen, NSW DPI
15:20	What is in the pipeline? Eradicat® , Curiosity® and other tools	Dave Algar, Dept Parks & Wildlife WA
15:30	Grooming traps and toxic Trojans for targeted poisoning of feral cats	John Read, Ecological Horizons
15:40	Recognition software and toxins	Paul Meek, NSW DPI
15:50	Review of biocontrol for cats	Tanja Strive, CSIRO
16:00	Fertility control options	Lyn Hinds, CSIRO
16:10	Welfare considerations for cat management	Bidda Jones, RSPCA
16:25	Panel Discussion	All
17:00	Close	

Wednesday 22nd April 2015

Management Strategies and application of tools		
9:00	Introduction	John Tracey, NSW DPI
9:05	Environmental manipulation	Chris Dickman, Uni Sydney
9:15	Ecological controls on impacts on cats on small mammals in northern Australia	Christopher Johnson, Uni of Tas
9:25	Integrated predator management	Guy Ballard, NSW DPI, UNE
9:35	Eradication of feral cats from Western Australian islands: success stories	Dave Algar and Keith Morris Dept Parks & Wildlife WA,
9:45	Large islands: Kangaroo Island	Pip Masters, SA Govt
9:50	Within and beyond the fence: the essential role of cat-free mainland (fenced) islands	Atticus Fleming, John Kanowski, Hugh McGregor, Australian Wildlife Conservancy
10:15	Panel Discussion	All
11:00	Morning Tea	

Community engagement and opportunities for collaboration		
11:35	Introduction	Atticus Fleming, AWC
11:40	Land managers roles	David Peacock, PIRSA
11:50	Community engagement and opportunities for collaboration: Role of NGOs	Jim Radford, Bush Heritage Aust
12:00	Applying behavioural science for more effective cat management interventions	Lynette McLeod, UNE
12:10	Connecting communities- Feral scan	Peter West, IACRC
12:20	Panel Discussion	All
13:00	Lunch	
Where do we want to be? Overview and priority setting		
14:00	Break into Groups Prioritise key areas considering benefits, costs, feasibility and timeframe What are the recommendations/ national targets? Report to the group	Stuart McMahon, All
17:15	Summary/ outcomes	Stuart McMahon
17:25	Next steps	John Tracey/ Julie Quinn
17:30	Close	

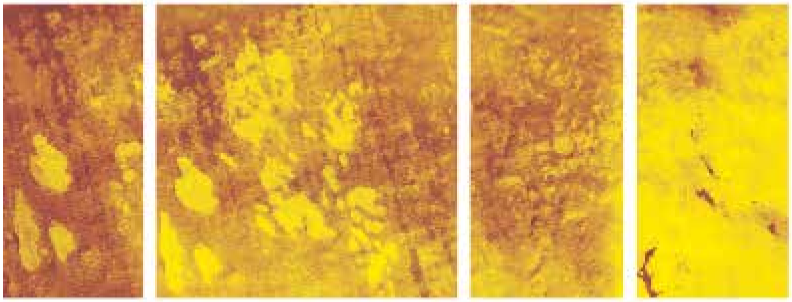
<u>Task</u> for participants prior to the workshop:

What are the top 3 priorities for effective cat management?

<u>Panel Discussions</u>

Session speakers will be included on a panel for each theme. A facilitated discussion with all workshop participants will focus on:

- Where are the gaps/ common threads?
- What are the most important areas for future work?



Workshop proceedings

Why are we here? – Context and opportunities

Opening address

Gregory Andrews
Threatened Species Commissioner, Department of the Environment

Feral cats are one of the greatest threats to terrestrial Australian fauna. Minister Hunt has made tackling feral cats a priority for both the Department of the Environment and the Threatened Species Commissioner. In tandem with this, the Minister has set the target of improving 20 mammal trajectories by 2020 and no more extinctions post 2020. In order to achieve this, we need practical, on-ground action that is supported by science.

The time for no-regrets science and action is now. We need tangible, achievable and easy to understand targets to tackle feral cats in the short, medium and long term. We need to bring the community along in this task and work in collaboration to protect our threatened species.

Strategic direction – policy and regulatory framework

Julie Quinn
Department of the Environment

Predation by feral cats is formally recognised as a key threatening process under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*. The Australian Government has had a threat abatement plan since the mid-1990s, which provides a national framework to guide and coordinate Australia's response to the effects of predation by feral cats on biodiversity. This recognition via national environmental legislation is important as feral cats are generally not considered as an agricultural pest.

The government has recognised the significant impact that predation by feral cats is having on native fauna and made it a key priority to be addressed in a number of government programs.

The impact of feral cats on biodiversity is also recognised nationally in other documents such as the 2014 Mammal Action Plan. Victoria and New South Wales state governments have recognised feral cats as a threatening process under their legislation related to threatened species. Nationally agreed codes of practice and standard operating procedures for feral cat management are other important documents which guide appropriate and humane control methods.

There is a regulatory framework with both the Australian Government and state and territory governments to ensure that control tools, including toxins and biocontrol agents, are safe and appropriate for the environment and people. This is also the case for feral cat control agents including the Eradicat® bait and the products in the pipeline using PAPP, including the Curiosity® bait.

The policy framework underpins funding that is provided for on-ground action to control feral cats or implement other actions to prevent predation on native fauna. Currently funding can be provided by the Australian Government via the National Landcare Programme and includes some resources that the Threatened Species Commissioner is able to mobilise for specific projects, such as trialling the use of guardian dogs to protect the eastern barred bandicoot. Regional natural resource management groups are also able to direct National Landcare Programme funds to projects that include feral cat management activities.

Beyond governments, non-government organisations who manage conservation lands are able to support the national policy framework through their critical research and on-ground management. Non-government organisations with an animal welfare interest can advocate to ensure that feral cat management is as humane as possible.

Other conservation organisations can provide advocacy support for well-targeted and effective policies and programmes. Research undertaken through all avenues provides the backbone that informs government policies.

Regulation of pests occurs through state and territory legislation and, in some instances, is supported by local government by-laws. Pest regulations vary between jurisdictions regarding: the lead portfolio (primary industry, natural resource management or environment); the way pests are categorised; the level of management required; and who is responsible for that management.

For these and other reasons, the regulation of feral cats is highly variable across Australia. In particular, feral cats are declared as pests in Queensland (class 2) and the Northern Territory.

The Australian Government is keen to see feral cats declared as pests in all states and territories to ensure there are no impediments to landholders and other land managers undertaking control now or in the future when other tools are available.

Draft national targets for feral cat management: Towards the effective control of feral cats in Australia – targets with teeth

John C.Z. Woinarski[A], Keith Morris[B] and Euan G. Ritchie[C]

[A] *Threatened Species Recovery Hub of the National Environment Science Programme, Charles Darwin University*
[B] *WA Department of Parks and Wildlife*
[C] *Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University*

Summary

Feral cats have been present in Australia since soon after European settlement. They are now numerous and pervasive across the continent, and occur on many islands. Although they have been recognised as a Key Threatening Process to Australian biodiversity under the EPBC Act since 1999, and there has been a Threat Abatement Plan for them in place since 2008, there has to date been little progress towards their effective management.

The challenges to effective control of feral cats in Australia are formidable. The geographic scale of concern is immense; many potential control mechanisms (such as trapping and shooting) typically have only superficial, transient and localised benefits; design of effective baits has only recently progressed substantially; there may be significant non-target impacts (including for threatened species such as quolls) from such toxic baits; baiting programs may need to be sustained for many years, and in many places need to also consider integration with control of foxes; reduction in cat numbers may have unwanted consequences (increases in other pest species, such as rabbits or introduced rodents); control programs will be expensive; and there will be some community concern about cat control.

However, progress towards the effective control of feral cats will achieve marked biodiversity benefits. Such control is likely to be substantially more efficient and cost-effective, and produce more enduring outcomes, than alternative conservation approaches based on intensive management for individual threatened species.

Here, we propose short-term (one year) targets towards the effective control of feral cats in Australia. These targets are set within a broader contextual and long-term (ca. 20 years) objective:

> No further extinctions of Australian wildlife, and pronounced recovery (and return to the wild) of at least 40 currently threatened animal species.

The targets recommended here are designed strategically to help establish a robust foundation for the decadal-scale campaign likely to be required to achieve enduring success. This should not be taken to indicate that significant progress can be achieved, if at all, only at glacial speed. Rather, explicit and dramatic short-term targets set now are required to overcome inertia, to recognise that this is a problem that should be confronted, to demonstrate that successful outcomes are possible, and because the continuing existence of some threatened species requires immediate action.

The targets proposed here are multi-dimensional, recognising that overall benefit will arise most substantially from attention directed at complementary aspects of this problem.

The 5 recommended immediate (one year) targets (some with subsidiary targets) are:

- at least 10 animal species, currently most imperilled by feral cats, are secured or recovered through intensive management (primarily through networks of exclosure fencing);
- feral cats are effectively managed in more than 1% of Australia (i.e. >75,000 km^2);
  - programs have been commenced to eradicate cats from at least 5 biodiversity-significant islands within 5 years;
  - consultation is initiated to implement cat eradication programs for at least 20 additional islands over the next 10 years;
  - a coherent policy framework and biosecurity management program is developed to stop the introduction of cats to islands that are currently cat-free;
  - cat populations have been reduced by >80% across >10,000 km^2 of Australia, through broad-scale cat-baiting programs;
  - cat populations and predation pressure have been reduced by >50% across >20,000 km^2 of Australia through broad-scale trial environmental management (e.g. fire) programs;
- exemplary feral cat management programs are established and implemented effectively on all Commonwealth lands, particularly conservation reserves managed by Parks Australia;
- a harmonised national approach is developed and implemented for the management of stray and domestic cats;
- a coherent set of priority research and monitoring programs is implemented, aimed at allowing more effective and cost-efficient broad-scale management of cats;

- the economic costs of toxoplasmosis to livestock production, and the extent to which the effective control of feral cats can mitigate these costs, is determined;
- research aimed at the development of more effective cat eradication options is supported;
- effective protocols are developed and applied for monitoring cat populations, impacts and responses of cat-affected species to management;
- the management implications of feral cat interactions with other species (notably Tasmanian devils, dingoes, foxes and pest prey species) are resolved through research and adaptive management trials.

These targets are broadly consistent with, or complement, the objectives and actions now being drafted in revision of the *Threat abatement plan for predation by feral cats*.

Note that another possible national target – an annual tally of the total number of feral cats culled – is not recommended because (i) it focuses on activity rather than on conservation outcomes, (ii) it would be extremely difficult to measure reliably, (iii) (given rapid recruitment) it would not well indicate the extent to which the overall population size of feral cats is reduced, (iv) it may encourage a far more scatter-gun than strategic approach to the problem, and (v) it may unhelpfully alarm that section of society sympathetic to cats and with animal welfare concerns.

Background

Rationale – the need for action

Much Australian biodiversity is in decline. This has been shown most recently and starkly in the comprehensive review of the fate of the Australian mammal fauna since European settlement: this concluded that between 28 and 30 Australian mammal species (more than 10% of that fauna) had been rendered extinct since the 1840s, that the rate of extinction (of 1-2 mammal species per decade) was continuing unabated, and that very many mammal species were now threatened and/or declining rapidly (Woinarski *et al.* 2014). That review concluded that predation by feral cats was the factor responsible for the most extinctions, and for most current declines, in the Australian mammal fauna. It also concluded that the single action that could provide the greatest benefit for the conservation of the Australian mammal fauna was the effective control of feral cats. Without such control, conservation efforts directed towards many to most threatened land mammals are likely to be severely constrained, piecemeal and cost-ineffective, and may deliver benefits that are only short-term. Although the evidence is strongest for cat impacts upon native mammals, predation by feral cats is also likely to be a primary threat for some threatened bird and reptile species (Doherty *et al.* 2015), such as the western ground parrot.

In addition to causing ongoing decline in many species, feral cats have also inhibited or prevented many attempted reintroduction and other recovery efforts, rendering those investments an ineffective and frustrating use of the limited resources available for conservation (Christensen and Burrows 1994). One of the notable conservation success stories for Australian mammals, the recovery of many species associated with a sustained large-scale fox-baiting campaign in south-western Australia (Western Shield), may now be jeopardised by a resulting increase in cat predation, with reversals again for several mammal species that had previously been recovering (Marlow *et al.* 2015).

The impacts of predation by feral cats are profound. But feral cats may also pose significant detriment through spread of disease to Australian wildlife (and to livestock and humans). Cats are the primary vector (the definitive host) for toxoplasmosis (Fancourt and Jackson 2014), with spread to many native mammal and bird species through contact with food, soil or water contaminated with infective oocysts that are shed by cats in their faeces. The lethal and sub-lethal consequences of toxoplasmosis to Australian wildlife are poorly resolved, but may be substantial.

Challenges: impediments that constrain progress

The control of feral cats is a difficult problem. In part, this is because of characteristics of the cats themselves, because of societal attitudes, because of limited knowledge, and because of potential detrimental environmental consequences of some cat control mechanisms.

Feral cats are now pervasive and abundant, in all environments, across the Australian mainland and on many islands. Eradication on the mainland is not feasible in the foreseeable future. This recognition is mutually reinforcing, as the problem may be seen to be intractable and hence not worth investing in. However, effective control of feral cats over large mainland areas may now be possible.

Unlike some other threats to biodiversity, feral cats were considered until recently to pose little or no threat to agricultural productivity or other community values, so the ability to draw on resources for their management is relatively limited. (However, recent reports from Tasmania have indicated some at least localised cases of major losses of lambs due to toxoplasmosis.) Furthermore, given the popularity of pet cats, there may be antipathy from some sections of the community towards cat control generally, and some control options specifically. Around settled areas, there may be ongoing recruitment to the feral cat population from stray and pet cats, and population increase arising from the deliberate or untargeted provision (e.g. rubbish dumps) of food and other resources.

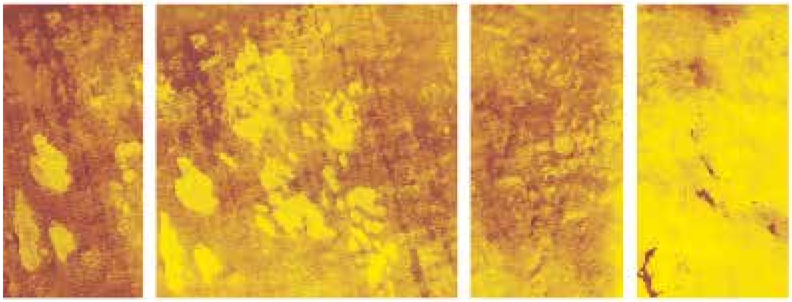
Feral cats have a flexible ecology and an extremely broad diet. This helps drive their ecological impact as they can kill and consume all individuals of a species in an area, causing local extinction, and then readily shift to another prey item without lasting consequences to their own population. A broad diet, and wariness, also means that they may take baits (or enter traps) only when little other food is available, constraining options for broad-scale control (Algar *et al.* 2007). Cats also have a high reproductive output, meaning that individual control measures that simply reduce local population size may have only short-term benefits. Some studies have indicated that individual cats may hunt selectively and particularly effectively on individual threatened species, such that reduction in feral cat populations in an area to even very low numbers may be insufficient to provide protection to that threatened species (Christensen and Burrows 1994; Frank *et al.* 2014). We don't yet know whether there are 'safe' thresholds of feral cat density below which their impacts upon threatened species are negligible – or more likely, these thresholds will differ between different threatened mammal species.

Available control mechanisms for feral cats have some significant limitations. Shooting, trapping and hunting with trained dogs are likely to be effective only in circumscribed sites that can and need to be intensively managed, such as on small islands or at sites used for the establishment of exclosure fencing. Such predator exclosure fencing is effective for the protection of many threatened mammals highly susceptible to cat predation, but establishment (ca. $20-40,000/km) and ongoing maintenance costs dictate that such exclosures will be relatively small scale.

Baiting is more likely to be effective over larger areas, but is unlikely to kill all cats in the baited area. Whatever the control mechanisms, it will need to be sustained over multiple years because of the high rate of cat recruitment and (except on islands) immigration from adjacent areas; and some control methods may have diminishing efficacy over years. There are also substantial costs associated with current cat control options – for example, an aerial baiting program to control feral cats over an area of 2500 km^2 costs about $60,000 per year.

There are also concerns about direct mortality of threatened species (such as northern quoll) from cat baits in some regions. Dingoes are also susceptible to baits laid for feral cats: this raises some Indigenous cultural concerns and also may render the baiting counter-productive, with any reduction in dingo numbers potentially leading to increases in cat abundance.

In some situations, control of feral cats may also bring detriment for threatened species and other values, if such control results in subsequent increase in pest



species (such as rabbits or introduced rodents) that are currently limited by cat predation.

Current action and progress

A Threat Abatement Plan sets the broad framework for the management of feral cats in Australia (Department of the Environment, Water, Heritage and the Arts 2008). That Plan is currently being revised. However, there has been relatively little progress of actions to date, with little previous resourcing and little coherent national implementation. This is the case even for Commonwealth lands, for which the *Environment Protection and Biodiversity Conservation Act 1999* stipulates that Threat Abatement Plans must be implemented.

A 2006 review concluded that annual control operations of feral cats across Australia then comprised a total area of about 34 km^2 (Reddiex *et al.* 2006). It is likely to have increased substantially since, but no national tally is maintained.

However, there have been some significant achievements. Many Australian islands have very high conservation values and eradication of threats is far more feasible on islands than on mainland regions. Feral cats were eradicated from Hermite Island (Montebello group; 10 km^2) in 1999, from Macquarie Island (128 km^2) in 2001, and Faure Island (51 km^2) in 2002. There are current programs aimed at eradication of feral cats on Christmas (135 km^2), Dirk Hartog (586 km^2), and West (Pellew group: 134 km^2) Islands. Substantial biodiversity benefit has been demonstrated as a consequence of localised control of feral cats on Christmas Island and, after subsequent eradication of other pest species, on Macquarie Island.

However, feral cats remain present on at least 50 Australian islands (Abbott and Burbidge 1995), and cats have continued to be introduced to previously cat-free islands (Woinarski *et al.* 2011). Biosecurity programs are inadequate for all but a few islands.

Over recent decades, cat-free islands have been used very successfully as translocation sites for many threatened Australian mammals, and such actions have prevented extinction and allowed recovery for some species, such as the mala (Langford and Burbidge 2001). However, translocation to islands is not a feasible option for some threatened species, not all islands are suitable for translocation, and marooning of threatened species on islands may best be seen as a necessary stepping-stone (towards eventual successful return to previous mainland range) rather than a conservation end-point.

More recently, ‘mainland islands’ (sites at which otherwise pervasive threats are excluded or otherwise intensively controlled) have become a major focus for conservation effort for threatened mammals. About 30 such predator-proof exclosures have now been established in Australia. The most notable examples include four sites maintained by the Australian Wildlife Conservancy (with total area of 171 km^2 and largest exclosure of 80 km^2), Arid Recovery (with total predator-exclosure area of 60 km^2), WA Parks and Wildlife's Matuwa (Lorna Glen) (predator-exclosure area of 11 km^2) and Perup Sanctuary (4 km^2), and Mulligan's Flat Woodland Sanctuary (predator-exclosure area of 4.5 km^2). These programs have demonstrated remarkable recovery of many threatened mammal species when feral cats (and foxes) are excluded.

There has been some substantial recent progress with development and trialling of baits specifically targeting feral cats, most notably the *Eradicat*® and Curiosity baits. Some larger-scale (>1000 km^2) programs using these baits are now being implemented, notably including at Matuwa (Lorna Glen) and Fortescue Marsh in the Pilbara region, with results demonstrating substantial reduction in feral cat numbers (e.g. 85% mortality at Fortescue: Clausen *et al.* (2014)) to levels that allow the persistence of some, but not all, threatened mammal species. However, it is likely that baiting programs may vary appreciably in their effectiveness depending upon seasonal conditions and prey abundance.

Environmental management may have a key and more cost-effective, enduring and large scale role to play in cat control. Recent studies in the Kimberley have demonstrated that feral cats select extensively burnt areas for foraging, and that their impact upon native mammals is much higher in such areas than in unburnt areas and in areas burnt with a fine-scale mosaic (Leahy 2013; McGregor *et al.* 2014), probably because the extensively burnt areas provide less protective shelter (such as hollow logs and dense grass) and fewer food resources for native mammals (so they must forage for longer and take more risks). Accordingly, in mainland regions now subject to frequent fire, improved fire management may allow threatened species to persist or recover even in the absence of targeted cat control. Over-grazing (by livestock and feral animals) may similarly lead to increased predation impacts.

Another environmental management option relates to interactions ('trophic cascades') amongst predator species. Mainland Australia's apex predator, the dingo, regulates to some extent the abundance and impacts of foxes and feral cats (Letnic *et al.* 2012). Broadly, a higher abundance of dingoes leads to less impact on threatened fauna from foxes and cats, and less overall predation impact. However, dingoes (and wild dogs) are currently subject to broad-scale control programs in many (pastoral) parts of Australia. An increase in dingo numbers in such areas is likely to benefit some threatened mammal species. Some current research trials indicate that the undesirable consequences to pastoralists of any increase in dingo abundance may be mitigated effectively and cost-efficiently by use of guardian dogs (Van Bommel and Johnson 2012). Comparably, a strategic reintroduction of

Tasmanian Devils to some mainland areas may cause a decrease in the abundance and impacts of feral cats, and hence provide a net benefit for some threatened species.

Response: target options

Here, we recommend a multi-dimensional approach to achieving substantial conservation benefit through the management of feral cats and of species affected by feral cats. We emphasise that control of feral cats is a means to an end (biodiversity conservation), so targets should not focus solely on cats themselves, but also on the management of cat-affected threatened species and on securing areas not currently occupied by cats.

Accordingly, we do not recommend a numerical cull target, such as an annual tally of the total number of feral cats killed. We advise against such a target because (i) it focuses on activity rather than on conservation outcomes, (ii) it would be extremely difficult to measure reliably, (iii) (given rapid recruitment) it would not well indicate the extent to which the overall population size of feral cats is reduced, (iv) it may encourage a far more scatter-gun than strategic approach to the problem, and (v) it may unhelpfully alarm that section of society sympathetic to cats and with animal welfare concerns.

For the set of targets we propose, we recommend a longer-term (*ca*. 20 years) objective that sets broad context:

> *No further extinctions of Australian wildlife, and pronounced recovery (and return to the wild) of at least 40 currently threatened animal species*.

The enhanced management of feral cats will make a substantial contribution to this goal, probably more so than any other single factor.

Substantial and enduring conservation benefits for cat-affected threatened species will be achieved only with a coherent, long-term and strategic program. Short-term (one year) targets are necessary to provide impetus and direction to that program, to demonstrate commitment, and to allow an assessment of progress. However, they need to be encapsulated within longer-term commitments that allow continuity of management actions.

Here, we propose a series of complementary *one-year targets* that are achievable, measurable and, if implemented, will deliver significant conservation progress. These targets can readily be expanded in a strategic manner in subsequent years. These targets are described below.

TARGET 1. At least 10 animal species, currently imperilled by feral cats, are secured or recovered through intensive management. This should be done particularly through networks of exclosure fencing, but also including captive breeding, translocation and intensive baiting.

Rationale: Longer-term programs aimed at increasing the landscape-scale control of feral cats may come too late for highly imperilled species (such as bridled nailtail wallaby, western ground parrot, mountain pygmy-possum, Gilbert's potoroo, numbat, red-tailed phascogale, woylie and others): to avert extinction, these species need immediate attention. Some of these species are currently the subject of conservation management actions (in some cases based on recovery plans), but some of these programs are tenuous and need further support.

Options: The number of target species and the size and number of predator-proof exclosures can be varied, but a target of 10 species in a one-year timeframe is tractable.

TARGET 2. Feral cats are effectively managed in more than 1% of Australia (i.e. >75,000 km^2).

Rationale: This target provides a national indicator that can be readily increased and monitored over longer time frames. The initial target may appear unambitiously small, but this level highlights the extent of the problem.

Options: The only previous available national estimate for the extent of active feral cat control operations for Australia is that of 34 km^2 (Reddiex *et al.* 2006), or a nugatory 0.0004% of the Australian landmass. With the dedicated increase (described in the following subsidiary targets) in the area of predator exclosures, island eradications, broad-scale baiting and broad-scale environmental modification programs aimed at reducing cat impacts, this proportion could be increased readily to 0.2%. Inclusion of currently cat-free islands for which enhanced biosecurity measures could be implemented would increase the area to *ca*. 1% (i.e. 76, 920 km^2).

Target 2a. Programs have been commenced to eradicate cats from at least 5 biodiversity-significant islands within 5 years.

Rationale: Many Australian islands have very significant conservation values. However, on some islands these values are being jeopardised by feral cats. Eradication of cats on islands is far more feasible than on mainland areas.

Options: The number of islands and the time period for eradication programs can be varied, but the suggested values are realistic. Note that there are current control programs at various states of progress for four islands.

Target 2b. Consultation is initiated to implement cat eradication programs for at least 20 additional islands over the next 10 years.

Rationale: Feral cats are present on at least 50 Australian islands. Control programs may need to have substantial consultative periods. Note that islands should be prioritised based on biodiversity value and tractability of eradication (Dickman *et al.* 2010). Consultation will need to involve relevant land-owners, state agencies and other stakeholders.

Options: The number of islands and the time period for eradication programs can be varied, but the suggested values are realistic.

Target 2c. A coherent policy framework and biosecurity management program is developed to stop the introduction of cats to islands that are currently cat-free and to increase biosecurity programs for islands of particular conservation significance.

Rationale: Cat-free islands offer a diminishingly small haven for many threatened species, and there is currently no consistent national approach for retaining their cat-free status. Note that this target will require consultation and coordination with state and territory governments and other relevant stakeholders.

Options: The present ad hoc approach could be retained, or left to different jurisdictions to act individually, but a coherent national approach would better highlight the issue. In some cases, legislative change may be required.

Target 2d. Cat populations have been reduced by >80% across >10,000 km^2, through broad-scale cat baiting programs.

Rationale: There has been considerable recent progress with the design of baits and baiting protocols, but there remain unresolved issues about the optimal scale, sustainability, longer-term effectiveness at reducing cat abundance to acceptably low levels, cost-efficiency, non-target impacts, and net biodiversity benefits. These issues can be addressed only with well-designed large-scale management trials that are closely monitored. Large-scale baiting programs may offer the most practical short- to medium-term option for increasing the area in which cats are intensively controlled beyond the small area of more expensive cat exclosures and islands. Note that baiting programs would need to operate over at least several years to allow assessment of efficacy. Note also that there are at least two current such baiting trials, in the Pilbara. Note that implementation of such programs will need to be complemented by careful monitoring of impacts upon cat numbers and on threatened species.

Options: The number of management programs and the area over which they are implemented can be varied, but the suggested values are realistic. Note that this action focuses on mainland areas, but could reasonably also include large islands (Tasmania, Groote Eylandt).

Target 2e. Cat populations and predation pressure have been reduced by >50% across >20,000 km^2 through broad-scale trial environmental management (e.g. fire, native predator) programs.

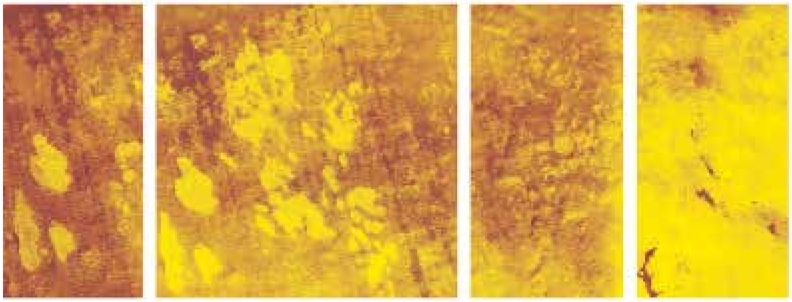
Rationale: Management of fire (to reduce the extent of intensively-burnt areas) and dingoes (to restore populations to areas in which they have been substantially reduced) – and possibly livestock and feral herbivores – may offer the only immediately available cost-effective mechanism to reduce the impacts of feral cats over very large areas. However, while there have been some limited, brief and localised studies that indicate that these approaches may be beneficial to some cat-affected threatened species, proof-of-concept is required over larger areas and longer periods. Note that implementation of such programs will need to be complemented by careful monitoring of impacts upon cat numbers and on threatened species.

Options: The number of management programs and the area over which they are implemented can be varied, but the suggested values are realistic.

TARGET 3. Exemplary feral cat management programs are established and implemented effectively on all Commonwealth lands, particularly conservation reserves managed by Parks Australia.

Rationale: The EPBC Act (s. 269) stipulates that the Commonwealth must implement a threat abatement plan to the extent to which it applies on Commonwealth land. However, to date there has been little or no effective implementation of the feral cat threat abatement plan (or any other effective management of feral cats) on any Commonwealth lands. Use of this target would indicate national conservation leadership and help provide for the recovery of threatened species on Commonwealth lands, particularly conservation reserves.

Options: The target could be restricted to Commonwealth-managed conservation reserves, or could be phrased to provide more explicit quantitative outcomes.



TARGET 4. A harmonised national approach to the management of stray and domestic cats is developed and implemented.

Rationale: Around settled areas, the population of feral cats is supported by provision of food sources and recruitment from pet and stray cats; and pet and stray cats cause at least localised biodiversity impacts. However, there is no coherent management of pet and stray cats across local and state/territory governments, and many cat owners have little awareness of these impacts, or of the extent of the conservation problem imposed by feral cats more broadly. There is likely to be little community support for ambitious programs aimed at the extensive management of feral cats unless that awareness is increased.

Options: The extent to which pet and stray cats contribute to the national population of feral cats is poorly resolved, and it may be that this issue is relatively insignificant, so this target may be less important than others.

TARGET 5. A coherent set of priority research and monitoring programs is implemented, aimed at allowing more effective and cost-efficient broad-scale management of cats.

Rationale: There have been substantial recent advances in the knowledge of feral cat ecology and management, and in development of baits and baiting protocols, but there are still some major knowledge gaps that significantly impede management. The set of research and monitoring programs proposed here represents the priority actions that can most enhance knowledge of the role and impacts of feral cats and of our ability to manage them more effectively.

Target 5a. The economic costs of toxoplasmosis to livestock production, and the extent to which the effective control of feral cats can mitigate these costs, are determined.

Rationale: Societal attitudes to cats are complex. A demonstration of significant economic detriment to agricultural production due to feral cats may help refine those attitudes, and provide some impetus for ongoing resourcing of cat control.

Options: This target does not relate directly to biodiversity conservation, so may be inappropriate to include here.

Target 5b. Research aimed at the development of alternative more effective cat eradication options is commenced.

Rationale: The currently available cat control options are impractical to apply at national scale, so will never entirely resolve the conservation problem posed by feral cats. Such continental scale control is likely to require a biocontrol agent; however, the development and trialling (to ensure no undesirable non-target impacts) of any such agent may take decades.

Options: It may be inappropriate to include a consideration of a longer-term research program within a package of short-term targets.

Target 5c. Effective protocols for monitoring cat populations, impacts and responses of cat-affected species to management are developed and implemented.

Rationale: There is no reliable estimate of the feral cat population in Australia, or in local areas; and few estimates of the effects of management actions on the population size or viability of cats (or cat-affected native species) in managed areas. Furthermore, these variables may be substantially influenced by seasonal conditions. Without more reliable and consistent protocols, it will be difficult to evaluate alternative options for cat management or to measure the extent of success of imposed management actions.

Options: There may be no pressing need for a national population estimate for feral cats, or for nationally consistent protocols for assessment of local population size or impact, or of responses to management.

Target 5d. The management implications of feral cat interactions with other species (notably dingoes, foxes and pest prey species) are resolved through research and adaptive management trials.

Rationale: Management focus solely on feral cats may come at considerable risk if there are undesirable ecological reverberations of cat control (such as consequential increases in rabbits or introduced rodents). Furthermore, across much of Australia, both feral cats and foxes exert considerable and additive predation pressure on many threatened species, and management directed only at one of these pest species may have net detriment if predation pressure due to the other species increases. Note that some research on interactive management of foxes and cats is currently being undertaken in SW Australia.

Acknowledgements

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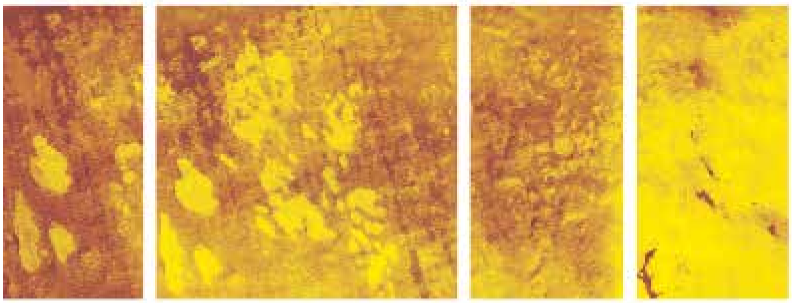

Impacts

Background

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What are the impacts of feral cats on ecosystems? Depending on viewpoint, feral cats are perceived to have positive and negative impacts. A third possibility is functional neutrality, where cats are present but have no significant impact: this is obvious but often forgotten in the rush to 'do something' about cats. In this session, we will be concentrating on the negative impacts of feral cats on environmental and agricultural values, but should keep in mind possible indirect negative impacts on human health and neutral impacts.

Underlying any decision-making about cat management is the determination of the relationship between the density of cats and the quantity of corresponding impact (Figure 1).

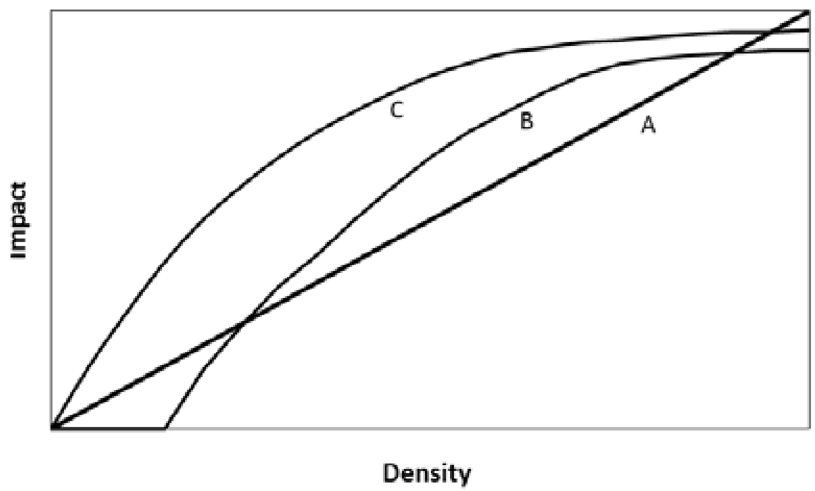

Figure 1. Theoretical density:impact functions describing the negative impacts of feral cats on native wildlife populations. In the simplest function, line A, the impacts increase linearly in proportion to increased density of feral cats. In B, impacts reach saturation at some level of cat density, and line C describes situations where cats have no impact until a threshold is reached, after which the response follows the trajectory of B. The effort required to stop or mitigate wildlife population decline differs between functions and the functions likely differ between ecosystems.

We must understand that relationship, or at least that it is as-yet undetermined, when making decisions about resource allocation. If predation by feral cats is the agent threatening a particular value we wish to conserve, then we must estimate how much effort is required to suppress their populations or their ability to access that value. We should also think about extinction theory (see: Tracey, “Is the eradication of feral cats feasible? An introduction”, below) when deciding what management objectives, from eradication through to retaining the status quo (i.e. by doing nothing), are feasible.

If we do not invest the minimum effort required to make our desired and measurable outcomes feasible, any investment in feral cat control becomes a waste of money and effort. In the absence of the minimum necessary effort, we simply promote failure and angst by making negative outcomes inevitable. However, we have the capacity to both qualify and quantify the impacts of cats. Then we have the choices of doing nothing, doing something or doing something useful. We are well placed to make judgements about where effort is best expended and to do something useful.

To focus on why we manage feral cats, papers of this section outline some negative impacts (Chris Dickman and Pip Masters), and demonstrate a prioritisation support tool to assist allocation of resources for cat management (Chris Dickman).

Environmental impacts of feral cats

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Abstract

Feral cats have been present in the Australian environment since the nineteenth century and have been linked to the early extinction of several species of small mammals prior to 1900. Contemporary evidence for the negative impacts of feral cats on native wildlife derives from several different sources, including the results of dietary studies, monitoring the effects of introducing cats to (or removing cats from) islands, from failed attempts to reintroduce native mammals and birds to sites where cats occur, and from controlled and replicated experimental studies. Taken together, this body of evidence confirms that feral cats have negative impacts via direct predation on populations of native fauna in the Australian region. As well as predation, feral cats may have additional or interactive effects on wildlife by competing with them, by acting as disease vectors or by exerting diverse indirect effects that flow from altering prey behaviour or from removing ecologically important species so that the services they provide can no longer be performed. Mammals weighing up to 220 g and ground-active birds are probably most adversely affected by predation from feral cats, but larger mammals, reptiles and other prey cannot be assumed to be immune. More research is needed to quantify the direct and indirect impacts of feral cats using appropriate experiments.

Introduction

House cats (*Felis catus*) were introduced to Australia by early European settlers and began to establish feral populations that were independent of people during the nineteenth century. Historical evidence implicates feral cats in the disappearance of several species of native small mammals around the middle and later part of that century, with species inhabiting open, arid and semi-arid environments being most severely affected. The potential effects of feral cats on contemporary fauna were not a prominent part of conservation thinking until the 1990s when concerns again began to resurface. Here, I review very briefly the different lines of evidence suggesting that feral cats can have damaging effects on native wildlife in Australia. The account draws heavily on Dickman (1996) and Denny and Dickman (2010) and the studies cited therein, but selectively notes more-recent work as appropriate.

Dietary evidence

Feral cats have been shown recently to hunt and eat at least 400 species of vertebrates throughout continental Australia and its offshore islands, including 28 species listed as threatened on the IUCN Red List, as well as many species of invertebrates (Doherty *et al*. 2015). Rabbits (*Oryctologus cuniculus*) are staple prey where available, but are replaced by dasyurids and native rodents where rabbits are scarce or absent. Longitudinal studies show further that the diet of feral cats changes with weather conditions or on a seasonal or longer-term basis depending on environmental productivity and shifts in the availability of different types of prey (Yip *et al*. 2014, 2015). In general mammals weighing 220 g or less appear to be preferred (Spencer *et al*. 2014), but larger mammals, birds and reptiles also may be taken disproportionately from the available prey base. There is increasing evidence that some cats develop individual specialisations for particular prey types, and attain their highest hunting success when pursuing these prey (Dickman and Newsome 2015). Despite these observations, dietary studies alone cannot provide unambiguous evidence of cat-impact at the level of prey populations. This is because cats may be taking prey individuals that are part of the 'doomed surplus' or because prey increase their rate of reproduction to compensate for individuals that are removed. Thus, unless cats can be shown to have depressive effects at the population level of prey, assertions about cat-impact that are based on dietary studies alone should be viewed with caution.

Evidence from cat removal or addition experiments

Islands are often viewed as biological laboratories, and introductions of cats to islands (whether accidental or deliberate) have provided opportunities to examine the effects on prey populations. In general, the results have been disastrous for small mammals and birds, with populations of many species declining to low numbers or extinction within months of years of the arrival of cats. Impacts have been particularly heavy on small, ground-active species that had limited access to rock piles or other forms of shelter (Burbidge and Manly 2002). Cats have been successfully eradicated from several islands as part of broader conservation measures, and these have alleviated impacts on susceptible prey and allowed their populations to recover. Although recoveries of native species are the usual targets for management, cat-removal from islands has led to unwanted irruptions in non-native species (e.g. Bergstrom *et al*. 2009). Such manipulations provide reasonable evidence for cat-impacts. However, because cat-additions to islands, or removals from them, are almost always unreplicated and lack control sites where cats remain unmanipulated, they do not provide unequivocal evidence about cat-impacts.

Stronger inferences about cat-impacts can be drawn from controlled experiments and also from meta-analyses. For example, Short *et al*. (1992) showed that only 8% of reintroduction attempts involving macropodid marsupials succeeded in establishing viable populations if predators (feral cats and red foxes *Vulpes vulpes*) were present, whereas 82% were successful if they were absent. Cats alone were linked to the failure of two of 11 reintroduction attempts and to the failure of another four if canid predators also were present. Broadly similar results have been obtained in reintroduction attempts involving potoroid and peramelid marsupials and birds.

Controlled manipulations of cat abundance have been seldom attempted, in large part owing to the logistical difficulties associated with maintaining treatment effects and simultaneously monitoring prey populations in both experimental and control sites. However, three examples can be cited. Firstly, Frank *et al*. (2014) introduced the native rodent *Rattus villosissimus* to two paired enclosures in savanna habitat in the Northern Territory that were either exposed to or protected from cats. Even though cats were present at low density (<0.03 km^{-2}), they extirpated rats in the two cat-exposed enclosures within 3-16 months, whereas rats in the absence of cats persisted for the duration of the study (18 months). Secondly, Mahon (1999) removed both cats and foxes from two areas in the north-eastern Simpson Desert and recorded a 3-fold increase in numbers of the native mouse *Pseudomys hermannsburgensis* in these areas compared with the numbers in control sites. Although both cats and foxes were manipulated, the increase in mouse populations was most likely due to the removal of cats as *P. hermannsburgensis* featured about three and a half times more prominently in the diet of the cat than the fox. Thirdly, working at Heirisson Prong in Western Australia, Risbey *et al*. (2000) showed that feral cats increased in abundance after experimental removal of foxes, and that this led in turn to much lower numbers of the native ash-grey mouse (*Pseudomys albocinereus*) than in non-manipulated control areas. These studies together confirm that feral cats can, and do, have strongly negative effects on small native vertebrates, and that predation is the major process driving this impact.

Other evidence of cat-impact

Although most research has focused on the predatory impacts of feral cats, there is some speculation that cats compete with native animals for food or shelter. Predatory birds, goannas, some snakes and quolls all overlap in diet with feral cats, and quolls also are likely to use similar shelters to feral cats in some habitats. Cats also act as hosts for several parasitic and disease-causing organisms that may affect other vertebrates. *Toxoplasma gondii*, a protistan parasite that can cause lethargy, poor coordination and eventual death in a wide variety of vertebrate hosts, is the most well-known pathogen carried by cats, but other organisms such as the tapeworm *Spirometra erinacei* may also cause chronic symptoms and death. *Sarcocystis* is another genus of cat-borne protistan parasite that affects many mammals and is of potential concern for producers of livestock such as pigs and sheep. Despite the potential ubiquity of these cat-impacts, there has been almost no research to quantify how pervasive they are and whether they affect any species at the population level. Such research should be a priority in future.

Indirect impacts

Feral cats may affect other species in a variety of non-obvious ways such as by scaring them and restricting their access to necessary resources (i.e. the 'landscape of fear' effect) or by reducing populations of ecologically important species such as ecosystem engineers, pollinators or seed dispersers to such low levels that they no longer perform their ecological services. Although most such effects are likely to be negative, feral cats may have indirectly beneficial effects on native wildlife if they keep populations of pest species (e.g. rabbits, introduced mice or rats) in check. As with some of the direct effects that feral cats exert, however, there has been little quantification of the ubiquity or strength of indirect impacts, and this remains a topic of much interest for future research.

In summary, different sources of evidence confirm that feral cats have negative impacts on populations of native fauna in the Australian region. Direct predation is the major process involved, but cats may have additional or interactive effects on wildlife by competing with them, by acting as disease vectors or by exerting diverse indirect effects. Mammals weighing up to 220 g and ground-active birds are probably most adversely affected by predation from feral cats, but larger mammals, reptiles and other prey cannot be assumed to be immune. More research is needed to quantify the direct and indirect impacts of feral cats using appropriate experiments.

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Impacts of diseases spread by cats (*Felis catus*) on agriculture

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The greatest economic impact of cats *(Felis catus)* on agriculture is caused by the spread of two protozoan parasites: *Toxoplasma gondii* and *Sarcocystis gigantea* (O'Callaghan *et al.* 2005). Both of these parasites impact heavily on the sheep industry and are found in many sheep-producing countries around the world (O'Donoghue 1978). In Australia, cats are the only primary host in which these parasites reproduce sexually (Munday 1975; O'Donoghue and Ford 1986; Jones *et al.* 1997).

Toxoplasma gondii

Toxoplasma gondii causes foetal re-absorption or abortion in pregnant ewes, or the birth of stillborn or weak lambs. Cats play the largest role in the transmission of *T. gondii*, being the only animal capable of excreting environmentally resistant oocysts (a cyst containing a zygote) in their faeces (Dubey 1995, 1996). However, there is a wide range of intermediate hosts, including the sheep, where asexual reproduction can occur. Sheep can become infected by ingesting the oocysts which are shed in the cat's faeces, or through trans-placental infection when a foetus becomes infected during gestation.

The prevalence of infection is generally greater in cool temperate regions of southern Australia compared to the northern or central areas of Australia (Dickman 1996; Smith and Munday, 1965). Within South Australia infection rates were spatially variable with infection rates much higher on Kangaroo Island than in other similar areas of the state. O'Donoghue *et al.* (1987) proposed that this was possibly due to the relatively high abundance and widespread distribution of feral cats on the island.

Other variables impacting the development of Toxoplasmosis include lowered immunity, stress related conditions, environmental, physiological or population based stressors, or intercurrent disease states. Nutritional and weather stresses were considered possible factors causing latent *Toxoplasma* infection to become clinically obvious and subsequently fatal (Obendorf and Munday 1990; Oryan *et al*. 1996).

Sarcocystis gigantea

Sarcocystis protozoans are present as parasitic cysts in herbivores and as microscopic protozoa in the intestinal walls of carnivores. There are a range of *Sarcocystis* species, but the one that is spread only by cats and has great economic impact on the sheep industry is *Sarcocystis gigantea*.

Sarcocystis gigantea causes large white cysts to develop in the meat of infected sheep. The meat is then classified as unsuitable for consumption, and trimmed at the abattoir. Heavy infestations can result in entire carcasses being condemned. The increased handling cost and loss of trade causes direct economic loss to the meat industry (O'Donoghue and Ford 1986). The cost to the industry is not available using today's values but in 1986 the estimated cost to South Australia was $670,000 based on the calculation that sheep infected with the disease will be, on average, worth half the value of those not infected (O'Donoghue and Ford 1986). Similarly the disease has been found to be highly prevalent in Tasmania and New Zealand (Munday 1975; ODonohue 1978). Abattoir figures, supplied by the Australian Department of Agriculture, showed that in 1972/73 the condemnation rate of infected sheep was 6 times greater in Tasmania than in New South Wales, Victoria or South Australia (Munday 1974).

The *Sarcocystis* life-cycle requires two hosts: an intermediate host, the sheep, and a definitive host, the cat (Ford 1986). Sheep become infected by consuming pasture contaminated with cat faecal matter. The sporocyst then hatches in the sheep's intestine and burrows through the intestinal wall, entering the blood stream and eventually forming a cyst in the muscle tissue. The cat becomes infected as a result of consuming cysts in the sheep meat. The cysts rupture in the cat's intestine and then spread from the cat in the faeces. The sporocysts can survive for up to a year on the ground with some evidence suggesting that survival may be influenced by temperature, humidity and ultraviolet light (McKenna and Charleston 1992, 1994).

Future directions

Cats are necessary for the maintenance and transmission of *Toxoplasma gondii* and *Sarcocystis gigantea*, and it is likely that areas with higher densities of cats are presenting higher levels of disease but the relationship between disease prevalence and cat density is not clear. In addition, other variables including climate, ground cover, and farm management practises have all been suggested as possible contributors to the higher rates of Toxoplasmosis and Sarcosporidiosis in sheep. A better understanding of the factors that contribute to the prevalence of these diseases is needed to assist industry mitigate against the disease effects. This could be achieved through more carefully designed studies that consider the cat density, farm practices and environmental variables in relation to the prevalence of Toxoplasmosis and Sarcosporidiosis in sheep.

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How to prioritise impacts of feral cats

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Abstract

At present the negative effects of the feral cat (*Felis catus*) on native wildlife species can be mitigated only at the local level by costly and labour-intensive methods such as shooting and exclusion fencing and, in some situations, poison baiting. Because the impacts of cats are pervasive and continent wide, we therefore need a process that allows strategic allocation of resources to sites of most value. 'Value' is not fixed, and may be viewed differently by different stakeholders. For example, sites with particular species that are highly threatened by feral cats may be considered valuable from a species-recovery perspective, sites with multiple species at lower risk could be valuable as biodiversity hotspots, and sites with livestock or other agricultural assets may be valued for these resources. Using a threatened species perspective, we outline a simple system—a decision tool—that identifies wildlife species that are most at risk from feral cats, and allows mapping of threat intensity at bioregional and local scales. The decision tool, developed in 2010, allows information about threats to be added adaptively as further information is received. Used in conjunction with knowledge of the wildlife species that are to be protected and resource allocation methods such as structured decision making, clear decisions can be made about when and where to implement effective cat management.

Introduction

The feral cat (*Felis catus*) is widely regarded as a key threat to native wildlife in Australia and many other parts of the world. Recent studies in Australia indicate that feral cats include at least 400 species of vertebrates in their diet, including 28 species that are on the IUCN Red List (Doherty *et al*. 2015). Despite the pervasive nature of its impacts, we have no effective means of controlling the feral cat over large areas; its impacts at present can be managed only in specific sites or over small areas via costly and labour-intensive methods such as shooting, trapping, exclusion fencing or, in some situations, poison baiting. Until broad-scale means of reducing the impacts of feral cats are available, it is likely that resources will need to be allocated strategically to key areas at critical times when cat-impacts are judged to be most damaging.

In considering how best to allocate resources, an important first step is to determine the relative value of the assets that are to be protected. Stakeholder interest in one situation may dictate that livestock or other agricultural assets need protection from cat-borne diseases such as sarcocystis or toxoplasmosis, or in another that certain native species need targeted protection from cat-predation. Here, we describe a simple system—a decision tool—that allows places containing high-value assets to be identified and prioritised for protection. Because of the critical impacts that feral cats can have on native vertebrates (Woinarski *et al*. 2014) we use the tool to identify places where most species of cat-susceptible vertebrates occur, but note that the tool is generic and could be adapted for any other kinds of assets that are spatially located. The development of the tool is described in detail in a report sponsored by the Department of Environment, Water, Heritage and the Arts (Dickman *et al*. 2010); the present paper provides a brief overview of the rationale and a summary of some of the results.

Constructing a decision tool

To provide a basis for prioritising places identified as impacted, or potentially impacted, by feral cats, a decision-making tree was developed to standardise the assessment of available data from specific sites and also from larger areas based on IBRA bioregions (http://www.environment.gov.au/land/nrs/science/ibra). Characteristics of both cats and prey species were considered for construction of the decision-making tree to use in formulating scores (Table 1) to allow prioritisation of sites of high conservation value impacted by cats. The decision-making levels considered for the construction of the tree comprise:

Cat presence/absence – data on feral predators in bioregions and at specific sites on the mainland and on islands were collated to determine the presence/absence of cats to provide a measure of the probability of cat-impacts. Data on abundance were considered to be too unreliable to use in the decision tree.

Likelihood of invasion or re-invasion – for sites where cats have never occurred, or have been eradicated, we compiled data on site-accessibility to provide a measure of the likelihood of cats getting to or re-invading the sites.

Threatened species – the original report (Dickman *et al*. 2010) specifically addressed those species listed in Appendix A of the *Threat Abatement Plan for Predation by Feral Cats* (TAP 2008); this list comprised 35 species and subspecies of birds, 36 species and subspecies of mammals, seven species and subspecies of reptiles and three amphibian species. Also included were four unlisted bird taxa and two species of reptiles that could be adversely affected by feral cats, as well as two listed critical habitats.

Vulnerability of threatened species to cat predation – cats prey as individuals, in contrast to the co-operative hunting techniques of most canids. Thus prey taken by cats is restricted to a size manageable by an individual. Studies of the diets of cats on the Australian mainland suggest that small mammals (< 220 g) or small birds and reptiles (< 25 cm long) are most vulnerable to cat predation (Dickman 1996). On offshore islands, species up to 3 kg (mammals) or 45 cm long (birds and reptiles) are also vulnerable to cat predation. Prey species are also more vulnerable to cat predation if they are nocturnal rather than diurnal. Those species that are terrestrial or scansorial are similarly more vulnerable than those that are fossorial or volant (Dickman 1996). The above measures were included in the decision-making tree to provide a score for the vulnerability of prey species. The ability of a prey species to defend itself against cat attack (aggression, sharp claws and teeth) was also factored into the decision-making tree (Dickman 1996).

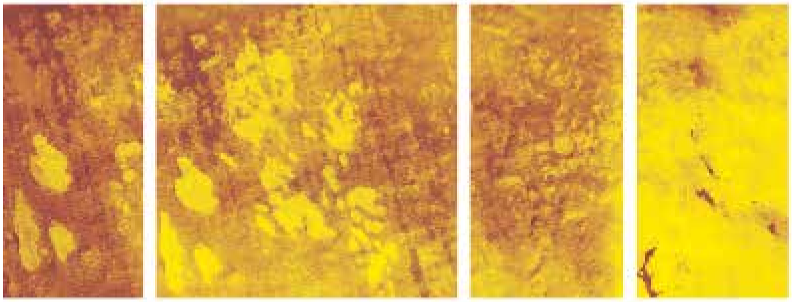
Status of species identified in specific sites and bioregions – The Australian Government's *Environment Protection and Biodiversity Conservation Act 1999* provided the status of each TAP-listed species, with status noted as critically endangered, endangered, vulnerable or conservation dependent.

Using the decision tool

Working through each of the levels in the decision tool (Table 1) allows users to compile scores for individual species that may be at risk from feral cats or, alternatively, to identify areas where cats do not occur or are otherwise unlikely to have significant impacts on threatened fauna. Because of the branching structure of the tool and its utility in assessing many species, it can be viewed as a multiple-use decision-making tree. By compiling scores allocated for each of the levels and summing across all the threatened species known to be present in a site or a broader regional area, users can identify places with high scores as priority locations to reduce cat-impacts. The process, and detailed results of the scoring of results at both individual site and IBRA levels, have been presented elsewhere (Dickman *et al*. 2010); only a brief summary of the findings is provided below.

Table 1: Levels of decision-making used in the construction of a multiple-use decision-making tree for prioritising the impacts of feral cats, and scores awarded at each level

Level 1a Level 1b	Cat presence. Branches to either an assessment of cat control (Level 2a) or an assessment of the likelihood of feral cat invasion of the site (Level 2b). Threatened species either present or absent. Links to under options for threatened species multipliers at level 4.	Present Absent	1 0
Level 2a	Feral cat management at site where cats present. Branches to…	Exclusion with active ongoing control Systematic ongoing control undertaken Systematic irregular control undertaken Incidental **control** undertaken No cat control undertaken	0 1 2 3 4
Level 2b	Likelihood of feral cat invasion of site: At this point sites are removed from the tree where feral cats are absent and the likelihood of invasion is nil. Remaining sites lead on to level 3. Islands Uninhabited, accessible only by air Uninhabited, infrequent access by boats Uninhabited, frequent boat access; inhabited, pet/pest cat control Inhabited, no pet/pest cat control Mainland Predator-proof fence, ongoing control Predator-proof fence, no ongoing control No predator-proof fence, ongoing control No predator-proof fence, no ongoing control	Nil Low Medium High Nil Low Medium High	0 1 2 3 0 1 2 3
Level 3 ***	Vulnerability of threatened species to cat predation based on a modified version of Dickman (1996). Note: where cat predation is on juvenile animals, use juvenile weight NOT adult weight		



	Mainland mammals (body weight)	> 2000 g	0
		1001 – 2000 g	1
		220 – 1000 g	2
		< 220 g	3
	Mainland birds (body length)	> 45 cm	0
		35 – 45 cm	1
		25 – 35 cm	2
		< 25 cm	3
	Island mammals (body weight)	> 3000 g	0
		1001 – 3000 g	1
		220 – 1000 g	2
		< 220 g	3
	Island birds (body length)	> 45 cm	0
		35 – 45 cm	1
		25 – 35 cm	2
		< 25 cm	3
	Reptiles (snout-vent length)	> 45 cm	0
		35 – 45 cm	1
		25 – 35 cm	2
		< 25 cm	3
	Habitat use	Very dense ground cover/heath	0
		Closed forest, mangroves, swamps, caves	1
		Open forest, moderate ground cover	2
		Woodland, grassland, cultivated land, urban	3
	Behaviour	Diurnal	0
		Nocturnal or crepuscular	1
		Oceanic, aquatic, arboreal, fossorial, volant	0
		Terrestrial, scansorial	1
		Defences such as teeth, claws, aggression	0
		No defences	1
Level 4	Threatened species multiplier based on the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* levels. **Note:** multiplier is applied only once per site and is based on the highest level present at the site.		
		Critically Endangered	4
		Endangered	3
		Vulnerable	2
		Conservation Dependant	1
		No TAP species present	0.5
*** Level 3 scores are cumulative for each threatened species present at a site			

Priority areas for managing the impacts of feral cats

At the IBRA level, 76 of 85 bioregions were identified as containing both feral cats and threatened species that could be at risk of predation from feral cats. A single threatened species was recorded from 16 bioregions, up to 11 species in one bioregion, the South Eastern Highlands. No threatened species were recorded in nine bioregions. As may be expected, bioregions containing the most species at potential risk from feral cats tended to score most highly (the priority score for the South Eastern Highlands was 328, compared with scores of 24 - 39 for regions with a single threatened species). At the site level, using data provided by land managers or available in the literature, priority scores varied from highs of 117 for the Diamantina National Park in Queensland and 108 for the East Gippsland area in Victoria, to a low of 10 for Dirk Hartog Island off the Western Australian coast. As with the bioregional results, sites with more threatened species scored more highly than those with few. Individual sites also scored less than bioregions owing to their smaller areas and hence lower capacity to support large numbers of threatened species. Detailed scores for all sites and bioregions, together with associated maps, are provided in Dickman *et al*. (2010).

Further scores were calculated for sites at which cat control is uncertain ('data deficient') and from which cats had been eradicated or never recorded to identify sites that could be potentially impacted by feral cats in future. These scores varied from a high of 201 for sub-Antarctic Macquarie Island to a low of 9 for Boondelbah Island off the coast of New South Wales. Because of the adaptive nature of the decision tool, information about cat activity or the presence of threatened species can be added at any time to allow a re-evaluation of where management priority should be placed. Used in conjunction with resource allocation methods such as structured decision making, the decision tool should ensure that clear decisions can be made about when, where and how to implement effective cat management.

We conclude that feral cat control on the Australian mainland is a long-term, multi-faceted, labour- and resource-intensive venture requiring site-specific control methods that provide systematic and regular downward pressure on feral cat populations. The multiple-use decision-making tree should assist managers in identifying places where such control measures should be used. An effective program of management should also include concurrent control of populations of both stray and owned domestic cats. We conclude further that greater success in cat control programs will be achieved by targeting specific sites using site-specific control methods. Human activities such as urban and rural development, agriculture and habitat modification favour the establishment and maintenance of feral cats. We recommend that a 'nil tenure' approach to cat control, with management activities encompassing public- and privately-owned reserved land as well as adjacent urban, rural and semi-rural developments, is necessary to reduce the feral cat population on the Australian mainland and offshore islands. In the absence of a sustained and integrated approach of this kind, declines and losses of native species are likely to continue.

Acknowledgements

Liz Denny played an integral part in the development of the decision tool described here and in the compiling of the original report to DEWHA, and we gratefully acknowledge her input. The production of the original report and this summary paper also would not have been possible without the generous input from many cat researchers, land managers and researchers who responded to our surveys and phone calls and who gave their time and knowledge freely.

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Monitoring

Quantifying cats: How many are there and do we need to know?

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Abstract

Feral cats (*Felis catus*) have deleterious impacts on native Australian wildlife species. However, the quoted abundance of feral cats at a national scale is highly questionable. There is no strong evidence or reliable knowledge for the abundance of feral cats at a continental scale in Australia. We could not find any sound basis for the often-quoted figure of 18 million feral cats in Australia. We traced the citing of this figure back in an attempt to find its origin but were unsuccessful in doing so. We propose a possible origin for the figure. It may have arisen from an incautious extrapolation of the summer and winter densities of feral cats in one study site in north western Victoria.

Rather than knowing continental-scale abundance figures, it is more important to know if feral cats are having an impact on prey species at a population level and, if so, managing that impact rather than simply attempting to reduce feral cat abundance. We propose that impact be measured in terms of the annual instantaneous rate of increase (r) of the prey species to allow for comparison between programs and prey species. Knowing the abundance of feral cats at a local or management unit scale is needed to determine the impact – density relationship when that is unknown or cannot be appropriately estimated. It is also important to determine and report the effort - outcome relationship during feral cat management programs. Using abundance figures that have no sound basis to estimate the level of damage that feral cats are causing is flawed and could lead to the implementation of policies and / or management programs that waste money and could fail.

Introduction

The domestic cat (*Felis catus*) entered Australia with European settlement (Abbott 2002). Since then it has spread across mainland Australia, Tasmania and many offshore islands (Burbidge *et al.* 1997; Abbott 2002). This spread across Australia was facilitated by an abundant food source – the European rabbit (*Oryctolagus cuniculus*), naïve native prey species (Russell and Banks 2007; Salo *et al.* 2007; McEvoy *et al.* 2008) and the breeding and intentional release of domestic cats into the wild in an attempt to curb rabbit plagues (Rolls 1969; Abbott 2008). Through this combination of intentional and unintentional releases, the domestic cat has now established self-sustaining feral populations in all sections of the Australian environment (Dickman 1996b).

The general public and media regularly ask: how many feral cats are there in the Australian environment? On the face of it, this is a simple and straightforward question. However, obtaining an accurate or precise answer to that question using appropriate abundance estimators (Caughley 1980; Seber 1992) is both time consuming and expensive and has not been undertaken to date at a continental level. Despite this lack of knowledge, there are regular reports stating the abundance of feral cats in Australia (for example McLeod 2004; Anon 2008; Denny and Dickman 2010).

Hone and Buckmaster (2015) reviewed the providence of each of the cited abundance figures for feral cats, feral pigs (*Sus scrofa*) and red kangaroos (*Macropus rufus*) from 1983 to 2012. The figure of 18 million feral cats quoted by Denny and Dickman (2010), (Anon 2008), and McLeod (2004) originates from Pimentel *et al.* (2001) (Figure 1). By following the citation trail from Pimentel *et al.* (2001), they found that the figure had originated from a speech in the New South Wales Parliament by The Honourable Bob Martin, who stated that wildlife experts had stated there were between 5.6 million and 18.4 million feral cats in Australia. It was unable to be tracked back past that point.

More recently the number of feral cats has been stated in the media as "between 15 and 23 million" (Borschmann and Groch 2014), "up to 20 million" (Stein 2014) and "15 million" (Ham 2014). The background to these numbers was unable to be followed as the sources of the figures were not cited.

Moodie (1995) quoted the number of feral cats in Australia as being between 5.5 and 18.4 million and cited Potter (1991) as the source of these figures. Hone and Buckmaster (2015) tracked this citation and found that no figure for feral cat abundance was given by Potter (1991) and that the numbers most likely came from an extrapolation of a single study undertaken in north-western Victoria in 1982 by Jones and Coman (1982). The summer and winter densities of feral cats estimated in that study were 2.5 and 0.74 cats km^{-2} respectively. Simply multiplying those densities by the land area of Australia gave values almost identical to those cited by Moodie (1995) and Bob Martin in the NSW Parliament (Hone and Buckmaster 2015).

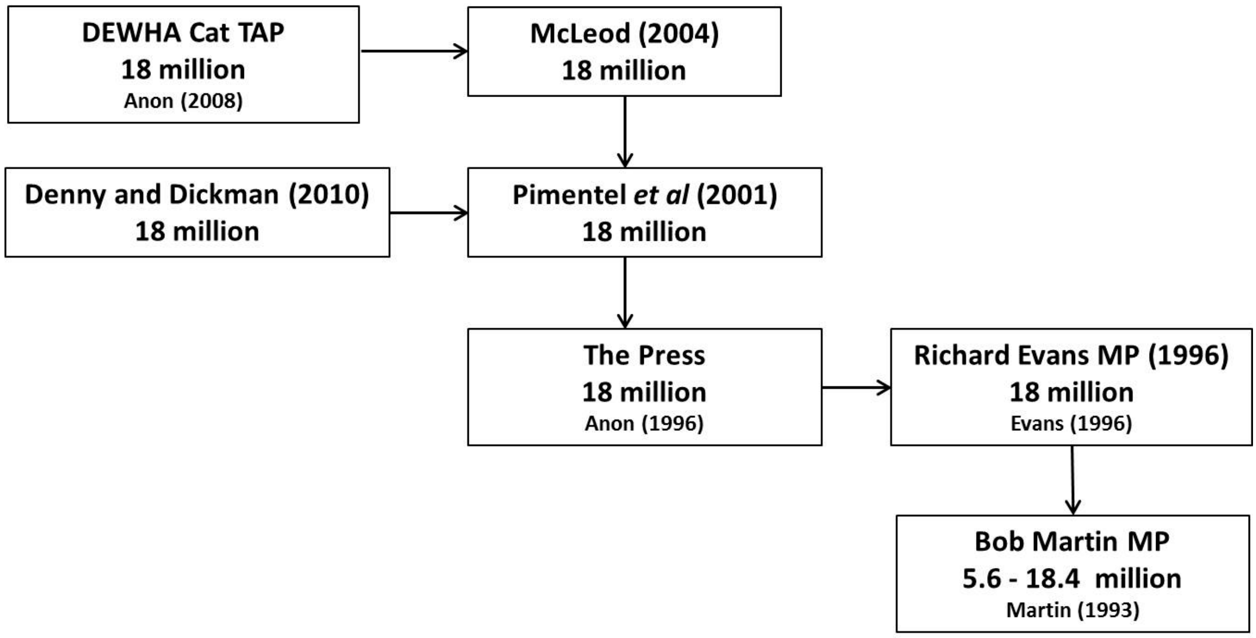

Figure 1. Flowchart following the citation trail for the feral cat abundance guess of 18 million. It was not able to be tracked prior to it being used by Bob Martin MP in 1993. Citations are shown in smaller font where needed. Adapted from Hone and Buckmaster (2015)

Misuse of the quoted abundance figures.

When managing an invasive species with little or no economic value, it is more appropriate to evaluate the impact caused by those species and, subsequently, the changes in that impact that arise from any management intervention rather than simply assess changes in abundance of the pest species (Braysher 1993; Olsen 1998; Hone 2007; Braysher *et al.* 2012). The guesses as to the abundance of feral cats in Australia have been used inappropriately to estimate the number of native animals killed by feral cats (Ham 2014) or to place an economic value on the impact of feral cats (Pimentel *et al.* 2001; McLeod 2004) (Table 1).

Table 1. Examples of how feral cat abundance guesses have been misused to state economic and environmental damage by feral cats. ** Ham (2004) is used as an example. There are other instances available where the abundance guesses have been used to describe the total nightly kills by feral cats.

	McLeod (2004)	Pimentel *et al.* (2001)	Ham (2014)**
Number of feral cats	18 million	18 million	15 million
Number of kills	8 birds per year	8 birds per year	-
Value of each kill	AUD $1	USD $30	-
Total kills	-	-	75 million native animals per night
Total economic damage	AUD$ 144 million	USD $4.3 billion	-

The use of the feral cat abundance guesses to state a level of impact on native species is imprudent for several reasons. Firstly, it makes the assumption that the relationship between abundance and impact is linear when the shape of this relationship for feral cats in Australia is unknown (Hone and Buckmaster 2015). The relationship between pest abundance and damage can also be convex or concave curved (see Hone 2007 table 2.2 for empirically calculated examples). This relationship should not be assumed if not known, but rather calculated empirically or through using robust estimators.

Secondly, multiplying the feral cat abundance guess by an average number of prey items that a feral cat may eat per night assumes that feral cats only consume native prey items and potentially results in overinflated numbers. Empirical evidence from dietary studies (e.g. Coman and Brunner 1972; Jones and Coman 1981; Catling 1988; Read and Bowen 2001) shows that rabbits and non-native rodents form large portions of the diet of feral cats when available. Similarly, the occurrence of rodents and native dasyurids in the diet of feral cats has been shown to decrease with increasing consumption of rabbits across multiple dietary studies (Doherty *et al.* 2015).

Thirdly, inclusion of a species in the diet of feral cats neither demonstrates nor implies that feral cat predation is having a negative impact on that species at a population level. Where predation rates are below a certain threshold, the prey populations are generally resilient to the exploitation and can compensate for the losses through increased rates of survival or fecundity (Krebs 2001). It could be that it is the doomed surplus in those species populations that is being consumed by feral cats which would result in no impact on the species at a population level (Banks 1999). Negative impact occurs when the rate of off-take through predation or other causes exceeds the maximum rate of increase (r_m) of a particular species (Hone 1999). Many species are commercially harvested – analogous to predation - with no negative impact on that species at a population level. As an example, red kangaroos are commercially harvested in New South Wales, Queensland, South Australia and Western Australia. Over 533 000 red kangaroos were harvested across those four states in 2012 (Anon 2013); however, there is no evidence that harvesting this number had any negative impact on the red kangaroo population.

Is it necessary to know the abundance of feral cats at a continental scale?

We would contend that knowing the abundance at a continental scale is unnecessary as a) the feral cat has no commercial value, b) the relationship between abundance and damage is unknown, c) the level of impact on native species is unable to be accurately estimated from national abundance figures, and d) continent-wide eradication of feral cats is not possible. We would also contend that it is more important to know the level of impact that feral cats are having on native prey species and the level of management intervention needed to reduce this impact to an acceptable level.

We suggest that impacts on feral cat prey be defined in terms of the instantaneous rate of increase (r) of the prey population. Where $r \geq 0$, the prey population is stable ($r = 0$) or increasing ($r > 0$) and no detrimental impact is occurring, however where $r < 0$, the prey population is declining (Hone 1999). This would allow for direct comparison of impact between prey species. Averaging r over several years allows for the natural fluctuation that occurs within a population to be accounted for (Caughley and Sinclair 1994; Hone 1999). Where a strong negative r is detected in the early stages of monitoring the prey species population, we would suggest that the precautionary principle would dictate that management intervention is required (Thompson *et al.* 2000; Calver *et al.* 2011).

The impacts of feral cats on native prey species are most obvious on islands (Burbidge and McKenzie 1989; Nogales *et al.* 2004); however; there are few studies that have empirically demonstrated or quantified the impact that feral cats have on prey species on mainland Australia. The majority of the evidence of feral cat impacts is circumstantial and based on comparative studies or population recovery following feral cat management (Dickman 1996a,b; Robley *et al.* 2004). There is little current knowledge as to the actual level of impact of predation, competition with native animals for resources, and/or the other effects of feral cats on the majority of prey species populations. We propose that determining the level of impact of feral cats is more important than knowing their abundance, as reducing this impact is the primary aim of any management intervention (Hone 2007; Braysher *et al.* 2012). In addition to assessing the responses of the impacted prey species to management actions, determining feral cat abundance at a local or management unit level allows the relationship between impact and feral cat abundance to be calculated. We caution that unless this relationship is known, a reduction in feral cat abundance should not be used to define the success of a management program. A decrease in the level of impact on the prey species population should be used to define success of the program rather than the number of feral cats removed (Braysher 1993; Olsen 1998). Measuring any change in abundance of the feral cats during a management program allows for the impact - abundance relationship to be calculated.

We propose that determining the effort – outcome relationship for feral cat management is also important. This relationship is often implied but it needs to be explicit (Hone *et al.* 2015). Once known, it allows the level of resources required to achieve the desired reduction in feral cat impact to be determined and applied to the management program. This relationship can be linear or curved. There are positive linear relationships between the population rate of growth of black rhinoceros (*Diceros bicornis*), and of African elephant (*Loxodonta africana*), and the cost of anti-poacher activities across nine African countries (Leader-Williams and Albon 1988). There is a positive relationship between the abundance of malleefowl (*Leipoa ocellata*) nests and costs of fox (*Vulpes vulpes*) control efforts. When effort is high, however, this relationship becomes negative (Walsh *et al.* 2012).

There is a curved negative relationship between the number of lambs killed by foxes and the amount of fox control undertaken (Greentree *et al.* 2000), the abundance of red (*Cervus elaphus*) and sika (*Cervus nippon*) deer and hunting effort using helicopters (Forsyth *et al.* 2013) and the density of moose (*Alces alces*) and hunter effort in Quebec, Canada (Crête *et al.* 1981). These negative relationships are suggested to arise from having variables that are not management outcomes but rather are intermediary steps to the desired management outcomes (e.g. increased regeneration of impacted plant species is the desired management outcomes rather than simple reduction in deer abundance) (Hone *et al.* 2015).

Knowing the effort – outcome relationship allows for more effective planning of management activities. The costs and amount of effort required to achieve the desired change in the rate of increase of the impacted prey species can be determined and funding can be applied appropriately to the management intervention.

Conclusion

Hone and Buckmaster (2015) proposed four criteria for the use of continental-scale estimates of wildlife abundance. The figures quoted for feral cat abundance fulfil none of these requirements and appear, *prima facie*, to be no better than guesses. There is no strong evidence or reliable knowledge to be able to estimate the abundance of feral cats at a continental level in Australia. The figures quoted should not be referred to as “estimates” but rather as guesses. Estimates arise from following a formal set of steps using appropriate mathematical and statistical steps in their calculation, and this was not the case for the feral cat abundance figures (Hone and Buckmaster 2015). We caution against using those guesses for policy, planning management action or reporting the impact of feral cats.

Of greater value to managing the impact of feral cats is knowing the relationship between the impact and feral cat density, and the effort-outcome relationship, as these allow for the estimation of impact where actual impact is unknown or hard to measure and for assessing the amount of management effort needed to reduce the impact to an acceptable level.

Addendum

In the above manuscript, we proposed a possible origin for the often quoted abundance of feral cats as being between 5.6 and 18.4 million. Since this manuscript was submitted we have located an earlier citation of these figures that specifically calculated those figures using the method we proposed. Cross (1990) suggested that there are between 5.6 and 18.4 million feral cats in Australia with an average abundance of 12 million. These figures were arrived at by multiplying the winter and summer feral cat densities (0.74 and 2.5 /km^2 respectively) found by Jones and Coman (1982) by the areas of Australia (stated as 7,682,300 km^2) (Cross 1990). The average of 12 million is simply the mean of the upper and lower values. This supports our proposition that the abundance figures for feral cats in Australia arose from an imprudent extrapolation of the density figures from Jones and Coman (1982). It is noted that no author that has quoted the those abundance figures has cited Cross (1990) as being the origin of those figures even though some have cited that work for other reasons in the same publication. We again caution against using inappropriate techniques for estimating wildlife abundance and using figures obtained from such for policy, planning management actions, or reporting the impacts of feral cats.

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Methods to monitor cats (*Felis catus*)

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Abstract

There are many challenges with designing effective monitoring methods for feral cats in Australian ecosystems. The common metrics used are absolute abundance, relative abundance, kill rate and diet and behavioural studies, all of which require different collection and analysis methods. Numerous techniques have been trialled and tested to varying levels of success, and feral cats are recognised as a species for which we have yet to adequately design a robust monitoring method. Historical methods (Table 1) have focussed around spotlighting and sand plots (Mitchell and Balogh 2007). Recent innovations have been developed using algorithms to identify footprints in tracking tunnels, taking relative index methods to a new level of accuracy (Shin *et al.* 2012).

The historical methods of trapping and radio tagging are common practice in Australia and have been successfully undertaken, but the process is very resource hungry and trapping cats in some ecosystems is very difficult. Cage traps are used in some circumstances but padded jaw traps are more effective, especially over large study areas, although this requires expertise to be successful. These old tools are still worthy but there are many new and emerging technologies being developed and trialled that may have a role in future efforts to monitor feral cats. Tools include short term radio collars (e.g. i-GOTCHU) and Go-Pro cameras that can store considerable data on board the device. These devices are providing new insights into the ecology of animals but with less expense than GPS radio collars, although each method has its limitations. In the case of new electronic technology, the temporal scale is limited by the power source, in particular the battery life of the devices.

In recent years the use of camera traps as a monitoring tool has increased exponentially and shows promise (O'Connell *et al.* 2011; Meek *et al.* 2015b). However, in many cases the simplicity of the apparent deployment of camera traps has surpassed a thorough consideration of how to optimise the use of the tool, let alone considering the limitations of the technology and how this affects animal detection (Meek *et al.* 2015a).

Contemporary camera traps have been designed to satisfy the large hunting market in the northern hemisphere and as such are customised to detect large mammals like deer and elk. Most devices use passive-infra-red sensors to detect a temperature

differential between the target animal and the background. This is often referred to as heat-in-motion, although other types of camera traps are available that use active sensor systems, where triggers do not rely on a PIR, or time lapse that can be automatically programmed to trigger at pre-set time intervals.

There are also three choices of illumination available in camera traps. Firstly, incandescent flash using xenon gas; this is old technology and now superseded by the second option, white LED flash. This new technology is still being refined but provides higher quality night images with a much faster trigger delay between detections than incandescent camera traps. This means capturing more images per trigger event, and more detail on each image, making identification and individual recognition easier. The third and more popular choice are the infra-red flash camera traps that can be fast to first trigger and between triggers. The monochrome images produced by these, however, can be limiting if unique identification is needed or when species identification is difficult.

Before camera trapping can be considered an effective monitoring tool, we propose that many factors must be considered and addressed; this is a focus of our research team. Camera traps have a multitude of functions that need to be customised and optimised according to the monitoring objectives and analysis. There are many settings that can be used to collect the best quality data depending on factors such as site conditions, target species and the temporal scale of the monitoring program. Deployment of camera traps is often considered a straightforward task, but our research has shown that placement and orientation is critical to maximising detection (Meek *et al*. in press; Ballard *et al*. in press). If camera traps are placed too high (or too low), and facing the wrong direction in relation to the target's passage of travel, the detection rate will be diminished. Potentially meaning that target species are not detected, despite being present.

There are a plethora of factors that must be addressed if camera trapping is going to be heralded as the future of feral cat monitoring tools in Australia. Moreover, considerable in-roads need to be made in data management, coding and analysis to make better use of the huge volumes of data currently collected but not analysed throughout this country.

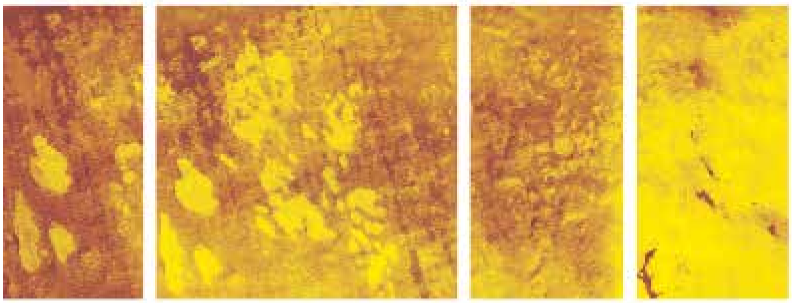

Table 1

Methods	Advantages	Disadvantages	Gaps
Trapping and Tagging *Cages* *Jaw traps* *(GPS and i-GOTCHU)*	**Animal in-hand** Accurate individual data **Data rich method** High fidelity (GPS tracking)	Expertise required Animal handling can be hazardous Optimising attractants Resource hungry High animal welfare concerns Affected by wet/cold/hot weather **Very high cost (GPS)** Technology required for analysis Standards required **Unreliability of equipment (Tracking)** Affected by terrain (tracking) Subset of population	Optimal olfactory, visual, audio lures Effect of season on lure attraction Range (igotchu) Battery life (igotchu) Better quality GPS/satellite tech
Go-Pro	**Visual = Funky** New insights into behaviour **Predation events** Contact rates	Medium animal welfare concerns **Limited to sample animal only** Short temporal scale Technology required for analysis Relatively costly **Limited battery and storage capacity** Retrieval required	Battery life Storage capacity
Micro-chip or Wildlife Identification Device (WID)	Low-medium animal welfare concerns Relatively simple to set up **Unique identification of indiv**. Medium temporal scale **Data logging**	Technology required for analysis **Restricted to receiver placement** High resource costs **Research limited technique** Standards required Sunset of population	Range
Track counts (sand plots)	Low animal welfare concerns **Multi-species data** No animal capture **Easier to conduct than abundance surveys**	Affected by bad weather Affected by time-of-day High cost in some areas Substrate variability in some sites Evidence of animal aversion	Effect of animal aversion Consistency in pad structure Effect of obs. bias Optimal asymptote (days) Actual relationship

		Requires track/pad consistency Survey duration inadequate Print identification training needed Standards required **Survey vs spatial coverage** Subset of population? **Assumption of relationship between true abundance and indices**	to true abundance
Tracking Tunnels (foot algorithm)	Low animal welfare concerns **Accurate species ID** **No animal capture**	Resource hungry Unknown animal aversion Survey duration? Cost?? Standards required **Subset of population ?** **Technology required**	Unproven population method Duration?
Spotlighting	**Quick and simple to conduct** **Relatively inexpensive** Low training requirement Low animal welfare concern No animal capture	Data are highly variable between obs. **Cats not optimal species for survey** **Affected by ecosystem (sightability)** Affected by weather Standards required Subset of population?	Effect of ecosystem and weather on data
DNA (hair snares and scats)	Low animal welfare concerns Unique identification of indiv. No animal capture	**Variability of lures** **Expensive** Requires specialist Unknown neophobia Individual behavioural responses Standards required Subset of population?	Optimal olfactory, visual, audio lures Effect of season on lure attraction Aversion to lures and devices Rapid assessment method
Bait take	**Simple to conduct** **No animal capture**	**Limited to control monitoring** **Does not relate to population** Toxin dependent i.e. cyanide? High animal welfare concerns Standards required Subset of population?	Extent of caching Relationship b/w removal and mortality

Camera Trapping	Low animal welfare concerns Visual = Funky Relatively easy to deploy? **Data rich** Long temporal scale **Large or small spatial coverage** No animal capture	**Initial financial cost high** Analysis is challenging Technology required for analysis Limited battery and storage capacity Theft Training required Standards required Subset of population? **Cats do not seem to show aversion**	Better detection systems Active sensor system Power source Illumination

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Sampling designs for effective monitoring and evaluation of research questions relating to cats

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Introduction and context

Research questions relating to small mammal conservation that may involve feral cats as a hypothesised agent include determining how to:

- Identify and mitigate drivers of declining populations,
- Increase existing, stable, populations, and
- Facilitate successful reintroductions.

The first two questions relate to increasing the rate of population increase of the prey species of concern, the first wildlife management option of Caughley & Sinclair (1994). The third research question requires not only that the introduced population has a positive rate of increase, but also that it can withstand the stochastic misfortunes that may afflict a small population. Clearly population rate of increase is the key response variable of interest in experiments designed to elucidate and mitigate the role of feral cats in small mammal declines. It is also useful to think how research questions and management actions relate to the 'declining' vs. 'small' population paradigms in conservation biology outlined by Caughley (1994), and how this may influence experimental designs. For example, small populations may end up persisting in refugia where the original cause of the decline is excluded or attenuated (Caughley & Gunn 1996) – experiments in these refugia sites may produce different responses from those undertaken in areas where the cause of decline remains.

The drivers of the distribution and abundance of species, including climate, fire regimes, livestock grazing pressure and land use are all changing. For example, the current sheep population size at *c.* 72 million is the lowest it has been since about 1920, due to more frequent drought conditions, generally low wool prices, exacerbated in places by wild dog depredation (Allen & West 2013). Competition with alternative land uses that act to mitigate CO_2 emissions will also increase, as will marginal land returning to the conservation estate (private or public) or being managed by an increasing tree changer movement. The net effect will be the revegetation of some environments and a decrease in the amount of land where landholders are seeking to actively control wild dogs. Already, wild dog populations are becoming established in areas where they have been absent since early European times. Such changes may provide unexpected research opportunities through observational experiments to resolve some of the unresolved arguments relating to interactions between cats, foxes and wild dogs and their impact on fauna. Inference from such observational experiments is strengthened if outcomes and their implication for the support for current working hypotheses are developed (and written down somewhere for everyone to see) *a priori*.

Experimental designs

There are many texts that can help (e.g. Green 1979; Manly 1992; Hone 2007). The strength of inference varies with design (e.g. observational vs. experimental), analysis (e.g. regression vs. pairwise comparisons), degree of replication, and measurement accuracy. McArdle (1996) provides a good discussion of levels of evidence in studies of competition, predation and disease in wildlife with reference to the situation in New Zealand some decades ago. Then, the issue was the decline of native bird species, and the knowledge gaps related to the relative contribution of introduced predators (e.g. stoats, weasels, ferrets, ship rats), habitat loss and modification, and introduced herbivores such as brushtail possums which research demonstrated to have a key predatory role also.

At a minimum, the chosen design should enable the testing of at least one key hypothesis. Furthermore, the experimenters should be able to write down exactly how this will be done.

What to measure?

Newsome *et al*. (2015) put some thought into designing an experiment to answer questions relating to the possible role of dingo reintroduction in ecosystem restoration. The schema in Figure 1 illustrates the number of interacting components in what would be considered a simple study system (Sturt National Park) that may warrant monitoring – their sketch is a deliberate simplification – one could easily add other components of potential importance such as rabbits, raptors, presence of artificial water etc.

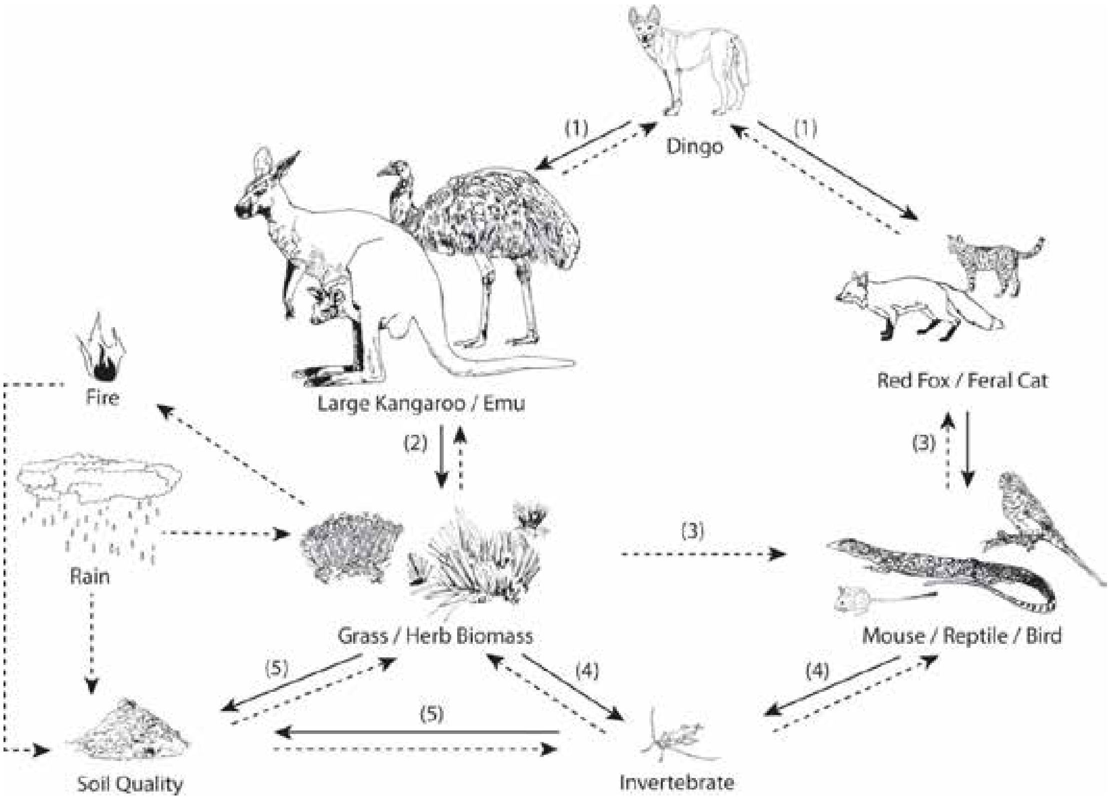

Figure 1. Illustration from Newsome *et al*. (2015) of interactive components of a system (Sturt National Park) where experimentation (dingo reintroduction) could be used to make inference on the impact of changing the predator guild on biodiversity outcomes.

Experimental costs quickly escalate as components are added to the list of things to be monitored. It is sometimes hard to distinguish between the "need to know" versus "nice to know". For example, Newsome *et al*. (2015) recommend the satellite collaring of dingoes, foxes, and cats to estimate population densities, rates of mortality and movement, and to provide data for behavioural studies, though without being too explicit as to how these data would contribute to the research question. One needs to avoid simply undertaking another "collar and follar" study. That said, the technology for tracking animal movements and quantifying interactions is constantly improving.

The alternative minimalist, and cheaper option (in terms of upfront costs at least), is to simply "pull the management" lever considered the best option (e.g. apply cat control as a treatment), and monitor the response of the component of interest (e.g. small mammal species). This can still have a robust experimental design (e.g. replicated treatment and non-treatment sites). If the desired outcome occurs, and can be replicated, then it can be argued that all is well from management sense. However, if the desired response doesn't occur, then the reasons for failure are largely unknowable. Was it because the control method failed, or another predator increased in response to cat control, or the experiment was confounded by changes to some other component (e.g. rainfall) across the study sites?

Analysis methods

Methods for surveying wildlife populations are constantly changing (e.g. Fleming *et al.* 2014), with an accompanying and sometimes dazzling array of new analysis methods. That said, the latest methods are not necessarily the best methods – meeting the study aim needs to be the primary consideration. For example, camera trapping with individual animal recognition has much utility for estimating the abundance of feral cat populations with distinct markings (Bengsen, Butler & Masters 2011), though not for foxes, where computationally more challenging methods are being explored (Ramsey, Caley & Robley 2015).

With regard to the current debate regarding methods for monitoring carnivores (see Hayward & Marlow 2014; Hayward *et al.* 2015; Nimmo *et al.* 2015), there is no guarantee some of the "robust" methods (e.g. distance sampling, occupancy estimation) are truly robust to departures from underlying assumptions, which are often quite onerous. There are challenges with interpreting occupancy measures (see Efford & Dawson 2012), and issues with modelling detection (Welsh, Lindenmayer & Donnelly 2013). The recent claims by Gopalaswamy *et al*. (2015) of index-calibration problems are also being contested. Ultimately we need to ensure that chosen methods can answer the scientific question at hand – there is no place for doctrine.

What scale and level of replication?

There is a common refrain that experiments must be "large scale" and replicated. I would argue that the scale needs to be adequate for the question at hand. There are many ways on making inference on the impact of predator populations on prey and they may be assessed at different scales. Furthermore, the scale of the treatment may differ from the scale of the response variable of interest.

Replication is a fundamental component of strong inference, but is sometimes difficult to achieve within a single study for reasons of limited resources and/or restricted scope to apply treatments (e.g. lack of populations to work on). In reality, studies rarely have adequate replication, and are "repeated" elsewhere, often by different researchers. This raises the need for a degree of harmonisation of monitoring methods and measurements of covariates. Regarding covariates, researchers need to consider which are required to not only evaluate their preferred working hypothesis but also the (often) competing hypotheses of other researchers.

Replication of large studies with adequate within-study replication is rare in applied ecology, but see Williams *et al*. (2007) and Twigg *et al*. (2000).

Working together better

Resolving issues relating to cats and biodiversity conservation will be aided by researchers sharing and critiquing research designs pre-implementation, and sharing data and findings post collection. Clearly this involves a high degree of trust and professional behaviour by all involved.

There is probably some benefit in the use of more Bayesian analyses in combining inference across studies—greater emphasis on estimating the net strengths of effects in concert with identifying weaknesses in study design. That said, the role of prior beliefs in Bayesian analyses has been, and always will be a source of contention.

Finally, gaining reliable knowledge in natural systems has long been challenging, and revisiting insights on the matter (e.g. Romesburg 1981) is time well spent.

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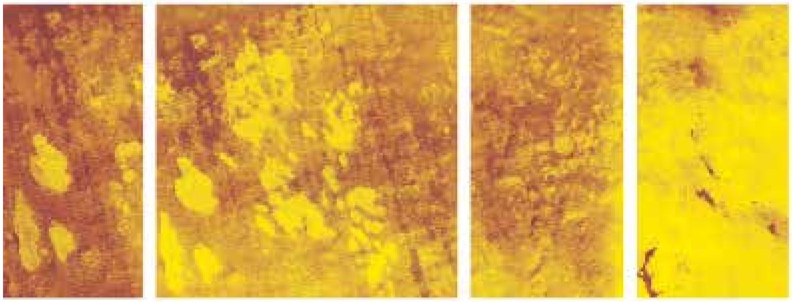

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Control tools

Requirements of tools to control feral cats

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Introduction

In 2008, the background document to the 'Threat abatement plan for predation by feral cats' (DEWHA 2008) considered the main control techniques for feral cats as trapping, shooting and exclusion fencing. Baiting was recognised as the most cost-effective method for broad-scale control, but was not commonly employed on the Australian mainland, although it had been used successfully in island eradications (Campbell *et al*. 2011). A sausage bait using 1080, *Eradicat*, had recently been developed and employed in Western Australia (Algar and Burrows 2004), but there were concerns over its application to the eastern states where native species are less tolerant of 1080 (Johnston *et al*. 2011). Development of an effective, humane cat-specific toxin and bait was seen as a high priority for feral cat management in Australia (DEWHA 2008). There has been progress on this front with development of the *Curiosity* bait using PAPP as a toxin (Johnston *et al*. 2011, Johnston *et al*. 2012) and other toxin delivery methods (Read 2010, Read *et al*. 2014). There have also been further applications of *Eradicat*, including on the mainland (Algar *et al*. 2013), and other control methods, and there is a better understanding of cat ecology and impacts, which will help improve strategies for their control. A review of control techniques and their application is thus timely.

As a precursor to papers in this workshop on particular control techniques, this paper provides a brief guide on what is required for a technique to be acceptable. Suitable control techniques for feral cats need to meet a number of criteria, including being:

- Target specific
- Humane
- Available to all members of the feral cat population
- Feasible (technically and economically)
- Applicable on a broad scale
- Effective in all environments and seasons
- Long-lasting (e.g. biocontrol, habitat manipulation, fencing)
- Publically acceptable (e.g. domestic cat owners opposed to biocontrol)

These are largely self-explanatory and represent an ideal. The control method selected for use by a pest manager or approved by a regulatory authority will to some extent be a compromise, such as between efficacy and non-target risk. The level of risk that is acceptable cannot be objectively determined and comes down to community or stakeholder values. Target specificity can be achieved in a number of ways including using the control tool at a time or place where a non-target is not susceptible (e.g. goannas in cooler months and outside the tropics, placing baits above ground) or using a species recognition system (Falzon *et al*. 2014). Most conventional lethal control methods require reapplication to stop population recovery through immigration and reproduction of survivors. Efficacy of cat control is notoriously variable, such as cats being generally reluctant to take baits when natural prey are readily available (Short *et al*. 1997, Algar *et al*. 2007, Johnston *et al*. 2012). Public acceptability of pest control goes beyond animal welfare, particularly when the pest subject to lethal control is also a popular domestic pet.

The presentations on particular control techniques in this workshop will address a number of the above suitability criteria. The emphasis in this paper is on efficacy and exploring what is required through population modelling.

Efficacy

Lethal control

Efficacy is obviously critical and the extent to which cat abundance needs to be reduced will vary case-by-case, possibly involving upper thresholds in cat abundance or lower thresholds in threatened prey numbers. Baxter *et al.* (2008) modelled the cost effectiveness of five contrasting predator control strategies in conserving threatened native prey. An 'upper-trigger' harvest strategy, where predators are removed when they are above a certain density, gave the lowest probability of prey extinction and the best return on investment. Other strategies (eradication, fixed number and lower trigger harvests) struggled to meet removal targets when predator density was low. This may be particularly relevant to managing arid zone cat populations that can increase dramatically at a site through immigration and reproduction following an increase in prey abundance (Letnic and Dickman 2006, Johnston *et al*. 2012). Sinclair *et al*. (1998) offered an alternative approach that focuses on the prey population. In the light of predator-prey theory, they examined the rates of increase of small, reduced extant populations and rates of increase of and predation rates on reintroduced populations of Australian mammals threatened by introduced predators, including cats. The data conformed to theoretical predictions and suggested the density of prey and amount of predator control needed for persistence of prey.

The relatively high maximum rate of increase of cats (exponential r_m = 0.99 or finite R = 2.69) can trivialise control removals to which cats rapidly compensate. This estimate is based on vital rates (age at first reproduction and annual fecundity)(Hone *et al*. 2010) and is supported by field data (Short and Turner 2005). Assuming logistic population growth and an r_m of 0.99, the reduction in a population's size from its carrying capacity from an on-going removal of animals can be determined. Figure 1 shows that the effort required is substantially greater than a suite of other pest animals in Australia. It is important to emphasise that the harvest must continue each year for many years to achieve the reduction identified on the *x*-axis in Figure 1. This difficulty will be exacerbated by immigration. McCarthy *et al*. (2013) painted a more pessimistic picture in their individual-based model of a stray cat population, which suggested annual removal rates of >80% are needed over more than a decade to eradicate a population. Annual removal rates of nearly 60% for a decade may only reduce population size by 25%. The density dependence used in these modelling exercises is likely to be overly strong for a population in a fluctuating environment such as arid Australia. The harvest rates for a particular percentage reduction are therefore likely to be overestimated in this environment (Caughley 1977).

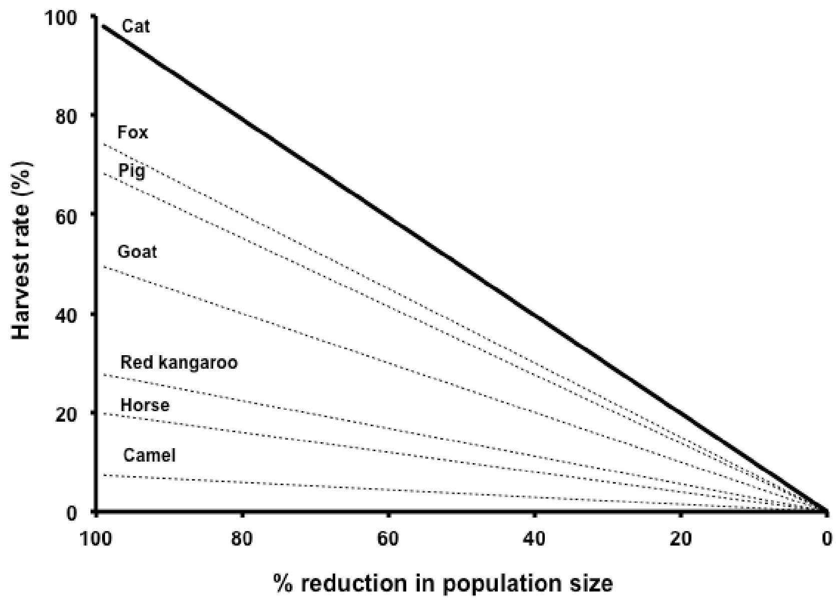

Figure 1. Percentage reduction in population size at carrying capacity for seven mammal species in Australia assuming logistic growth and long-term, annual instantaneous harvest rates.

Fertility control

While fertility control through trapping or darting is only feasible on a small scale, the modelled outcomes are of interest to managing broad-scale populations if a contraceptive can be administered in bait or through a self-disseminating agent. It is also relevant to eradication programs on human-populated islands with a domestic cat population. McCarthy *et al*.'s (2013) individual-based model of managing a closed stray cat population contrasted lethal control with castration/ovariohysterectomy of typical trap-neuter-release (TNR) programs and trap and release following vasectomy and hysterectomy (TVHR). Fertility control through TVHR can be more effective than TNR and lethal control as sexually active but infertile cats compete for matings and prevent less dominant animals from breeding. The modelled population was eliminated in 11 years by TVNR with a capture rate of 57%, whereas TNR and lethal control achieved only modest reductions. Again, immigration will compromise control efforts.

Biocontrol

The attraction of biocontrol is the possibility of self-dissemination and long-lasting control. Biocontrol with feline panleucopaenia virus proved successful in suppressing an initially naïve and high-density cat population on Marion Island, but this needed to be supplemented with conventional lethal control to achieve eradication (Bester *et al*. 2002). Other pathogens may have better characteristics for population control such as higher transmission rates. Courchamp and Sugihara (1999) modelled the impact of two feline retroviruses, feline immunodeficiency virus and feline leukemia virus, as promising alternatives. Eradication was possible with feline leukemia virus, with low natural immunity, but not feline immunodeficiency virus, although the latter could provide effective long-term control. Oliveira and Hilker (2010) considered the modelling by Courchamp and Sugihara (1999) was flawed and so used an alternative modelling approach for feline immunodeficiency virus and similarly found that it was unlikely to eradicate cats, but could reduce their population size sufficiently to allow recovery of endangered prey.

Dingoes and other predators provide alternative biological controls for feral cats (e.g. Brook *et al*. 2012), but the situations (including densities) where these predators provide effective control need to be clarified (Allen *et al*. 2014). Part of the problem is that dingoes and foxes are also predators of threatened species.

Conclusion

On a positive note, while cat control has proven difficult, island populations have been successfully eradicated and mainland feral cat populations have been controlled (i.e. their impacts managed) at a local scale. New tools and strategies founded on past experience (including integration of techniques) offer some cause for optimism.

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What do we have in the toolbox? Review of cat control methods

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Introduction

Compared to many other pest animals, the history of feral cat control for strategic management in Australia is short, and the suite of tools available is limited. A survey of pest mammal control programs in Australia between 1998 and 2003 found that most (59%) feral cat control programs used trapping to remove cats from the target population, followed by baiting (21%), shooting from the ground (18%) and other, unspecified, tools (Reddiex *et al.* 2006).

Methods and results

To evaluate the relative effectiveness of trapping, baiting and shooting as cat control tools, I examined 49 published evaluations of feral cat control operations conducted in Australia between 1985 and 2013 (Table 1). Most (43) evaluations were of baiting operations and most (38) of these were evaluated using changes in passive tracking indices calculated before and after baiting and/or mortality of collared cats (13). The distribution of results using both evaluation methods was bimodal, with most baiting operations producing index reductions or mortality estimates of < 30% or > 70%. Despite the widespread use of trapping as a feral cat control tool, I could find only four evaluations of cat trapping operations. Of these, one removed a trivial number of cats and the remaining three showed signs of rapid population recovery through immigration. Press reports of feral cat control programs in western Queensland repeatedly cited large numbers of cats removed by ground shooting, but no published studies have evaluated the effects of shooting operations on cat populations. Two studies evaluated feral cat eradication programs on islands that used a combination of methods. One of these reported that shooting was more effective and efficient than trapping in eradicating feral cats from a small island in Queensland (Domm and Messersmith 1990).

Discussion

Sustained control of feral cats requires repeated removal of a large proportion of the population to suppress population growth (Pople, these proceedings). Of the three control tools evaluated in the studies collated here, only poison baiting was demonstrably able to achieve this. There was substantial variability in the results of baiting operations, but much of this can probably be attributed to the experimental nature of the work. Many of the baiting studies that failed to achieve large reductions in cat activity were conducted under conditions that are now recognised as sub-optimal, such as: using low bait densities (e.g. Moseby and Hill 2011); using poorly prepared baits (e.g. Algar *et al.* 2011a; Johnston *et al.* 2013); or baiting when prey species were highly available (Christensen *et al.* 2013).

Poison baiting is clearly able to produce large population reductions. However, current baiting products and tactics are not yet available or appropriate in many regions due to the high risk they pose to non-target species. Furthermore, evaluations of baiting programs for other species have shown that results obtained under tightly controlled conditions do not always translate to routine operations in the 'real world' (e.g. Carter *et al.* 2011; Bengsen 2014) and some proportion of cats in any population can be expected to be resistant to taking baits. Other control tools therefore remain important in their own right or as part of integrated control programs.

Trapping using cages or soft-jaw foothold traps has been the most widely used form of cat control (Reddiex *et al.* 2006) and is likely to remain important because it is widely available. Cage trapping, in particular, is accessible to a wide range of users, although it can be less efficient than foot hold trapping (Short *et al.* 2002). The major limitation with trapping is the high labour requirement, which means that it can usually only be used intensively over small areas or sparsely over large areas. Consequently, cats removed by trapping are likely to be rapidly replaced by cats from adjoining areas or from untrapped holes within a sparsely treated area (e.g. Bengsen *et al.* 2011; Lazenby *et al.* 2014).

Shooting programs have been able to remove large numbers of cats from the landscape (e.g. Pettigrew 1993). However, their effects on cat populations have not been described, so the value of shooting as a primary means of reducing or supressing populations remains unclear.

Despite recent advances in the development of cat control tools and tactics (e.g. Algar *et al.* 2002; Christensen *et al.* 2013; Fisher *et al.* 2014), there are large gaps in our understanding of how to best control cats. Areas of study that should help fill in some of the most important gaps include: tools and tactics to control cats within an integrated predator management framework; methods to consistently target cats that are not reliant on responses to food; and integrating different control tools in sustained management operations. Many feral cat control programs are conducted in different situations across Australia each year. Robust evaluation and reporting of routine management programs could help build a body of knowledge that would complement much of the experimental work that has been reported to date, advancing our collective capacity to manage the damage caused by feral cats.

Table 1. Results of 49 evaluations of feral cat control programs in Australia, 1985-2013, expressed as mortality in a sample of collared animals or change in occupancy or activity index after control.

Location	***Area treated (km²)***	***Year***	***Control tool used***	***Mortality***	***Change in*** **occupancy**	**activity**
Cape Arid[1]	259	2010	bait	0.20	na	0.00
Cape Arid[1]	1,200	2010	bait	0.25	na	-0.85
Christmas Island[4]	50	2009	bait	na	na	-0.87
Cocos Islands[2]	6	2002	bait	na	na	-0.89
Dirk Hartog Island[5]	250	2009	bait	0.80	na	-0.84
Faure Island[2]	?	2001	bait	na	na	-0.90
Flinders Ranges[6]	150	2011	bait	0.10	-0.16	-0.50
French Island[7]	60	2008	bait	0.75	na	na
Gibson Desert[2]	2,500	2002	bait	na	na	-0.96
Gibson Desert[3]	?	1994	bait	na	na	-0.76
Gibson Desert[3]	?	1996	bait	na	na	-0.14
Gibson Desert[3]	?	1998	bait	na	na	-0.28
Gibson Desert[3]	?	2001	bait	na	na	-0.84
Gibson Desert[10]	400	1996	bait	na	na	-1.00
Gibson Desert[10]	400	1998	bait	na	na	-0.25
Hermite Island[2]	?	1999	bait	na	na	-0.80
Lorna Glen[3]	?	2003	bait	na	na	-0.77
Lorna Glen[3]	?	2005	bait	na	na	0.00
Lorna Glen[3]	?	2006	bait	na	na	0.00
Lorna Glen[8]	625	2003	bait	na	na	-1.00
Lorna Glen[8]	1,725	2004	bait	na	na	-0.76
Lorna Glen[8]	1,725	2005	bait	na	na	-0.85
Lorna Glen[8]	1,725	2006	bait	na	na	1.55
Lorna Glen[8]	2,350	2007	bait	na	na	-0.50
Lorna Glen[8]	2,350	2008	bait	na	na	-0.77
Lorna Glen[8]	2,350	2009	bait	na	na	0.00
Peron Peninsula[2]	1,500	2002	bait	na	na	-0.80
Peron Peninsula[3]	?	1997	bait	na	na	-0.21
Peron Peninsula[3]	?	1998	bait	na	na	-0.16
Peron Peninsula[3]	?	2003	bait	na	na	0.00
Peron Peninsula[3]	?	2006	bait	na	na	-0.10
Peron Peninsula[3]	?	2007	bait	na	na	-0.15
Pilbara[9]	268	2012	bait	0.00	0.00	na

Roxby Downs[11]	650	2002	bait	na	na	-0.82
Roxby Downs[11]	1,800	2003	bait	0.83	na	0.00
Roxby Downs[11]	1,800	2003	bait	0.83	na	0.00
Roxby Downs[11]	1,800	2004	bait	na	na	0.00
Roxby Downs[11]	1,800	2005	bait	na	na	0.00
Roxby Downs[11]	1,800	2006	bait	0.17	na	0.00
Roxby Downs[11]	1,800	2006	bait	0.17	na	0.00
Roxby Downs[12]	430	2013	bait	0.58	-0.52	na
Shark Bay[13]	12	1995	bait	1.00	na	-0.74
Wilsons Promontory[14]	90	2011	bait	0.50	0.00	na
Glenelg Nat Park[15]	90	2009	trap	na	0.00	na
Kangaroo Island[16]	16	2010	trap	0.78	0.00	0.55
Mt Field[17]	40	2009	trap	na	0.00	2.11
Tasman Peninsula[17]	45	2009	trap	na	0.00	0.75
Gabo Island[18]	1.5	1992	combination	na	-1.00	-1.00
North West Island[19]	1	1985	combination	na	na	-1.00

[1] Algar *et al.* 2011a; [2] Algar and Burrows 2004; [3] Christensen *et al.* 2013; [4] Johnston *et al.* 2010; [5] Algar *et al.* 2011b; [6] Johnston *et al.* 2012; [7] Johnston *et al.* 2011; [8] Algar *et al.* 2013; [9] Johnston *et al.* 2013; [10] Burrows *et al.* 2003; [11] Moseby and Hill 2011; [12] Johnston *et al.* 2014; [13] Short *et al.* 1997; [14] Johnston 2012; [15] Robley *et al.* 2010; [16] Bengsen *et al.* 2011; [17] Lazenby *et al.* 2014; [18] Twyford *et al.* 2000; [19] Domm and Messersmith 1990

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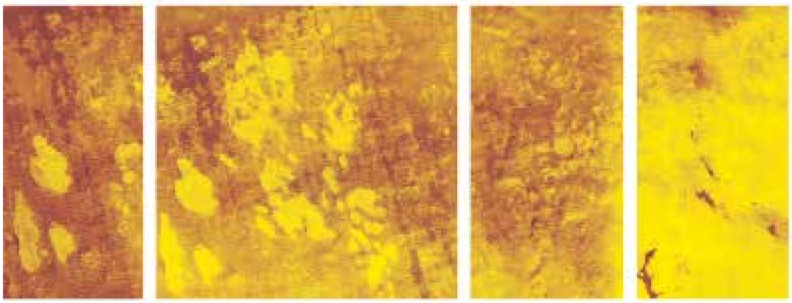

What is in the pipeline? Eradicat®, Curiosity® and other tools

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Bait types

Poison baiting is recognised by most practitioners as the most effective method for controlling feral cats (Algar and Burrows 2004; Algar *et al*. 2007; DEWHA 2008; Short *et al*. 1997). The implementation of an annual baiting strategy can provide for the effective and sustained control of feral cat populations at the landscape level (Algar *et al*. 2013a).

There are three feral cat bait types that are at various stages of development. The *Eradicat®* bait is similar to a chipolata sausage in appearance, approximately 20 g wet-weight, dried to 15 g, blanched and then frozen (Algar and Burrows 2004). The bait is composed of 70% kangaroo meat mince, 20% chicken fat and 10% digest and flavour enhancers (Patent No. AU 781829). Toxic baits are injected with 4.5 mg of the toxin sodium monofluoroacetate (compound 1080) per bait. *Eradicat®* baits have recently been registered for operational use in Western Australia. *Curiosity®* and *Hisstory* baits are based on the *Eradicat®* bait medium but differ in their method of toxicant delivery. These baits were developed to mitigate impacts on non-target wildlife species for use at sites where baits that have been directly-injected with 1080 present a hazard.

The alternative approach of toxin delivery used in *Curiosity®* and more recently the *Hisstory* bait uses an acid-soluble encapsulated pellet known as the 'hard shell delivery vehicle' (HSDV) (Johnston *et al.* 2011). *Curiosity®* contains 80 mg of the toxin para-aminopropiophenone (PAPP) and *Hisstory* contains 4.5 mg 1080 in the HSDV. The HSDV ensures that the toxin does not disperse throughout the bait but releases in the cat's stomach. This method of delivering the bait also plays a key role in reducing the potential exposure of non-target species. When feeding, feral cats are known for consuming large food items, they do not in general masticate but, using their carnassials as "shears" cutting prey up into pieces which they then swallow whole (Leyhausen and Tonkin 1979). Consequently, baits are simply cut into manageable portions which are then swallowed entire, including the HSDV. Conversely, most wildlife species process food items more thoroughly in the mouth. Field studies have shown that most Australian species tend to reject the HSDV if they consume the bait and therefore avoid exposure to PAPP (Hetherington *et al*. 2007; Forster 2009).

Curiosity® is to be submitted for registration over the next two months. *Hisstory* is currently being tested in field efficacy trials in northern Australia where a HSDV is required to minimise risk to mammalian and avian species but where species that have relatively high susceptibility to PAPP such as varanids (Eason *et al*. 2014; Johnston *et al*. 2014), are active at the time of baiting.

Baiting strategies

There are three factors that are critical to the outcome of baiting programs: 1) bait density and bait encounter; 2) the abundance of prey items; and 3) weather conditions at the time of baiting. Cats, despite being opportunistic predators, will only consume a food item if they are hungry (Bradshaw 1992). If a cat encounters a bait when not hungry it may not be consumed regardless of the acceptability of the bait. For feral cat baiting programs to be efficient and cost-effective, baits must be delivered at a level that maximises their uptake by feral cats but minimises the number of baits required which will also reduce the potential risk posed to non-target species. The relationship between bait consumption and hunger can be extended to prey abundance, which is also a function of long-term weather conditions (season/rainfall). The likelihood of cats encountering baits when hungry is potentially diminished in the presence of an abundant prey population. Therefore bait uptake is invariably low when prey availability is high (Algar *et al*. 2007). The impact of baiting can also be substantially reduced if significant rainfall occurs immediately following the baiting program. Rain renders the baits less palatable to cats by washing away the oils and flavour enhancers that sweat to the surface of the bait. Bait longevity in the field is a critical component in developing successful baiting campaigns to target feral cats.

The current prescription for aerial baiting campaigns requires the deployment of 50 baits/km^2 along flight lines 1 km apart and for ground baiting campaigns, baits are located at 100 m intervals along road/track access. Baiting efforts should be maximised during seasonal declines in prey abundance/activity, termed the "baiting window" (Algar *et al*. 2007). Baiting outcomes can be improved if long-term weather forecasts are used to ensure that baiting programs are only conducted when prolonged periods of fine weather are assured.

With the development of new technologies such as GPS data-logger radio-collars that now can be fitted to cats and the data they provide, we can now be smarter in the way we bait. Instead of the blanket approach currently used we can be more strategic and develop baiting programs based on likely bait encounter rates and distribution patterns and also habitat preferences. These refinements will further improve baiting efficacy and cost-efficiency.

Other tools

Fundamental to the development of an effective control strategy for any pest species is the ability to effectively trap the target species for the collection of biological information, and to enable radio-collaring of individuals to monitor various key parameters. Trapping is also a useful follow-up technique post-baiting, where eradication of cats is required (e.g. small scale areas and islands) or to provide additional control effort (Algar *et al*. 2013; Fisher *et al*. 2014). We have developed a method of trapping that takes advantage of cats' agility and ability to jump for use at sites where conventional trap sets pose a hazard to non-target species. Here, traps are set on a raised platform that minimises the capture risk to non-target fauna yet is still effective for the capture of feral cats. These elevated trap sets are a refinement of the earlier 'bucket trap' used to reduce the risk to non-target species such as robber crabs (*Birgus latro*) on Christmas Island (Johnston *et al*. 2010).

We are also developing a lethal implant, '*Tic-Toc*' that will allow release of radio-collared individuals, retrieval of the radio-collar and data collection, and provide greater certainty about the fate of animals used during studies on 'high stakes' programs such as island eradications.

A revision to the 'Feline Audio Phonic' audio lure is being manufactured that produces the sound of a female cat calling when in oestrus. The phonic consists of a printed circuit board with a microprocessor data driven voice ROM that produces the sound. This phonic will have potential use in both trapping and monitoring programs.

We have also been able to synthetically manufacture the compound from the plant species, *Acalypha indica*, which stimulates cats to chew the plant's roots and then roll in it. This behaviour induces what appears to be a drugged stupor (Algar *et al*. 2013b). The compound is likely to be incorporated into baits and lures to further enhance their attractiveness.

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Grooming traps and toxic trojans for targeted poisoning of feral cats (Available and potential new tools for control of feral cats)

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Introduction

Predation and disease transfer by feral cats continue to pose one of the most serious threats to small wildlife in Australia and elsewhere. Currently available techniques are unable to provide sustainable control of feral cats on mainland Australia to the level required for persistence or reintroduction of many threatened fauna. We review current and potential tools for feral cat control and identify key areas for further research and development

Biological Control

Biological agents are likely to provide the only feasible and sustainable (at least in the medium term) method for broadscale limitation of cat predation in Australia. Although several biological and social challenges limit the current availability of biological control agents for feral cats, we argue that community understanding and political will for the need for feral cat control has improved in recent years. This awareness is overcoming some of these barriers that may open doors for investigation of agents formerly considered off-limits in Australia.

In addition to promoting development of direct control agents for feral cats, we demonstrate dramatic declines in cat (and fox) populations following the spread of RHDV through rabbits, and associated response of several cat-vulnerable prey species using examples from Roxby Downs and Flinders Ranges. We propose that investment into improved biological control of key cat prey species (especially rabbits and house mice) may again yield cost-effective broadscale suppression of feral cat predation on threatened species.

Trapping

Conventional cage and leg-hold trapping of feral cats has been (and continues to be) important for control of cats in small areas of high biological value and also for eradication of cats from confined populations. However, feral cats are seldom attracted to baited traps when live prey are available and conventional trapping also suffers from many logistical, ethical and non-target challenges. Automated grooming traps that spray toxin onto the fur of feral cats walking past, circumvent the need to lure wary cats into conventional traps and also eliminate the requirement to check traps on at least a daily basis. The grooming pathway also eliminates exposure to many nontarget species that are unable or unlikely to groom as fastidiously as feral cats (Read *et al*. 2014). Here we demonstrate current developments of an automated grooming trap that uses an array of sensors to distinguish cats from larger and smaller nontargets and instantaneously sprays them with a measured dose of toxin from a range of 4 metres. Because the new Grooming Traps can fire at a cat walking along a road or clearing, they should potentially be able to control any cat that is photographed by a camera trap.

Proposed developments include a fully programmable audiolure, a camera that records all activations and potentially radio frequency identification (RFID) readers and visual recognition software that can provide additional blocking tools to further minimise non-target exposure. Incorporation of technology to distinguish registered and tagged cats from strays or ferals will enable councils to control unregistered cats in jurisdictions where pet cats must be contained. At present these containment laws are largely benign due to the logistical challenges of identifying and enforcing control on wandering cats. Donors to this R&D, including South Australian Innovation Vouchers, Department of Environment, Water and Natural Resources, Sporting Shooters Association of Australia and the Foundation for Australia's Most Endangered Species Ltd, are gratefully acknowledged.

Baiting

Specially formulated poison baits have been integral to cat eradication from islands such as Faure (WA) (Algar *et al*. 2010) and have proven effective at short-term reductions in some mainland feral cat populations when conditions are favourable (Moseby and Hill 2011). However, poison meat baits have low uptake by feral cats in many areas when live prey are available or when weather conditions render baits unpalatable (Christensen *et al.* 2012). Increase in cat prey (including threatened species) is a desirable outcome of most feral cat control, which presents a conundrum for sustainable cat control using poisoned baits. Because cats are primarily visually-stimulated hunters rather than scavengers, bait uptake by scavenging birds, large reptiles and other mammals typically exceeds rates of cat ingestion of baits, which reduces their efficacy and poses nontarget and social risks in some environments.

Recent reviews have determined that rather than being generalist predators that are efficiently controlled using a standard tool such as a bait, individual cats often exert disproportionate predation pressure on threatened species (Dickman and Newsome 2015; Marlow et al. 2015, Moseby et al. in prep.). We propose to target those cats responsible for 'catastrophic' predation of threatened species by making their first predation event lethal, rather than the cats learning to target remaining members of the threatened species population (Read *et al*. in prep.). *In situ* and particularly reintroduced threatened species could be fitted with an attachment to their radio-collar or harness that releases toxins into a cat's mouth when it seizes its prey on the back of the neck. Alternatively, a toxic dose could be contained within a microchip-style capsule that is inserted into live individuals of species preyed upon by cats. This capsule would be stable at the neutral pH of the subcutaneous environment but dissolve in the acidic gut of a cat. Both the kill collars and toxic implants are effectively creating 'live baits' that appeal to cat's hunting instincts and are far less available, and potentially less toxic, to nontarget scavengers than conventional baits.

Toxic Trojans

Cat predation on several threatened wildlife species in south-west WA has been restricted by the poisoning of cats feeding on more tolerant prey species that have consumed toxic seeds of several *Gastrolobium* species (Short et al. 2005). Historical accounts suggest that consumption of the flesh and even the bones of pigeons and other prey that have eaten *Gastrolobium* can be fatal for cats (Peacock *et al*. 2011), suggesting toxins other than 1080, which is not incorporated during ossification, may also be present in these seeds (Peacock 2003). The abundance and distribution of *Gastrolobium*, along with its ecological role in safeguarding threatened species from cat predation, has declined and we advocate for research and trials of the benefits of restoring and promoting *Gastrolobium*, through appropriate fire or disturbance regimes, to confer advantages to cat-vulnerable prey. We also note that cats are particularly sensitive to toxins found in a variety of other native and exotic plants and suggest that attention is paid to identifying whether changes in these species could help explain contemporary declines in cat-sensitive fauna in northern Australia. Enhancement, reintroductions, or introductions of toxic plants may prove to be a cost effective and sustainable means to curb cat predation in a range of environments, provided that weediness and off-target poisoning issues are manageable.

An alternative technique to render live cat prey toxic to feral cats is to make toxic food pellets or grain available to targeted prey species. Bronzewing pigeons, for example, are tolerant of *Gastrolobium* and 1080 and could be provided with 1080 oats or *Gastrolobium* seed at sublethal doses that render them lethal to predating cats. Targeted cat control could thus be provided by multiple toxic feeding stations for pigeons and potentially other species that could act as a permanent predator sink for immigrating cats.

Further justification and details of these novel potential feral cat control techniques will be available in Moseby et al. (in prep.) and Read et al. (in prep.), which have been submitted for publication. Financial and logistical requirements for future R&D

and trials of these techniques to deliver continuous targeted cat control are discussed.

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Recognition software and toxins

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Abstract

Australia leads the world in the adoption of technology, and our innovative advances in the wildlife management arena are well recognised. Accordingly, the adoption of camera traps in place of historical monitoring methods has been rapid (Meek *et al.* 2015), leading to the demand for computer assisted technologies to aid interpretation of data (Falzon *et al.* 2014). This demand ranges from software programs to store and code image data, to analytical software that produces abundance indices from camera trap photos, and sophisticated algorithms to expedite interpretation and identification of image data.

Working with image data has numerous challenges depending on the intent of the program. Turning photos into numerical data for analysis is complicated and, where identification of species or individuals is necessary, camera trap data can be limited. Our research team has been trialling the use of computer assisted technology to automate detection of feral cats and many other species using camera trap technology. It can be difficult to distinguish between individual feral cats using the human eye, so we have been building models to test if we can uniquely identify individuals. As a component of this research we have also built models to identify individual animals using facial recognition algorithms. If this smart technology can be refined it provides unique opportunities to develop target specific tools for monitoring and control, for example a grooming trap or sentinel baiting device.

The development of new tools for monitoring and control of feral cats and other pest species will be enhanced with the utilisation of advanced technology, and devices such as the feral cat grooming trap is a prime example. Current grooming trap prototypes have been constrained in their capacity to distinguish feral cats from other species, thus not achieving a higher level of discrimination for delivery of the toxin. Using image recognition technology and sophisticated processing equipment, there is potential to build devices that can recognise particular species over non-target animals and discriminately deliver a toxin. This computer assisted technology can be used in many other monitoring and control systems; it will enable the development of systems like sentinel baiting devices that dispense toxic baits when a target animal is detected. Moreover, the systems can be incorporated into software programs to expedite analysis and interpretation of camera trap image data,

including the ability to identify individuals, that is particularly important in some monitoring investigations.

New computer based technology has endless applications and opens the door to developing early detection and warning systems that alert land managers to the presence of a target species. For example, a system can be remotely deployed to a high valued location such as an endangered species colony or an exclusion fence-line. When a feral cat is detected approaching the colony or walking along the fence-line, the system can detect the animal, identify its species and transmit an automated signal to a personal hand held device or personal computer warning of the detection. This technology can also be applied to trap closure devices, allowing land managers to set traps remotely and receive a signal when the device has been triggered.

There are endless opportunities with the emerging electronic technological advances being made in the computer science field. Fostering an integrated approach between computer scientists and ecological scientists provides a greater breadth of opportunities for developing new tactical tools to improve monitoring and control of feral cats. The integration of technology into land management is only constrained by our failure to recognise the potential and our inability to facilitate adequate funding to explore the opportunities.

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Review of biocontrol for cats (Biological control options for feral cats in Australia)

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A question often asked is why, if we have effectively controlled rabbits using biological control, we cannot do the same for other feral animals especially cats? For rabbits, Australia has been fortunate to have not only one, but two new emerging extremely specific and pathogenic diseases available for effective lethal rabbit biocontrol: Myxoma virus and Rabbit Haemorrhagic Disease (RHDV). Both diseases are highly virulent and species specific, persist in the environment and cause repeated outbreaks, and are insect transmitted allowing them to reach disconnected, sparse and remote rabbit populations [1]. Although not sufficient to sustainably control or eradicate rabbits, the two viruses provide ongoing benefits to Australia's rural industries and the environment at no extra costs [2]. While Myxoma virus has attenuated over time [3], RHDV is evolving to maintain high levels of virulence [4], and is still killing rabbits faster than some toxins [5].

No such new diseases exists for cats that a) is specific to only feral cats but not big endangered or pet cats, b) meets animal welfare concerns the way RHDV does [6]. There is one case where classical biocontrol has helped to eradicate cats, from subantarctic Marion Island: Feline panleukopenia virus (or feline parvovirus) was used to achieve an initial population knockdown which then had to be followed up intensively with conventional control measures [7]. Prerequisite for this success was the absence of feline parvovirus from the isolated island population, which is in contrast to most other feral cat populations where natural pre-existing immunity to parvovirus is likely to be high [8]. Duration and severity of the disease poses serious welfare concerns regarding its use as a biocontrol tool, and there are also potential issues regarding species specificity – canine parvovirus is believed to have evolved from feline parvovirus by very few genetic changes only [9], which raises the question of how readily the virus could adapt to other carnivore species.

Virally vectored immuno-contraception (VVIC) involves the use of a genetically modified vaccine virus to elicit an antibody response to reproductive antigens, and thus interfering with fertility [10]. VVIC was explored for foxes using a dog herpesvirus as a vector to deliver anti-fertility agents by CSIRO several years ago, but was unsuccessful as the dog herpesvirus did not replicate sufficiently in foxes [11]. Similar approaches are currently being investigated for cats using cat herpesvirus as a vector, but a successful outcome of this work has not been reported yet [12].

A new approach coming over the horizon is 'genetic drive' technology where modified genetic traits can copy themselves onto both copies of the chromosomes. If this process occurs in the germline, the resulting organism will be homozygous, and all offspring will inherit the desired trait for multiple generations [13]. This approach is currently actively debated regarding its applicability for suppressing invasive species populations, including mammals. A series of gene drive approaches, including from gene drives that bias sex or those that sensitise a target population to a special toxin, are theoretically feasible for broad scale application. However, due to the potential of uncontrolled spread, strategies ensuring safety and demonstrated controllability of gene drives are a prerequisite for such technologies ever to be considered for field release [13]. While it may be possible to technically address these safety issues, regulations and public perceptions regarding the generation and release of genetically modified organisms are important matters that also needs to be taken into consideration [14].

In summary, while a safe, effective, humane, species specific and self disseminating biological control agent would be highly desirable for the management of feral cats in Australia, or any invasive species for that matter, there is currently no such agent available for immediate use. Groundbreaking new technologies open up exciting possibilities to alter entire populations, however such approaches are in their infancy and it is not clear if and when such technologies would be available for use in vertebrate pest populations.

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Fertility control options for cats

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The development and application of fertility control as an additional and non-lethal tool for vertebrate pest management has gained public acceptance because it is perceived as more species specific, more humane and potentially more cost effective.

Ideally, a fertility control agent needs to induce permanent sterility leading to reduced recruitment in the pest population, be easily delivered to reach an adequate proportion of the target population, produce minimal side-effects to the target species (behavioural and/or social structure changes), be host specific, be environmentally benign and be cost effective. For any particular species, it may be difficult to meet all of these requirements and significantly reduce the impact of the pest in the landscape.

Reproductive targets for fertility control include disrupting either the hormonal feedback associated with the hypothalamic-pituitary-gonadal axis, the function of the gonads, fertilisation, and/or implantation. To date, steroid implants and hormone agonists or antagonists have been shown to be effective, as have various immunocontraceptive vaccines, while chemosterilants and germ cell specific peptides conjugated to cytotoxic chemicals are being tested. None of the agents available are orally deliverable – their delivery requires the capture of individual animals to enable treatment.

Thus the greatest challenge at this time is the inability to orally deliver fertility control agents efficiently and effectively at an appropriate broad scale.

Welfare considerations for cat management

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Abstract

There are few species in pest animal management that provoke such a wide range of responses than cats. From cute bundles of warm fur, to ravenous beasts devouring every small animal in sight, imagery and perspectives on cats reflect this whole spectrum of views. Whatever we individually think about the impact of cats on Australian wildlife or their place as human companions, one thing we must not ignore is that cats can experience pain, suffering and distress and thus warrant humane treatment and protection from cruelty.

Humane cat management requires consideration of the animal welfare impacts of strategies as they affect owned cats, stray cats and feral cats. Policies for owned cat management, such as containment and mandatory desexing, should balance the impact on cat welfare with the need to reduce their potential negative impacts on wildlife. Simple changes to ownership requirements, desexing practices and the way we socialise and house owned cats can assist in reducing cat overpopulation and the stray cat problem, but to be effective these require consistent government support across jurisdictions.

Methods for the reducing the impacts of feral cats should follow recognised principles of humane vertebrate pest control, ensuring that techniques are justified, effective and humane. Minimising animal welfare impacts must be a priority in the development of new techniques (for example, PAPP) – indeed this is crucial to gaining public support for new methods – as well as protecting owned cats from associated risks. Objective assessment of the impacts of existing control methods – trapping, shooting and poisoning with 1080 – needs to be incorporated into future management strategies and threat abatement plans. While it is clear that cats will never be eradicated from mainland Australia, more strategic and effective cat management at all levels will not only benefit biodiversity, but also result in improvements to cat welfare in the long term.

Attitudes and perception of cats

The management of cats is a complex problem. They are valued as companion animals and are encouraged as control agents for rodents and rabbits but they also pose a significant predation risk to many native animal species (Denny & Dickman, 2010). For any management strategies to be effective, support of the public is required. Unlike public perception of many pest species that are not domestic pets, perception of cat control is likely to elicit a greater negative public response if it is not humanely implemented and causes animal suffering (Farnworth, Dye, & Keown, 2010). There will also inevitably be vocal opposition to options that affect owned (or companion) cats, so there must be a commitment to achieving humane, socially acceptable options.

The terminology used to describe cats can influence people's perception of cats, and importantly, their perceptions about the acceptability of control measures (Farnworth, Campbell, & Adams, 2011).

There is much variation in the terms used to describe cats (Bradshaw, Horsfield, Allen, & Robinson, 1999; Farnworth et al., 2011) and it can get complicated describing animals that live in peri-urban areas. In the New Zealand companion cat code of welfare, the term 'feral cat' often refers to cats that are wild, undomesticated and not reliant on humans for their existence. 'Owned cats' are companion animals that live with humans and are dependent on them for their welfare, whereas 'stray cats' refers to companion cats which are lost or abandoned and are living as an individual or in a group (colony). Stray cats have many of their needs indirectly supplied by humans, and live around centres of human habitation whereas, feral cats live largely independently of humans, and the population is self-sustaining and not dependent on input from the companion cat population (Farnworth et al., 2011, 2010).

Figure 1 "That Feral Cat" Kaye Kessing, 2004

The depiction of feral cats as crazed, ravenous creatures devouring every native animal in sight (for example, see Figure 1) does not help with constructive discussion on the issue. Too often, feral cats are demonised and their impacts exaggerated or inaccurately presented to justify calls for their eradication. For example, in an interview on ABC Landline, the federal Minister for the Environment, Greg Hunt was quoted as saying "There are up to 20 million feral cats taking up to four native Australian animals a night. That is over 20 billion Australian native species being destroyed a year" (Greg Hunt, ABC Landline, 2 November 2014). However, in reality, there are limited data on feral cat numbers and their impacts in Australia (see http://www.abc.net.au/news/2014-11-13/greg-hunt-feral-cat-native-animals-fact-check/5858282 for further information). This type of commentary only acts to polarise the community further and can serve as an impediment to effective implementation of feral cat management strategies.

Management of owned and stray cats

Any cat management program that aims to minimise cat predation must adopt a holistic approach and address all cats, regardless of how they are described. One important aspect is 'responsible cat ownership' and this should be strongly promoted in the community. The RSPCA believes that the management of owned cats should balance the need to ensure the welfare of cats and the need to reduce the negative environmental and social impacts of cats, reduce overpopulation through desexing prior to sexual maturity, promote containment of cats and be nationally consistent in terms of breeding, ownership, desexing and identification requirements.

Traditionally the desexing age for cats is 5.5 to 6 months, however female cats can attain sexual maturity as young as 4 months of age, therefore RSPCA recommends desexing from the age of eight weeks. The surgery is simple and recovery is rapid and straightforward. We argue that adoption of early age desexing (prior to sexual maturity) would greatly reduce the number of unwanted domestic cats (RSPCA Australia, 2012).

The RSPCA also supports the containment of cats (within property boundaries), an important behaviour of responsible cat owners that receives wide community support (Toukhsati, Young, Bennett, & Coleman, 2012). Containing cats can protect them from disease and injury caused by fighting and accidents, increase opportunities for positive owner-animal interactions, reduce the impact of hunting by cats and minimise disturbance caused to neighbours. Contained cats need opportunities for exercise and environmental enrichment (complexity) so it is preferable that they have access to an outdoor enclosure, which increases opportunity for activity and stimulation. We argue that there need to be widespread awareness-raising campaigns to make confinement of cats the norm.

Trap, neuter and release (TNR) has been suggested as a strategy for addressing problems with unowned or stray cats (Schmidt, Swannack, Lopez, & Slater, 2009) and indeed there may be some very specific circumstances where this could be an option, for instance when it is a well-managed program with sufficient long-term resources and includes desexing, re-homing, and euthanasia where necessary. However, we argue that resources may be better spent on education, increased community awareness, targeted desexing programs and better laws and regulations. Thus we do not recommend TNR as a management strategy for most of Australia (RSPCA Australia, 2011). In more remote areas, the most cost-effective and humane option is likely to be targeted and ongoing lethal control in priority areas where adverse environmental impacts are highest.

Management of feral cats

RSPCA Australia acknowledges that, in certain circumstances, it is necessary to manage populations of feral cats in order to reduce adverse impacts on threatened native fauna and that lethal control methods are sometimes required. However, whenever control is undertaken, animal welfare impacts must be minimised and the methods used must be humane, target-specific and effective.

Over the past decade a number of tools have been developed to improve the humaneness of different control methods and to allow a more objective evaluation of their welfare impact. A code of practice (COP) for the humane control of feral cats (Sharp & Saunders, 2012) and standard operating procedures (SOPs) for ground shooting (Sharp, 2012a) and trapping using padded jaw (Sharp, 2012c), soft nets (Sharp & McLeod, 2013) and cages (Sharp, 2012b) have been developed by the NSW Department of Primary Industries with support from the Australian Government. These are available on the Pest Smart website (http://www.pestsmart.org.au/), developed by the Invasive Animals Cooperative Research Centre to provide information on best practice management of pest animals in Australia. The COP provides general information on best practice management of feral cats, control strategies, feral cat biology and impact and also a summary of the humaneness, efficacy, cost-effectiveness and target specificity of a range of control methods. The SOPs describe specific control techniques and their application as well as animal welfare impacts for target and non-target species and strategies to minimise any harmful impacts.

The humaneness of different control methods is highly dependent on how they are applied and on the skill of the operator. Details such as the timing and coordination of control, how a bait is delivered, lethal dose rates, type of firearm and ammunition can all have significant effects on animal welfare and target outcomes of control programs. By standardising the way in which control methods are applied, many of the negative welfare impacts can be reduced or even prevented. In many cases the way in which control methods are applied varies considerably between locations, operators and species. The control COPs and SOPs have been specifically developed to address this issue.

A framework to assess the humaneness of control methods has also been developed which can help to guide the choice of appropriate control methods (Sharp & Saunders, 2008, 2011). This framework uses published scientific information and informed judgement to examine the negative impacts that a pest control or culling method has on an animal's welfare and, if it is a lethal method, the impacts of the method of killing. A score is generated so that the relative humaneness of different methods can be compared. To date, more than 100 assessments have been conducted in Australia and New Zealand on a range of introduced wild animals: birds, brushtail possums, cats, camels, wild deer, dogs, donkeys, ferrets, fish, foxes, goats, horses, pigs, rabbits, rodents (rats and mice), stoats and wallabies. The techniques covered differ among species and include ground shooting; aerial shooting; live trapping followed by release, transport or killing; pesticides; mustering (herding) followed by various procedures; and warren (burrow) destruction and the introduction of a disease agent for rabbits (Littin, Fisher, Beausoleil, & Sharp, 2014). Humaneness assessments for some of the feral cat control methods used in Australia (ground shooting, cage traps and padded jaw foot hold traps) can be found on the Pest Smart website (http://www.pestsmart.org.au/animal-welfare/humaneness-assessment/feral-cat/).

The aim of these tools is thus to promote the use of humane methods whilst improving the standard and consistency of control across Australia. They provide a starting point for implementation of humane control practices; however, there is still a way to go. For instance, standard operating procedures and humaneness assessments are required for baiting with sodium monofluorocacetate (1080) and delivery of para-aminopropiophenone (PAPP).

Another important step towards more humane control of feral cats is the development of baits and dispensing devices containing PAPP. RSPCA supports the development of PAPP as a humane and effective toxin for feral cats, but we still have some concerns about target specificity with some methods of toxin delivery (e.g. grooming traps), especially with regard to the potential impacts on owned cats. In addition, we would also like to encourage further specific research on the effectiveness and method of dosing of antidotes to PAPP for cats as well as other potential non-target species.

Key messages

When discussing the management of cats, it is important to stick to the facts – exaggeration of the impacts of cats is unnecessary and counterproductive and could further the polarisation of community attitudes. Demonising cats is certain to cause reactance among those who value them as companions and will hinder constructive and balanced discussion on the issue.

Regardless of how we view cats, we must remember they are sentient animals that are capable of experiencing pain and suffering. Thus, all cat management needs to be not only justified and effective but also humane. Minimising harm and suffering is an important priority, and is just as important as these other factors if management is going to be successful and acceptable to the public.

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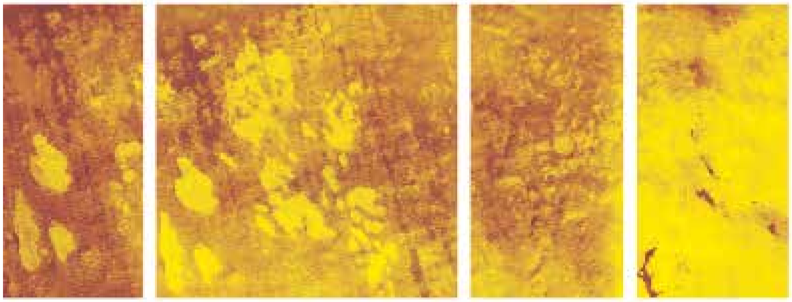

Management strategies and application of tools

Is the eradication of feral cats feasible? An introduction

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The effective management of any widespread pest nearly always requires an acceptance that it cannot be achieved everywhere. This is often difficult for the community to accept, particularly for significant high profile species. 'Eradication' is often used in the management of feral cats but is only feasible and desirable in some circumstances.

Bomford and O'Brien (1990) outline 6 criteria for the successful eradication of a pest species. These are particularly useful to consider for feral cats, because their eradication is often attempted in Australia, especially on islands and within predator proof fences, and the resources required to achieve success are often underestimated.

Criterion 1: Rate of removal exceeds rate of increase at all population densities

This is especially difficult to achieve for feral cats *cf*. many other species due to their high maximum rates of increase (Pople, these proceedings)

Criterion 2: Immigration prevented

Criterion 3: All reproductive animals must be at risk

Criterion 4: Animals can be detected at low densities

Criterion 5: Discounted benefit-cost analysis favours eradication over control

Criterion 6: Suitable socio-political environment

Consideration of these criteria for feral cats highlights that eradication is not possible for mainland Australia with current technology, and difficult to achieve even on islands and within predator-proof fences. Careful planning and considerable long-term investment are required to achieve success.

For these reasons it's also not appropriate to set targets for the numbers of cats killed over large areas, which is in direct conflict with long-standing pest management principles and more effective and focussed management of their impacts (Buckmaster and Hone, these proceedings).

An understanding of the drivers of feral cat populations, their environment, interactions with predators and prey is essential to effectively manage them. Papers of this section will outline approaches to improving our understanding of feral cat ecology and population dynamics (Chris Dickman, Chris Johnson), will discuss integrated management approaches (Guy Ballard) and will outline some success stories and challenges in eradication and management on islands (Pip Masters, David Algar, Keith Morris) and in reserves (Atticus Fleming).

Environmental manipulation to reduce the impacts of feral cats

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Abstract

Predation by feral cats (*Felis catus*) has strongly negative effects on many species of small vertebrates in the Australian region and beyond, and this has stimulated wide-ranging attempts at management. Broadly, these attempts can be placed into two categories. Firstly, cat-impacts can be managed by reducing the abundance or activity of the predator itself. This is the most common approach and can be achieved by lethal control (e.g. shooting, poisoning, trapping) and exclusion (e.g. eradication on islands or within fenced reserves); trap-neuter-release methods have also been advocated, but do not appear to mitigate cat-impacts on prey, at least in the short-term. These methods are variably effective but can be costly and labour-intensive to implement. Secondly, cat-impacts can be managed by improving the ability of prey to detect or avoid the predator. The latter approach—which can be considered broadly as environmental manipulation—has been seldom tried, but can be as simple as increasing the complexity of the habitat for prey so that they have access to refuges where cats cannot get them. In some systems this may entail reducing the frequency or intensity of prescribed burns and wildfires, or at least leaving places in the landscape that remain long-unburnt. In other systems, reducing grazing pressure may be sufficient to allow habitat structure to return. In arid areas where vegetation recovery is slow and depends on rainfall, artificial structures may be used to afford susceptible prey with protection from cats; an example of this is drawn from current work in the Simpson Desert, western Queensland. Other species can also be manipulated to reduce cat-impacts. For example, some evidence suggests that the presence of the dingo (*Canis dingo*) in open systems is sufficient to reduce cat activity or abundance, and the depletion of favoured prey species such as the European rabbit (*Oryctolagus cuniculus*) may also lead to reduced cat numbers and hence impacts on native prey. I suggest that environmental manipulation has been under-utilised as a management approach, but has a lot of merit and warrants more consideration for reducing cat-impacts on prey.

Introduction

Recent syntheses confirm that introduced predators have more strongly negative effects on native wildlife in the Australian region than elsewhere (e.g. Salo *et al*. 2007), and that the feral cat (*Felis catus*) has particularly damaging effects on populations of small and medium-sized native mammals (Woinarski *et al*. 2014).

Recognition of these deleterious effects of predators has stimulated much research about how best to manage and reduce predator-impacts. On the one hand, predators are often targeted directly using programs of lethal control to reduce their numbers and hence impacts on vulnerable prey species. Shooting and trapping are often used in small and specific locations, but are costly and labour-intensive to undertake. Poison baiting is used successfully in many conservation programs to reduce the impacts of the red fox (*Vulpes vulpes*); baiting also shows some promise for reducing cat-impacts at the landscape scale, but more development is needed to ensure high levels of knock-down and that non-target species are not adversely affected by baits. Fenced conservation reserves that have removed feral cats and other introduced species can provide excellent protection for vulnerable prey species, but require much capital investment and ongoing maintenance to ensure fence integrity. Other methods that have been proposed to reduce cat-impacts, such as trapping, neutering and releasing animals back into the wild population, are costly, labour-intensive and, in many cases, ineffective. These observations suggest that, at present, few tools are available that allow us to target feral cats directly to reduce their impacts on prey.

On the other hand, several approaches have been suggested that focus on improving the chances of prey detecting or avoiding the predator. Some of these approaches, such as training individuals of naïve prey species to recognise the actual predator or cues to a predator's presence, can be effective but are often short-term and may not have long-lasting benefits. Other approaches use environmental manipulation to reduce the impacts of a predator on prey species, and are the focus of this paper. They can be categorised as prey-habitat manipulations and predator-environment manipulations.

Prey-habitat manipulations

Feral cats usually eat animals smaller than themselves, so it follows that their impact on prey populations should be reduced if prey individuals have access to refuge sites such as narrow cracks in the soil, burrows, or small holes and crevices in trees and rocks where cats cannot get them. Early observations by Burbidge and McKenzie (1989) suggested that small mammals fared better in the presence of predators if they had access to rock piles than if they did not, and recent research confirms that small vertebrates are at particular risk of cat-predation if they occur in open compared with structurally complex habitats. Simplification of habitat structure by grazing, prescribed burns, wildfires, road-building or other disturbances can also have an interactive effect with predator activity, with feral cats in particular moving to areas that have been recently burnt and where they gain increased access to small prey (McGregor *et al*. 2014). These observations indicate that simple management options to reduce cat-impacts on prey could include reducing the frequency or intensity of prescribed burns and wildfires, retaining places in the landscape that remain long-unburnt, or reducing grazing pressure to levels that allow shrubs, small woody debris, logs and other habitat structures to return. In one recent study, small mammals were shown to respond positively to the absence of sheep; grass grew higher when not grazed, and this increase in cover led in turn to reduced risk of predation for small mammals (Kuiper and Parker 2013).

In arid regions where complex habitat structure has been lost due to overgrazing, fire or other causes, it may be possible to reduce cat-impacts by providing artificial refuges or habitat structures, at least until sufficient rain falls to stimulate recovery of vegetation. For example, Arthur *et al*. (2005) showed that refuges constructed using logs covered in wire netting provided house mice (*Mus musculus*) with protection from both foxes and cats in experimental enclosures, allowing marked increases in mouse survival and population numbers. Similar wire netting structures are currently being used in the Simpson Desert, western Queensland, to investigate whether these allow increases in populations of native rodents and small dasyurid marsupials in areas that have been recently burnt (Fig. 1). Although these structures have been in place for only about a year, there is evidence that they are being recognised by small mammals and lizards as sites of reduced predation risk: behavioural observations and evidence from giving-up density experiments indicate that animals spend more time in or near the wire netting than away from it. It is too early to know whether these behavioural responses will translate to responses at the level of the prey populations, although behavioural shifts are likely precursors of demographic effects. Such effects may not occur until rainfall stimulates a pulse of productivity and provides the resources needed for population increases.

Predator-environment manipulations

Manipulations here involve either reducing populations of non-native fauna that may comprise a large or important part of the prey base of the feral cat, or increasing populations of other species that have suppressive effects on feral cats. Such manipulations can have marked effects on cats but, because they are likely to have additional or interactive effects on other species within assemblages of native vertebrates, they need to be applied with caution. Two examples of predator-environment manipulations are most well-known and are described briefly here.

Figure 1. Wire netting tunnels (50 m × 1 m × 40 cm high), covered with bands of shade cloth, set in a recently burnt site in the Simpson Desert, western Queensland, to investigate whether artificial refuges from feral cats facilitate recovery of populations of small native vertebrates. Photo: Bobby Tamayo.

Firstly, the introduced European rabbit (*Oryctolagus cuniculus*) forms a staple component of the diet of feral cats in many parts of Australia (Doherty *et al*. 2015), and reductions in its numbers could be expected to reduce the numbers of feral cats capable of being sustained in local or regional areas. Following the passage of rabbit haemorrhagic disease (RHD) in the mid-1990s, this expectation was met: indices of cat abundance fell in many areas soon after crashes in rabbit numbers (Newsome *et al*. 1997). Similar fluctuations in cat abundance have been recorded following rain-driven pulses of productivity and irruptions of native rodents in arid regions where rabbits are scarce or do not occur (Dickman *et al*. 2014a). If staple prey species such as rabbits that are pests in their own right can be reduced by poison baiting or irruptions of epidemic disease such as myxomatosis or RHD, cat abundance also should decline. This approach to reducing cat abundance is not without risks; although cats will attempt to exploit rabbits even when rabbit numbers fall to low levels (Molsher *et al*. 1999), there is likely to be a period when returns are too low and cats switch to hunting other prey. If native species that are susceptible to cat predation can be managed through such 'crunch' periods, reducing populations of staple prey for feral cats may be a viable means of reducing their impact on target species of native vertebrates.

Secondly, suppression of cat numbers or cat activity has been reported in some situations where cats co-occur with a larger carnivore, the dingo (*Canis dingo*). There is little doubt that dingoes will kill feral cats if they encounter them (Moseby *et al*. 2012), and also some evidence that cats are less abundant or will alter their time of activity in the presence of dingoes (see Dickman *et al*. 2014b for a summary). The suppressive effect of the dingo on the feral cat is likely to vary between times and places, but the interaction offers a potential means of restricting the impacts of feral cats. The dingo, of course, is persecuted owing to its attacks on livestock, and its numbers in many areas are probably too low to be ecologically effective against feral cats. However, if improved protection of livestock can be achieved by means that retain dingoes in the landscape, such as by the deployment of guardian animals (e.g. van Bommel and Johnson 2014), it should be possible to realise the biodiversity-protective benefits of dingoes while maintaining—and even improving—the returns to the production industry.

I suggest that both prey-habitat and predator-environment manipulations, as discussed here, have been under-utilised as approaches to managing the impacts of feral cats. More research is needed to establish the efficacy of these approaches, but environmental manipulation broadly appears to have a lot of merit and warrants more consideration for reducing cat-impacts on prey.

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Ecological controls on impacts of cats on small mammals in northern Australia

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Many species of small mammals are declining in the tropical savannas of northern Australia. The ecological pattern of the declines, and traits of the species affected, suggest that predation by feral cats may be causing them. This is puzzling for two reasons: feral cats have been in northern Australia for more than 100 years, and their population densities in savanna environments are typically very low. This presentation summarizes work by many collaborators, particularly scientists from the Australian Wildlife Conservancy, which aimed to understand the nature of the impact of cats on prey in this environment and to develop management responses to mitigate that impact. We show that small numbers of cats can have large impacts by focussing their predation on localised small-mammal populations. The impacts of cats may be amplified by fire and grazing, which create open conditions that are favoured by cats for hunting and where their hunting success is elevated. Individual cats make long-distance movements to exploit areas burnt at high intensity, and consequently the mortality rates of small mammals increased dramatically in the aftermath of hot fires. On the other hand, dingoes suppress activity of cats. Inappropriate fire and grazing regimes together with the removal of dingoes create ideal conditions for cats and may explain their large effects on preferred prey. Conversely, fire, grazing and dingoes can be managed to reduce the impacts of cats and allow small mammals to coexist with them.

Integrated predator management

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We work predominantly in the mesic ecosystems of north eastern New South Wales, operating a large-scale manipulative experiment that aims to inform and improve our understanding of the ecology and management of terrestrial predators (i.e. dingoes, foxes, cats, quolls and goannas). Day-to-day, we monitor individuals, populations and communities, seeking to determine their responses to broad-scale control programs implemented by public and private land managers.

Associated discussions about predator management, especially where species are considered 'invasive', commonly involve calls for 'integrated management'. However, there are at least three levels at which this can and should be considered. We briefly raise and discuss opportunities and outcomes related to 1) integrating the management of multiple predators, 2) integrating multiple tools and 3) integrating learning from multiple sites and systems, with a view to optimising future management and research of feral cats in Australia.

Eradication of feral cats from Western Australian islands: success stories

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There is extensive evidence that the introduction of cats (*Felis catus*) to both offshore and oceanic islands around the world can have deleterious impacts on endemic land vertebrates and breeding bird populations (Bonnaud *et al*. 2010; Ratcliffe *et al*. 2009). Cats have been known to drive numerous extinctions of endemic species on islands and have contributed to at least 14% of all 238 vertebrate extinctions recorded globally by the IUCN (Nogales *et al*. 2013). In addition, predation by feral cats currently threatens 8% of the 464 species listed as critically endangered (Medina *et al*. 2011; Nogales *et al*. 2013). Island faunas that have evolved for long periods in the absence of predators are particularly susceptible to cat predation (Dickman 1992).

In the Australian region, cats have caused or contributed to population declines and extinctions on many offshore islands (Burbidge *et al*. 1997; Burbidge 1999; Dickman 1992; 1996). There are 788 islands, 100 ha or larger in area, off the Australian coastline with feral cats being recorded on 61 of these islands (Abbott and Burbidge 1995). Burbidge *et al*. (1997) and Burbidge (1999) further indicated that introductions of cats to islands should be prevented and the development and application of techniques to control or eradicate cats if present or are introduced onto islands of significance to mammal conservation is essential.

Today, the impact of cats broadly is acknowledged and control of feral cats specifically is recognised as one of the most important fauna conservation issues in Australia. As a consequence of this impact, a national 'Threat Abatement Plan for Predation by Feral Cats' has been developed (DEWHA 2008; EA 1999). Under the Threat Abatement Plan objectives and actions, the first two key objectives, were listed as:-

- *Eradicate feral cats from islands where they are a threat to endangered or vulnerable native animals;*
- *Prevent feral cats occupying new islands in Australia where they may threaten species or ecological communities with extinction.*

Cat eradication programs on islands around the world have usually been conducted using a combination of techniques that include baiting, trapping and hunting (Veitch 1985; Campbell *et al*. 2011). Globally, cat eradications have been attempted on a number of islands with 82 successful campaigns that range in size from 5–29,000 ha

(Campbell *et al*. 2011). There have also been eradication attempts on a further 15 islands that have failed (Ibid.). All successful campaigns on islands > 2,500 ha utilised primary poisoning with toxic baits, with the exception of Santa Catalina (3,020 ha). Interestingly, seven failed campaigns on the five largest islands (all > 400 ha) did not use toxicants (Campbell *et al*. 2011).

Locally, baiting has been the primary technique used to eradicate cats on islands off the Western Australian coastline (Algar *et al*. 2010). Feral cats have been successfully eradicated from four Western Australian offshore islands: Serrurier Island; Hermite Island in the Montebellos; Faure and Rottnest Islands (see Table 1) to enable reconstruction of the original fauna or protection of extant species. Eradication programs are also well advanced on two other, much larger islands, namely Christmas and Dirk Hartog Islands.

Table 1. Cat eradication on Western Australian islands

Island	Size (km^2)	Control technique	Reference
Serrurier	3	Ground baiting	Moro (1997)
Hermite	14	Aerial baiting + trapping	Algar *et al*. (2002)
Faure	58	Aerial + ground baiting	Algar *et al*. (2010)
Rottnest	17	Trapping	Algar *et al*. (2011a)
Christmas	135	Suspension baiting + trapping + urban cat management.	Algar and Johnston (2010); Algar *et al*. (2014)
Dirk Hartog	620	Aerial baiting + trapping	Algar *et al*. (2011b); Algar *et al*. (2011c);

The impact of cats on the biodiversity of Christmas Island has been of significant concern to island land management agencies and the local residents. Four of the five mammal species that were present on the island at settlement in 1888 have since become extinct. While several factors, including disease, habitat destruction (land clearing and natural catastrophes such as cyclones) and the proliferation of invasive invertebrates such as the yellow crazy ant (*Anoplolepsis gracilipes*), are likely to have contributed to the demise of these native animals, the introduction of cats is also a crucial factor. In addition, a number of extant Christmas Island bird and reptile species are listed under the Environment Protection and Biodiversity Conservation Act 1999 as being species likely to be significantly adversely affected by cats and would likely benefit from their eradication.

In 2010, a management plan (Algar and Johnston 2010) was commissioned that sought to mitigate the environmental and social impacts of cats across the island. A strategy was recommended that provided a staged approach to their management and control leading to eradication. Feral cat eradication programs that have failed in the past were usually attributed to lack of institutional and financial support (Campbell *et al*. 2011). In 2014, land management agencies on Christmas Island secured the five year funding required to see the project to its successful conclusion and ensure conservation of biodiversity. In addition, removal of much of the urban stray/feral cat population has been noticed by the community who have commented on the success of the campaign to date. The community at large have an optimistic and constructive view of the program and the enthusiasm with which it is embraced indicates continued support.

Dirk Hartog Island is the largest island off the Western Australian coast (Abbott and Burbidge 1995) where 10 of the 13 species of native terrestrial mammals once present are now locally extinct (Baynes 1990; McKenzie *et al.* 2000) probably due to predation by cats (Burbidge 2001; Burbidge and Manly 2002). The island also contains a number of threatened bird species and a threatened reptile species. Previously a pastoral lease, the island was established as a National Park in 2009, which now provides the opportunity to reconstruct the native mammal fauna (Algar *et al*. 2011b,c). Dirk Hartog Island could potentially support one of the most diverse mammal assemblages in Australia and contribute significantly to the long-term conservation of several threatened species. Successful eradication of feral cats would be a necessary precursor to any reintroductions. Globally, the Dirk Hartog project will become the largest feral cat eradication campaign attempted on an island.

Elsewhere in Australia, successful eradication of cats has been reported on Gabo Island, Victoria (Twyford *et al*. 2000); the subantartic Macquarie Island (Robinson and Copson 2014) and recently Tasman Island, Tasmania (Robinson *et al*. in press).

Commonly, there are additional challenges associated with undertaking management of cats on islands with respect to cultural and biological factors that distinguish these insular programs from mainland sites. However, advances in cat control technologies and management strategies recently developed (e.g. Algar *et al*. and others described in this workshop proceedings) are likely to prove extremely useful in assisting eradication of feral cats from many islands around Australia and elsewhere in the world.

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Cat management on large islands: Kangaroo Island

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Concerns that need to be considered when managing feral animals on large islands include complex human dimensions, the size and the area that the target species occupies, and abundant native species resulting in a high level of off-target species. This paper will outline the issues and solutions that have been encountered while carrying out feral animal control programs on Kangaroo Island.

Islands are protected from naturally invading terrestrial species because the borders are surrounded by water, and natural immigration diminished. Island species, however, are more vulnerable to extinctions than mainland species because they are geographically limited and their small population size makes them more susceptible to impacts of introduced species, particularly predators and competitors, disease, and natural disasters such as fire and floods.

On Kangaroo Island (440,000 ha), few native vertebrate species have been lost, largely due to the absence of rabbits and foxes. The island is located approximately 15 km from the South Australian coastline and is Australia's third largest island. It is nationally important for biodiversity conservation, primary production and tourism, with nearly 50% of native vegetation remaining.

Effective management of feral animals on large islands, such as Kangaroo Island, can have substantial biodiversity benefits but success depends on:

1. biosecurity and the control of importation of pest species
2. community support for control of domestic and feral populations
3. effective and humane control options
4. ability to monitor the species at low densities and assess whether eradication is complete, or whether the target density has been reached
5. unwanted responses of other species which may expand in abundance and distribution once effective control or eradication is in place
6. availability of resources and political support to carry out control in the long term with an understanding that as pest control reduces pest abundance, cost per removal increases exponentially.

(See Bomford and O'Brien 1995; and Hone et al. 2015).

Cats are known to be a difficult species to control because of their high reproductive output and replacement capacity, their solitary and elusive nature, and the limited choices available for effective control. To date eradication has only been effective on smaller islands but as control tools and techniques improve, the probability of controlling and eradicating cats over larger areas will increase.

1. Biosecurity and the control of immigration of pest species

Cat control on islands has the advantage of limited migration from off-island areas. Larger islands closer to the mainland, however, generally have a high level of human traffic which makes surveillance for accidental or deliberate importation of cats difficult. In addition, many larger islands also have domestic cats which can breed and act as a source of feral cats.

On Kangaroo Island a by-law was introduced in 2005 to minimise the chance of domestic cats adding to the feral cat population. Cat owners are required to register, microchip and desex their cats (unless registered as a breeder), and to confine their pets to the owners property. The island community decided that cats should be owned or unowned. This has made management easier because there is no half way house for stray cats. A cat cannot roam free with partial support from humans. The responsibility lies with the residents to take full responsibility, otherwise the cat is deemed feral and can be destroyed. Cats visiting the island need to be reported and registered as a visitor with the local council (Kangaroo Island Council 2010).

Although this by-law has been in place for 10 years, there are still problems with policing cat ownership requirements, particularly confinement. Without the financial support for a stringent enforcement program, there will always be issues with roaming domestic cats. The potential to remove all pet cats needs to be considered if eradication is to be achieved.

2. Community support for control of domestic and feral populations

Large islands usually have a resident human population which can be socially unique. Residents have shared problems of isolation and access to the mainland, higher transport costs and hence flow on effects to industry, job security and services. The communities can have a strong sense of community, but they can also be quite fractured on specific issues and suspicious of management solutions dictated from beyond island borders. On the small island of Lord Howe, for example, a planned rat eradication had financial support and was technically feasible, but to date has not had the support of the community so has not been able to progress.

On Kangaroo Island the community is passionate about cat eradication because of the impacts that predation and cat-borne diseases have on the sheep industry and wildlife (and therefore nature-based tourism), the two major forms of income. This provides opportunities not necessarily available on the mainland due to the common goal for cat eradication. There is also a general acceptance of humane destruction for management purposes.

3. Effectiveness of control devices which are species specific and humane

Unfortunately, the current control options make it difficult to eliminate cats faster than they can breed, or to target all individuals over a relatively large, and sometimes inaccessible landscape (Bomford and O'Brien 1995). Additional difficulties include an abundance of wildlife which complicates current control methods through high off-target impacts. For example, cage trap success on KI is around 15% but only around 5% are cats. The most commonly caught animal is the brush-tailed possum, but a wide variety of other species such as the southern brown bandicoot have also been caught (Fig.1). Similarly, earlier trials of non-toxic sausage baits resulted in a large uptake by non-target species including kangaroos, goannas, and corvids (Denny 2010).

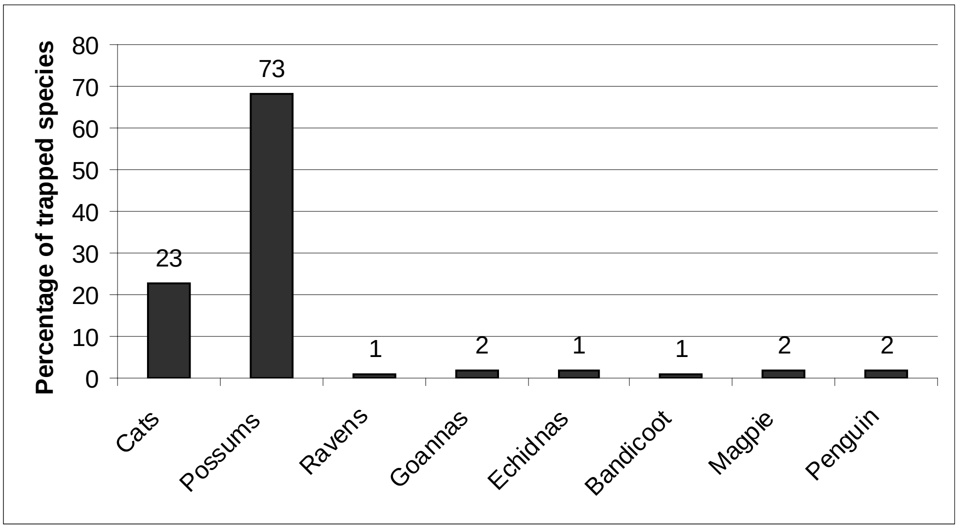

Figure 1: The percentage of each species caught in cage traps

Most successful cat eradication programs require more than one control method. For effective control the program needs a strategic, adaptive approach, which integrates baiting tools and control techniques so that it is difficult for cats to develop a response to control efforts. Hunting, trapping and shooting are time and labour intensive and not economically viable over large areas but may play a part in some situations. The hope lies with options such as new baits and toxin delivery devices (Read et al. 2014; Algar and Burrows 2004; Johnston et al. 2007).

It is important to understand the local situation. On Kangaroo Island trials have been carried out to determine the most effective baits and attractants for this area

(Bengsen et al. 2011a). Bengsen et al. (2011a) found that olfactory lures (Rudducks Catnip spray, Cats me dead and gland lure, and Feralmone synthetic fermented egg) were ineffective at attracting cats. Sites with auditory lures were more effective than those without. Sites baited with chicken and sardines were of equal effectiveness. No lure type was more attractive to off-target species than any other.

Radio-tracking has allowed managers to follow cat movements and to develop plans for the most effective placement of control devices. To target all individuals, devices or baits should be spaced no farther than 800 m from their nearest neighbour to ensure that all cats in an area are susceptible to control (Bengsen et al. 2011b).

New monitoring tools such as remote cameras have also allowed more effective population monitoring methods to be developed so that better estimates of the cat population size can be made and hence the effectiveness of management assessed (Bengsen et al. 2011c).

Cat trapping is a common activity for islanders based on the belief that any dead cat will reduce impacts. However, recent research in southern Tasmania found that low-level culling of feral cats over a 13-month period resulted in an increase in the relative abundance and activity of feral cats. Increases in numbers of cats probably occurred due to influxes of new individuals after dominant resident cats were removed (Lazenby et al. 2014). Trials on Kangaroo Island also found trapping in localised areas resulted in high levels of immigration into trapped areas, making it difficult to control cat populations using short term trapping programs (Bengsen et al. 2011c, Southgate and Masters 2011, Rowley and Masters 2013). This shows that any program needs to be strategic, systematic and ongoing if it is to be effective.

4. Ability to monitor the species at low densities and assess that eradication is complete or that the target density has been reached

Without reliable indices of activity, density or relative abundance of cats in various habitats, it is difficult to assess program success and the amount of time, labour and money required to reach a particular goal. The development of methods to assess population size and relative density and activity of cats has made monitoring more effective (Bengsen et al. 2011c) and has allowed cat management programs to more accurately estimate how well a program is going and the feasibility of reaching the target density or eradication. Detecting cats at very low densities, however, could be more difficult. An advantage of an occupied island is that the community can be very effective at identifying locations where cats still live and can be encouraged to report sightings, but more systematic monitoring will also be needed.

5. Unwanted responses of other species which may expand in abundance and distribution once effective control or eradication is in place

Eradication programs and control programs in the past have shown that there can be a release of other species once cats have been eliminated. For example, Macquarie Island had an increase in rabbit populations once the cats were gone. To ensure such situations do not eventuate it is important to monitor and potentially control the species which are likely to be impacted by cats. Some of these species may be pests while others may be threatened species which have been controlled by cat predation. Monitoring the impact of diseases spread by cats such as Toxoplasmosis and Sarcosporidiosis which impact on the sheep industry would also be important on Kangaroo Island. This would allow for an assessment of the costs to industry to be balanced against the cost of control activities.

6. Availability of resources and political support to carry out control in the long term with an understanding that, as pest control reduces pest abundance, cost per removal increases exponentially.

Maintaining a population at low levels requires ongoing management whereas eradication has an end point. Either way, substantial resources will be required over a long period of time for effective cat management to be successful on a large island. Planning should be carried out in stages to ensure that money is well spent and something is achieved at each stage. Ultimately, however, the political will needs to be there for the long term support which will be essential for such a program.

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Within and beyond the fence: the essential role of cat-free mainland (fenced) islands

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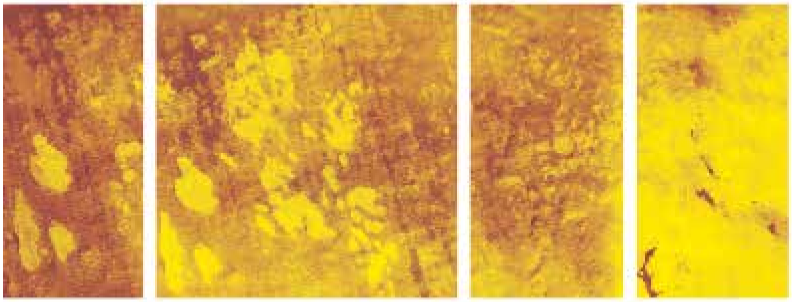
The establishment and management of a network of fenced, feral predator-free areas on mainland Australia is an essential strategy for the effective conservation of a range of native species, especially threatened mammals. In many circumstances, and for many priority species, a strategy of conservation fencing will currently deliver a higher ecological return than other available strategies.

Where possible, fenced mainland islands should be embedded in landscapes which are managed intensively and experimentally for the control of feral predators, with the long-term objective of establishing and restoring native wildlife populations beyond the fence. Recent evidence obtained by AWC shows that, in northern Australia, feral herbivore control and fire management may play an important role in reducing the impact of feral cats and increasing ecological returns beyond the fence. However, it is still largely unknown whether extensive management can deliver a sustained reduction in the impact of feral cats and a sustained increase in the populations of native species across Australian ecosystems – and, if so, the timeframe within which that can be achieved. Accordingly, while continued research into the development of effective landscape control of feral cats is important, an immediate priority should be to increase the level of investment in conservation fencing in order to deliver effective conservation of those species most threatened by feral cats.



Community engagement & opportunities for collaboration

The role of land managers in feral cat management

David Peacock and Peter Bird

Biosecurity SA

A land manager's role in feral cat management will depend on the incentive, scale and resources of the issue being managed. Trying to conserve the eastern barred bandicoot (*Perameles gunnii*) in a few hectares of western Victoria requires involvement of a few small landholders, whilst reintroducing golden bandicoots (*Isoodon auratus*) to the Gibson Desert (Project Desert Dreaming) or trying to reverse the decline in mammals in Kakadu National Park requires State and Federal agency efforts over vast land areas. All efforts are contingent on incentive and legal, social and technological capacity to manage cats. Both a Kangaroo Island grazier suffering economic loss from sheep carcass downgrades due to cat-vectored sarcosporidiosis and a Queensland Parks and Wildlife Service ranger trying to protect bilbies (*Macrotis lagotis*) from cats on Astrebla Downs National Park may have sufficient incentive to control cats, but ultimately each has limited capacity in time, labour and especially the tools to successfully mitigate the impact. The capacity of land managers to undertake meaningful feral cat control on their land is currently compromised by a lack of effective control measures. Only a concerted national effort to develop broadscale methods such as biocontrol will cat control be remotely feasible on any scale. Until then the efforts of individual land managers will be limited.

Community engagement and opportunities for collaboration: Role of NGOs

James Radford

Bush Heritage Australia

Abstract

There are now approximately 140 private conservation reserves in Australia, comprising almost 5 million ha, owned and managed by non-government conservation organisations and land trusts. In addition, non-government organisations work with private landholders and Aboriginal people who manage their land for conservation across vast areas of the continent. Control of feral cats is a key issue across much of this land, which presents challenges for management (e.g. coordination and prioritisation of effort) but also great opportunities for innovation and collaboration. Non-government organisations have often led the development of new approaches and technology to tackle cats (e.g. fenced exclosures, dogging, drones). Advantages of working with non-government organisations include access to large tracts of land managed for conservation, flexibility of management, willingness and ability to trial new approaches and tools, leveraging funding from the philanthropic sector, and links to the community to increase awareness and garner support for feral cat control.

Introduction

Feral cats have been implicated in the extinction of 22 Australian mammal species and are considered a risk factor for 75 other threatened or near threatened Australian land mammals (Woinarksi et al. 2015). A recent continental scale analysis revealed that feral cats are opportunistic and generalist predators, with evidence that they predate upon 400 vertebrate species, including 123 bird species, 157 reptile species, 90 mammal species and 21 frog species (Doherty et al. 2015). Conservation measures aimed at increasing existing populations of native fauna, or re-introducing species back into their former range, must incorporate cat control as a primary threat mitigation strategy.

Biodiversity conservation is no longer solely the domain of government agencies and public policy. Although public parks and reserves remain the backbone of the National Reserve System, there are now approximately 140 private reserves in Australia, owned and managed for conservation by non-government organisations and land trusts that together comprise almost 5 million ha (Fitzsimons 2015). A further 4.5 million ha of privately owned land is covered by conservation covenants, supported by land trusts such as Trust for Nature (Victoria) and Queensland Trust for

Nature (Fitzsimons 2015). Non-government organisations also often work in partnership with Aboriginal people to manage land for conservation (e.g. Moorcroft et al. 2012) within the 60 declared Indigenous Protected Areas that cover more than 48 million ha (http://www.environment.gov.au/indigenous/ipa). Taken together, private conservation reserves, covenanted private land and Indigenous Protected Areas now account for nearly 43% of the National Reserve System.

These two factors – the growing role of non-government organisations in the conservation sector and the imperative to control feral cats for effective biodiversity conservation – mean that non-government organisations have had, and will increasingly have, a vital role in developing strategies and approaches for feral cat control. Control of feral cats is a key issue across much of non-government reserve estate, which presents challenges for management but also great opportunities for innovation and collaboration. Sustainable, broadscale, effective feral cat control will require extensive collaboration between researchers (to develop new methods and tools), land managers (to implement approaches across different tenures), governments (to lead and resource) and community (to raise awareness and support actions). In this paper, I outline five key reasons why non-government organisations are well-positioned to lead collaborative efforts aimed at controlling feral cats in Australia: (i) access to land managed for conservation; (ii) adaptive management; (iii) innovation; (iv) leveraging; and (v) community engagement and awareness.

Access

There are three aspects to access that facilitate collaboration: (a) the amount and representativeness of land contained in private reserves, (b) the level of resourcing for conservation management on private reserves, and (c) the relatively low administration and transaction costs.

Private conservation reserves managed by non-government organsations such as Bush Heritage Australia, Australian Wildlife Conservancy, Nature Foundation SA and South Endeavour Trust, cover nearly 5 million ha and constitute a significant portion of the National Reserve System. They are located in all major biogeographic zones and contain a wide range of ecosystems, vegetation types, and floristic and faunal communities. Moreover, private reserves often complement the public reserve estate: many include vegetation communities that are poorly-represented in the public system, include land that is unavailable or unsuitable for the public system, or target areas of high diversity and endemism (Radford 2014). Thus, it is not merely the amount of land under private management but also the representativeness of private reserves that presents a significant opportunity to undertake cat control in some of the most biologically significant parts of Australia.

Private conservation reserves do not have many of the constraints imposed on public reserves, such as provision for public access and visitor facilities, and visitor management. This means a larger percentage of the available budget can be devoted directly to on-ground conservation management, including feral predator control. There are notable exceptions, such as the Western Shield (Western Australia) and Southern Ark (Victoria) projects – both of which have had success in controlling foxes – but in general, resourcing for intensive feral cat control may be more obtainable in the non-government sector. However, capacity and expertise often lies within government agencies and universities, highlighting the importance of collaboration that draws upon the strengths of the respective organisations.

For researchers and community groups interested in trialling or implementing feral cat control, non-government organisations are often smaller, less bureaucratic and simpler to work with than government agencies, although they are similarly bound by legislative and regulatory obligations. There is often a shorter 'organisational pathway' from research manager to land manager (they are often the same person), leading to lower administration and transaction costs, more effective communication and implementation of control strategies. Non-government organisations can supply suitable land, intensive management and resources for feral cat control but may need to call upon expert capacity from the public, private and community sectors to implement effective control and monitoring.

Adaptive management

Most conservation management agencies aspire to adaptive management – learning by doing – a cyclical process in which thorough planning and implementation of management actions are followed by monitoring and evaluation of the effectiveness of management, which is then captured in modified, or adapted, plans before the cycle starts again. This is an appropriate framework for implementing feral cat control in the absence of a proven approach that can achieve long-term, landscape-scale suppression or eradication of feral cats on mainland Australia. While we are still in the research and development phase, we cannot wait for a proven approach before implementing action.

Non-government organisations have an important role in implementing adaptive management. This is because they are already actively implementing a range of approaches – such as exclusion fencing, intensive ground-based and aerial baiting, maintenance of dingoes in the landscape, habitat manipulation – across the sector and at different sites within organisations, some of which public reserve managers are unable or unwilling to pursue due to costs, public pressure and opinion, or capacity. Given this, it is imperative that we evaluate, adapt and improve as different approaches and mechanisms for feral cat control are trialled in different locations around the country.

A critical component of adaptive management is the evaluation of management interventions across sites and systems. Non-government organisations are well-placed to do this due to their moral obligation to report on their conservation return on investment to donors and supporters. Further, they have the flexibility to adapt and change management relatively quickly depending on evaluation outcomes. As new methods of direct control (e.g. baits, traps, biocontrol) are developed, non-government land managers will be valued partners in implementation trials (e.g. Doherty and Algar 2015). Similarly, habitat manipulation to minimise the impacts of feral predators through management of fire, total grazing pressure and trophic regulation will best be implemented in an experimental adaptive management framework. This will require treatment and control areas subject to different fire, grazing and baiting regimes, and will likely require the coordination and integration of land managed by government, traditional owners, non-government organisations and private landholders.

Innovation

The development of new approaches and technology to tackle feral cats has often emerged from the non-government sector. For example, the concept of large-scale feral-proof fencing to create feral predator-free exclosures originated with John Wamsley's Earth Sanctuaries and non-government organisations remain prominent in this field with the Australian Wildlife Conservancy owning and operating more feral-proof fences than any other organisation in the country. Governments subsequently followed suit (e.g. Mulligan's Flat (ACT), Lorna Glen (Western Australia), Currawinya National Park (Queensland)), as have some corporates (e.g. Arid Recovery in South Australia was established by Western Mining). Similarly, the use of sniffer dogs to detect and eradicate cats from contained areas is being championed by non-government organisations, as is the use of drone technology to detect and monitor feral animals, including cats (e.g. ConservationDrones.org). The development of walk-past "grooming traps" as a novel way to transfer toxins to cats is the most recent innovative advancement arising from the non-government sector (Read et al. 2014).

Looking forward, reserves managed by non-government organisations will be crucial testing grounds and incubators for innovative techniques, tools and approaches. The close working relationship of ecologists (either in-house or through external collaboration) with land managers that characterise non-government organisations is a recipe for innovation, combining on-ground experience and pragmatism with scientific knowledge and rigour. Increasingly, other contributors will emerge from academia, private enterprise, community groups and government. The role of non-government organisations in leading a consortium to develop and trial new ideas will increase the likelihood of finding sustainable solutions to feral cat control.

Leveraging

Non-government organisations have privileged access to certain resources. Mobilising and leveraging these resources will create new opportunities and momentum in addressing the cat problem. Many non-government groups are supported by skilled volunteers, capable of assisting with and in many cases, leading monitoring, land management, education and awareness-raising activities. For example, pre- and post-baiting sand-pad monitoring at Bush Heritage Australia's Charles Darwin Reserve is conducted by a dedicated skilled volunteer. Harnessing this workforce will substantially increase capacity to expand the spatial, temporal and social reach of feral cat management. Volunteers are also a source of new ideas and approaches, given they come from diverse backgrounds and often bring a different perspective to conservation problems.

Non-government organisations have access to philanthropic support, which often brings funding from unexpected sources. This funding can then be used to leverage funding for both research and management from more traditional sources (e.g. government grants, Australian Research Council), thereby increasing the overall pool of funding available to tackle the issue.

Leveraging can also be achieved on the ground through aggregating activities to increase effectiveness and impact. Non-government organisations are often best positioned to broker collaboration between neighbours, including across state or tenure boundaries, such that management actions aimed at mitigating the impacts of feral cats are implemented at the landscape-scale. There are good examples of this in relation to fire management (e.g. EcoFire: Legge et al. 2011). In the Kimberley region of Western Australia, the Kimberley Land Council is working in partnership with Balanggarra, Uunguu, Wilinggin and Dambimangari Traditional Owners in partnership to achieve strategic fire management outcomes across a network of Indigenous Protected Areas and other tenures to achieve landscape scale conservation outcomes. Good examples also exist for feral herbivore and fox control (Martu Living Deserts project: http://www.natureaustralia.org.au/our-impact/local-communities/martu-living-deserts; Operation Bounceback, South Australia), and it will be necessary for effective feral cat control. Again, the leadership and reputation of non-government organisations will be central to the success of such collaborative programs.

Community engagement

Non-government organisations are founded on communities – be that a supporter base, a volunteer network, or member-based participation – so community engagement is natural territory for non-government organisations. They have communication networks (e.g. newsletters, web-sites, blogs, community functions, word-of-mouth among volunteers) that already serve their respective communities and are geared towards expansion of that community. In many ways, the community grants non-government organisations their 'social licence' to operate. Non-government organisations are well placed to leverage that social licence to introduce or promote new concepts, such as the threat posed by feral cats and the need for urgent resourcing and action. They build the case for support and disperse fears through information, evidence and education. In this way, many non-government organisations already have the ear of ordinary Australians, who are then willing to support practical initiatives or causes.

An essential element of community engagement is trust, which is built through honesty, credibility and following through on proposed actions. It is also built through listening to the community and two-way learning. That is, acknowledging that the community has wisdom and experience that can contribute to finding solutions. This will be especially important in feral cat management, where the messaging explaining the rationale and methods involved in cat control will be crucial to winning public acceptance and ultimately, support.

Conclusion

Non-government organisations are responsible for large tracts of land managed for conservation, and have developed and implemented many approaches to control feral cats. They are well-positioned to lead and facilitate collaborative efforts to manage feral cats in the future. Advantages of working with non-government organisations include access to large tracts of land managed for conservation, relatively low transaction costs, flexibility of management, willingness and ability to trial new approaches and tools, leveraging funding from the philanthropic sector, and links to the community to increase awareness and garner support for feral cat control.

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Applying Behavioural Science for More Effective Cat Management Interventions

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Abstract

A key challenge for feral cat management is to convince land managers and the general public to participate in control actions. This involves changing current behaviours and encouraging the adoption of new behaviours to reduce or eliminate the impacts of these animals. Providing information through educational interventions is an important strategy for increasing awareness and shifting attitudes. But many studies in the psychological literature indicate that providing information by itself is insufficient to change behaviour.

A successful behaviour change program requires that practitioners first identify the specific behaviour that should be targeted. They then need to gain an understanding of the perceived benefits (drivers) of the particular behaviour, as well as the barriers that prevent the behaviour from occurring. Using this information about drivers and barriers, in conjunction with behavioural science theory, practitioners can then select the most appropriate behavioural change tool for their circumstance to develop a more behavioural effective intervention.

Introduction

The primary aim of feral cat management interventions is to convince the target audience (land managers, community members, cat-owners) to participate in management actions to reduce the impacts these animals inflict on the environment. This could involve encouraging them to adopt one or more new behaviours or to change their current behaviour. Most existing interventions depend heavily on the provision of information to persuade these individuals to change their current behaviours (McLeod et al. 2015). Providing information is important in creating awareness and forming attitudes. However, there is considerable evidence in the psychology literature that the information by itself is usually insufficient to bridge the gap between attitudes and behaviour (Kollmuss and Agyeman 2002, Schultz 2014). To initiate behaviour change, practitioners must first establish what drives the target behaviour, as well as what prevents it from occurring. Once the drivers and barriers are properly understood in context, appropriate behaviour change tools can then be identified and implemented (McKenzie-Mohr 2011, Michie et al. 2011, Schultz 2014).

This paper will examine the steps required to design an effective intervention, based on the methodology of community-based social marketing (CBSM). The CBSM framework was specifically developed to improve on the traditional information-intensive educational approaches to deliver sustainable environmental behaviour change (McKenzie-Mohr 2011). Examples from current research on free-roaming cats in Tasmania will be used to illustrate the process and highlight some limitations in current design practice.

Step 1: Select the target behaviour

There are usually a variety of strategies and associated behaviours that can be promoted by intervention programs. To maximise effectiveness, the first step of a behaviour change program is to make an informed choice regarding which are the most worthwhile behaviours to target. The best strategy, or general classes of behaviours, that are going to have the greatest impact must be determined, which can then further broken down into specific, end-state behaviours for further analysis. In CBSM this is achieved by using a matrix comparing four dimensions: (1) the effect that each behaviour has on the outcome (impact), (2) the likelihood of the target audience performing the behaviour (probability), (3) the percentage of the target audience currently doing the behaviour (penetration), and (4) the proportion of the audience that has the potential to engage in the behaviour (applicability) (McKenzie-Mohr 2011).

In the context of our research (reducing impacts of free-roaming cats within our study area which incorporates urban, peri-urban and rural areas), 24 hour containment of pet cats was selected as the target strategy. We then determined the specific behaviour required for cat-owners to confine their cats for consideration of the next step in the process.

Step 2: Identify drivers and barriers to this behaviour

Why do people engage in certain activities and behave the way they do? There are many factors that can influence human decision-making and behaviour, and for an intervention to be effective, all of the drivers and barriers to a specific behaviour need to be understood if behavioural change is to be elicited. It is important not to rely on assumptions and speculations of these factors but to determine them directly from the target audience (McKenzie-Mohr 2011).

There are three broad categories of factors that influence human decision-making and behaviour (Michie et al. 2011, Rli 2014):

Abilities: the extent to which people are aware of the issue and the required behaviours to resolve the issue, as well as the capacity (know-how and both physical and psychological skills) to engage in the appropriate behaviour.

Circumstances: the context or setting which can encourage or preclude participation in the behaviour. These can include physical, economic, technological, social and cultural as well as institutional opportunities and obstacles.

Motivations: the reasons that direct and impel a person to behaviour in a particular manner. These incorporate a person's values, emotions, beliefs, attitudes, personal and social normative beliefs; can be attained through conscious, reasoned decision-making or be an intuitive or habitual reaction; and can be further influenced by the person's abilities and circumstances.

Who you ask and how you ask are important considerations when determining the drivers and barriers to invasive animal management actions. The first step in our research project was to pose the question "what are the main barriers to pet cat management actions (including containment)" at a workshop of professionals and experts from a variety of organisations involved in the cat industry and resource management (labelled 'Experts' in Figure 1). The responses received placed more emphasis on extrinsic factors such as external barriers (e.g. cost and resources) and current cat regulations, and less on intrinsic factors such as beliefs and capabilities. The responses received from cat-owners who already contain their cats (labelled 'CatContainers' in Figure 1) and those that do not (labelled 'OtherCatOwners' in Figure 1) when asked the more specific question "what are the main barriers to confining your pet cat" not only varied from each other, but unlike the "experts" placed more emphasis on intrinsic factors such as beliefs, motivation and emotions.

A problem when asking for people's opinions directly is that the response is biased, skewed towards those factors that people are consciously aware of (Podsakoff et al. 2003). Human decision-making is guided by two distinct processes; the automatic, subconscious system and the analytical, cognitive system (Tversky and Kahneman 1974). People may be totally unaware of those factors that are operating through the automatic process. Social norms are a good example, with most people not aware and unable to disclose how much of their behaviour is influenced by others. The responses in Figure 1 from direct questioning of cat-owners illustrate this point.

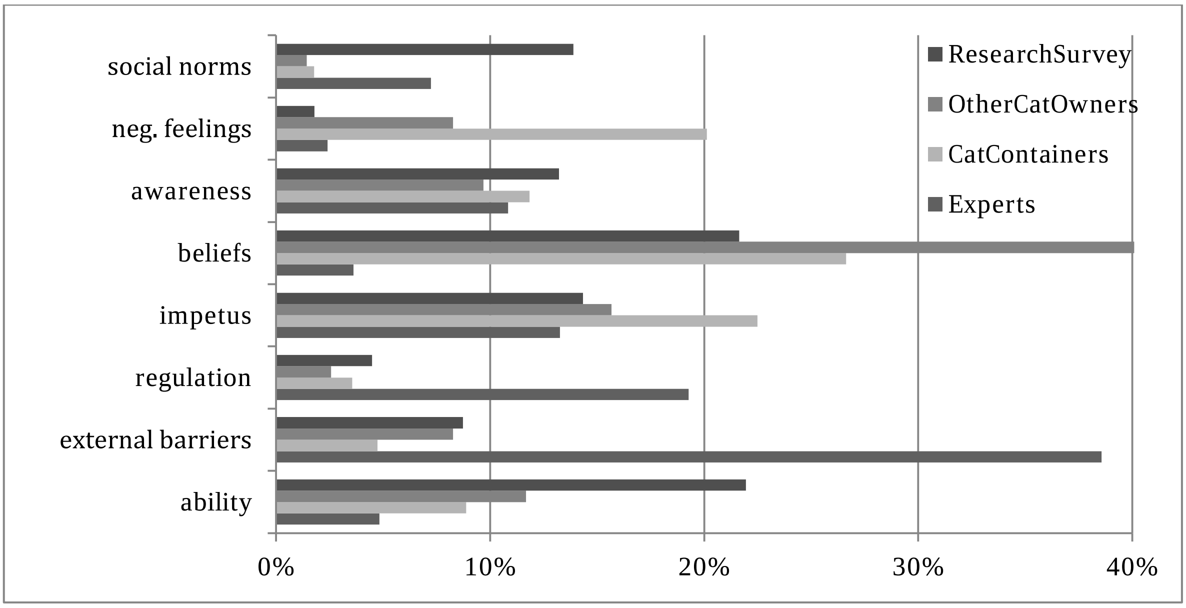

Figure 1: Drivers and barriers to cat containment identified by various groups as detailed in the text. Ability includes both physical and psychological skills and confidence; external barriers include a combination of physical and financial obstacles while regulation denotes an institutional circumstance; impetus, beliefs, awareness, negative (neg.) feelings and social norms are all types of motivations.

A way to reduce these self-reporting biases is to incorporate the appropriate questioning method in the survey design (Podsakoff et al. 2003, Fowler 2013). The final set of responses shown in Figure 1 (labelled 'Research survey') is those from the same cat-owners but elicited using multiple closed questions for each factor. Those intrinsic factors that operate through more automatic decision processes become more prominent, including social norms and psychological skills required for engaging in a behaviour. From these results we can conclude that two of the main factors influencing cat containment behaviour in our study area are cat-owners' beliefs about containment and their confidence in their ability to implement an effective containment strategy for their cat.

Once the drivers and barriers have been identified, they need to be prioritised for the next step in the process.

Step 3: Develop the intervention strategy

There are several key points to consider when developing the intervention strategy; the design (content, format and target audience) and the implementation (provider, setting, intensity and duration) (Whitlock et al. 2002, Davidson et al. 2003). To be effective the intervention must make use of tools that reduce the identified barriers and increase the benefits, as well as being affordable, practical, efficient, cost-effective, acceptable, and fair (Michie et al. 2014, Schultz 2014). The type and strength of the identified drivers and barriers, as well as how receptive the target audience is to change, are all important considerations when selecting the appropriate tools to use (see Table 1) (Whitlock et al. 2002, McKenzie-Mohr 2011). For example, a less-intensive intervention delivered from a distance may be a more affordable option for enthusiastic individuals; however, if key barriers are particularly strong and/or individuals less disposed to change, face-to-face instruction (either individual or group), requiring greater resources may be a more successful option.

Table 1: Examples of the types of drivers and barriers that specific behaviour change tools address (after McKenzie-Mohr 2011, Michie, van Stralen et al. 2011, RIi 2014, Schultz 2014).

Tools / Factors	Provide a service	Make it easy	Penalise	Social norms	Offer a reward	Provide information	Gain a commitment	Prompt action
Abilities								
Physical	HH	HH				LH		LH
Psychological	HH	HH				LH		LH
Circumstances								
Physical	HH	HH		LL		LH		LH
Social	HH	HH		LL		LH		LH
Motivations								
Reflective			HL	LL	HL	LH	HL	
Automatic	HH	HH	HL	LL	HL	LH	HL	LH

HH: effective when barriers are high and benefits are high (people already motivated to act)
HL: effective when barriers are high and benefits low (people show little motivation to act)
LH: effective when barriers are low and benefits high (people already motivated to act)
LL: effective when barriers are low and benefits are low (people show little motivation to act)

All interventions will have some form of communication component to create awareness, regardless of whether it is also being employed as a behaviour change tool. It is important that the intervention messages reach and engage the audience. There is a growing literature on effective communication practices. The manual produced by Hine et al. (2015) is particularly relevant for the development of effective communications for invasive animal management.

Steps 4 and 5: Pilot, implement and evaluate the strategy

Once the intervention strategy has been designed it is important to pilot it on a small scale before implementing on a broad-scale to test for design flaws and unforeseen problems. CBSM methodology promotes monitoring and meaningful evaluations of the outcomes (i.e. how many people actually modify their behaviour) as opposed to just outputs (e.g. number of factsheets handed out, number of web site hits, number of people aware of campaign) to ensure the intervention is having the desired results (McKenzie-Mohr 2011).

Take Home Messages

To develop an effective intervention to change individual's behaviour

- *Start with specific behaviours and context*
- *Consider all types of factors that can influence an individual's behaviour, both*
    - *intrinsic (conscious and automatic), and*
    - *extrinsic*
- *Be wary of any assumptions made and mindful of potential sources of bias*
- *Select appropriate tools and delivery strategies*
- *Evaluate outcomes, not just outputs*

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Connecting communities- Feral scan

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Community participation in recording evidence of pest species and their impacts is becoming increasingly useful in identifying and prioritising areas for pest control, as well as measuring the outcomes of various management actions. Importantly, the provision of a dedicated community space for mapping pests enables community participants (whether they be farmers, landcarers, local councils, or even grey nomads) to engage in the process of identifying and documenting problems, and creates an opportunity for more structured participation in pest animal management.

The FeralScan pest mapping resource (www.feralscan.org.au) hosts facilities for community mapping of many nationally significant pest animal species. Information recorded in FeralScan by the community is being shared with local pest management authorities to better connect communities with support services and organisations. Over 8,000 people have participated in recording sightings or evidence of pest animals in their local area, as well as documenting the problems those pests cause, and what control actions have been undertaken to reduce those problems. New online networking tools also provide users with a facility to come together online (via online groups) to record and share real-time data locally (including animal photos), and use that data to plan control activities. FeralScan is a free web-based mapping resource available via desktop, mobile-website and a new offline Mobile App for mapping in remote areas.

In partnership with the Australian Government's Department of the Environment, the Invasive Animals CRC will soon be developing a new citizen science platform for mapping feral cats called FeralCatScan. FeralCatScan will provide for the first time, a dedicated space for landholders, community groups, local councils, indigenous groups, NRM organisations and pest managers expertise to record and centralise real-time information about feral cat activity (including cat impacts on native species). It will potentially help to identify problem areas, but it will also offer the chance to engage with individual people who are keen to partake in some way in the management or mapping of feral cats. In this capacity, it will hopefully help to foster ownership of the problem(s) and help to identify locally-relevant and practical solutions, such as action plans based on collective knowledge.

In the hands of focussed motivated groups looking to take action to control feral cats, FeralCatScan will provide a free web and mobile app technology for detecting, monitoring, and targeting feral cat problem areas. FeralCatScan will initially be developed and evaluated on Kangaroo Island before being promoted elsewhere.

Sharing of camera-trap imagery will also enable the identification of individual animals in the landscape, and potentially assist with targeted removal. This new technology will potentially identify the extent of interest by the community in seeing action taken to address the feral cat problem, and provide a platform for sharing observations and knowledge at various scales.

Additional information

Summary of research and publication on feral cats in SA

Katherine Moseby and John Read

Ecological Horizons
University of Adelaide

A summary of research on feral cats that has been conducted over the last 20 years in the SA arid zone. Hopefully results can assist with the design of future cat control methods.

Read, J. and Bowen, Z. (2001). Population dynamics, diet and aspects of the biology of feral cats and foxes in arid South Australia. *Wildlife Research* 28: 195-203.

Study showed that cats feed on a diverse range of species and that rabbits are a key prey species. The population in the arid zone suffered large declines after RCD decimated rabbit populations. Results point to the importance of controlling key prey species as a non-direct way of reducing cat abundance.

Moseby, K.E., Selfe, R. and Freeman, A. (2004). Attraction of auditory and olfactory lures to Feral Cats, Red Foxes, European Rabbits and Burrowing Bettongs. *Ecological Management and Restoration* 5: 228-231.

Trialed different lures and found audio lures were more effective than olfactory lures for cats. Both lure types increased visitation relative to controls.

Moseby, K.E. and Read, J.L. (2006). The efficacy of feral cat, fox and rabbit exclusion fence designs for threatened species protection. *Biological Conservation* 127: 429-437.

Designed and tested a cat exclusion fence and published a detailed design. More than 30 cats and foxes were tested during the study and the fence design has since been adopted by other agencies. The only empirically tested fence design for the exclusion of feral cats.

Moseby, K.E., Stott, J. & Crisp, H. (2009). Improving the effectiveness of poison baiting for the feral cat and European fox in northern South Australia: The influence of movement, habitat use and activity. *Wildlife Research* 36: 1-14.

Home range study of feral cats and foxes in the arid zone. Home ranges varied from 0.5 square km to 132 square km with individuals moving up to 45 km in two days. Cats preferred habitat types with thicker vegetation such as sand dunes and creeklines. Cats found to use temporary focal points within their home range for periods of up to 6 days whilst foxes travelled through most of their home range in a night. This suggests that cats will take days or months to move through their entire home range and that control devices need to be placed every 1 km to be effective. Movement data indicated that a bait density of 30 per sq km would be required for a cat to encounter one bait in three days.

Moseby, K.E, Hill, B.M. and Read, J.L. (2009) Arid Recovery - A comparison of reptile and small mammal populations inside and outside a large rabbit, cat and fox-proof exclosure in arid South Australia. *Austral Ecology* 34:156-169.

Populations of small mammals were up to 15 times higher inside a cat, fox and rabbit proof reserve than outside. These differences suggest a significant impact of cats on native rodents, even those species not currently listed as threatened.

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

Initial trials of a grooming trap for control of cats were successful and demonstrated proof of concept.

Moseby, K.E., Read, J.L., Paton, D.C., Copley, P., Hill, B.M. and Crisp, H.M. (2011). Predation determines the outcome of 11 reintroduction attempts in arid Australia. *Biological Conservation* 144, 2863-2872.

Reintroductions within a fenced reserve were successful but all releases outside failed due to predation by foxes and cats. Demonstrates that despite intensive cat control through aerial baiting, predation levels are still too high to enable re-establishment of many native species.

Moseby, K.E. and Hill, B.M (2011). The use of poison baits to control feral cats and red foxes in arid South Australia 1. Aerial Baiting Trials. *Wildlife Research* 38: 338-349.

Moseby, K.E., Read, J.L., Galbraith, B., Munro, N., Newport, J and Hill, B.M. (2011). The use of poison baits to control feral cats and red foxes in arid South Australia II. Bait type, placement, lures and non-target uptake. *Wildlife Research* 38: 350-358.

These studies found that aerial baiting was only effective for cats when conditions were extremely dry and that when alternative food was available, cat baiting was ineffective. There was high bait uptake by non-target species and even when cats found baits they rarely ingested them. The issues with cats both finding and then consuming baits continue to be the major stumbling blocks for the implementation of successful baiting programs.

Moseby, K.E., Cameron, A. and Crisp, H.A. (2012). Can predator avoidance training improve reintroduction outcomes for the Bilby (*Macrotis lagotis*) in arid Australia? *Animal Behaviour* 83(4) 1011.

This study attempted to train bilbies to avoid cats and then compared survival of trained and untrained animals. Although training did appear to improve awareness and vigilance, there was no difference in survival between the two groups. All bilbies died within 18 months of release outside the reserve. High juvenile mortality was attributed to cats.

Moseby, K.E., Neilly, H., Read, J.L. and Crisp, H.A. (2012) Interactions between a top order predator and exotic mesopredators. *International Journal of Ecology Article* ID 250352, doi:10.1155/2012/250352

Investigation of the use of dingoes to control cats and foxes. The interaction between cats, foxes and dingoes was studied using GPS collars within a 37 square km paddock. Dingoes killed all foxes within 7 days and killed more than half the cats over 6 months. Results suggest that cats avoid core home ranges of dingoes spatially but that there is little temporal avoidance. Dingoes will kill cats and foxes when they encounter them but encounters appear to be random. Cats are better at avoiding dingoes than foxes.

Moseby, K.E., Carthey, A. and Schroeder, T. (2015). The influence of predators and prey naivety on reintroduction success; current and future directions. Pp 29-42 *In* Advances in Reintroduction Biology of Australian and New Zealand Fauna. (Eds. Armstrong, D.P., Hayward, M.W., Moro, D. and Seddon, P.J.), CSIRO Publishing, Melbourne, Australia.

Suggestions for future reduction in cat impacts include improving prey responses through exposure to low levels of predation pressure over long time periods. This formed the basis of an ARC project currently being implemented to determine if in situ predation (1 cat in with 350 bettongs in a 26 sq km paddock) and natural selection can improve anti-predator behaviour. Whilst these measures may be long term prospects we should be seeking long term solutions rather than looking for quick fixes.

Workshop discussion

Impacts

Common understandings

- Prey rate of release relationship
- Need to know density, impact relationship (individual cat activity creates challenge to this)
- Thresholds – increased variabilities

Gaps

- Economic impacts on tourism (eco)
- Lack of quantitative modelling > scenario testing
    - o Cat impacts/toxo
    - o Predator interactions
    - o Critical impact periods – modelling rainfall/cat numbers/predator interaction
- Consideration of ecosystem effects with cat number reductions (predator response)
- Predator exclusion sites for model development
- Data demonstrating species decline against measure of cat density (refer to Astrebla Downs study [in prep])
- National prioritisation/decision tree process – challenged by diversity of species impacts
- Critical impact period/mgt approach – budgetary and time frame issue
- Understanding around changes over time in different locations

Areas for future work

1) Development of improved collars – discover kill rates
2) Better understanding of spatial variation in cat impacts to define where effort goes
3) Assessment of cat free sanctuaries: compare demographic performance inside & out: small species, medium sized spp?
4) Explore Aboriginal cultural approach to change in environment re cat impacts: adaptation > animal mgt considerations
5) Quantifying impacts of feral cats relative to other impacts on threatened species

- Impacts on species
- Impacts on agricultural industries
- Impacts on tourism
- Economic cost overall

6) Identify sites for future intervention work
7) Further work on individual cat impacts and modifying control work to address individual predator activities
8) Develop rules of thumb around strategic mgt > impact/risk/strategic mgt options (thresholds e.g. with diet shifts)
9) Background (evidence) work to enable policy development around mgt of 'owned' and 'unowned' (stray/domestic) cats: interaction with feral cat mgt
10) Cat eradication from islands with indigenous community settlements > need to consider cultural acceptance of change (e.g. Cats adopted in cultural stories/dreaming)
11) Disease impact: Sarcocystis/Toxo?
12) Zoonoses impacts on people – update
13) How many cats?

Decision Matrix (1=highest, 5=lowest)

Future work projects	**Timeframe short ≤12 mths medium 2-5 yrs long ≥5 yrs**	**Overall ranking (1-5)**	**Feasability (1-5)**	**Benefit (1-5)**	**Costs (1-5)**
Development of improved camera collars to discover kill rates	Short	3	1	2	3-4
Better understanding of spatial variations in cat impacts assessment of cat free sanctuaries, compare demographic performance inside & out	Long	2	1	1	2
Explore Aboriginal cultural approach to change in environment re cat impacts: adaptation > animal mgt considerations	Medium	7	1	2	3
Quantifying impacts of feral cats					
- Impacts on species	Long	1	3	1	1
- Impacts on agric. Industries, tourism, economic cost overall	Short	6	2	2	5

Further work on individual cat impacts and modifying control work to address individual predator activities	Medium	3	2	2	2
Disease impact : sarcocystis /toxoplasmosis	Short	5	1	3	5
Zoonoses impact on people - update	Medium	4	1	1-5	4
How many cats?	Short	8	1	4	5

NATIONAL TARGET

Effective evidence – based cat management has been implemented in six sites of high priority for native species imperilled by cats.

Monitoring

Common understandings

- Monitoring is part of an accountability framework for measuring progress against targets
- Draft targets are a good start (Woinarski et al., in prep)
- Monitoring needs to be sensitive enough to be an adaptive management tool
- Monitoring is a key communication tool (community, NRM regions, politicians/bean counters)
- We must monitor/monitoring must be funded as integral part of effective cat management
- We need agreement on priority actions that can then be incorporated into the cat TAP
- Important to have understanding of past and current management and related inputs and outcomes
- Need to increase awareness of the cat issue: their impacts and ways to effectively manage them.
- There is a distinction between reporting and monitoring; not coupled, different audiences/different expectations
- Need information for different audiences – range of agreed metrics e.g. politicians, Gregory's aunty
    - Focus on impacts not numbers of cats (live or dead)
    - Measure changes in numbers of threatened species (against targets)
- We need to be realistic- shouldn't push for cat control everywhere. We need to prioritise and carefully plan our management activity.
- There is a reason for optimism for growing list of monitoring methods/technologies
- Need diversity of monitoring approaches
- Community awareness and engagement is critical
- Need for agreed outcomes from monitoring allowing fit for purpose methods/approaches, appropriate for each site/project
- We're on the cusp of increased range of monitoring methods > risk of diversifying monitoring approaches too much and fragmenting our research outputs

Gaps

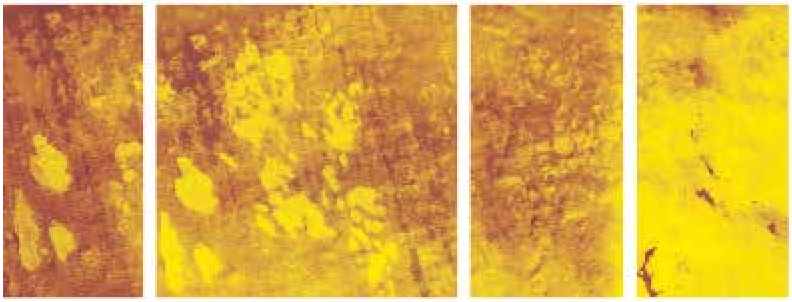
- Monitoring of predation
- Knowledge of threatened species data
- Relative value of quantifying species numbers
    - o Need standardised monitoring techniques
    - o Need to be able to compare apples with apples across different sites and scales
- need monitoring of effects on agricultural industries (disease levels) as well as threatened spp; as well as human health > bring key threatening processes TAP/EPANS processes together
- Require centralised process to cross analyse and compare different data sets
- Need to carefully plan long-term monitoring methods and calibrate for any changes
- Threatened spp surrogate monitoring is important
- Integrate cat and fox monitoring (+ other introduced predators)
- Parasite issue (Sarco) – monitoring needed
- Monitoring programs on perverse impacts on unwanted species

Areas for future work

1) Task force to develop guiding principles for feral cat/threatened species monitoring – specifically for TAP targets
2) Fewer projects recommended but those projects agreed to have clearly designed and defined monitoring programs over adequate time frames (funded long-term) > strategic and targeted intervention
3) Need to incorporate sustainability principle for national targets – long-term planning
4) Knowledge around agricultural/ livestock impacts of cats
5) Prioritisation process for allocation of monitoring effort
6) Studies on kill rates/predation rates

Decision Matrix (1=highest, 5=lowest)

Future work projects	**Timeframe short ≤12 mths medium 2-5 yrs long ≥5 yrs**	**Overall ranking (1-5)**	**Feasability (1-5)**	**Benefit (1-5)**	**Costs (1-5)**
Task force to develop guiding principles for feral cat/threatened species monitoring – specifically for TAP targets	Short	1	1	1	4
Design and implement National monitoring network (cats, threatened spp)	Medium/Long	1	3	1	1
Index calibration	Medium	3	2	2	3
Analysis of big data (eg. Bayesian, package of analytical techniques)	Medium	2	1	2	3
Improved collection of data from general public = citizen science tool	Medium	4	1	3	3
Review of cat monitoring methods	Short	1	1	1	4
Automated recognition – improved use of cameras, mgt and analysis of data	Medium	1	2	1	3 ($800k)
Monitoring/knowledge around agric./livestock impacts of cats	Short/Medium	4	1	4 (localised)	4
Prioritisation process for allocation of monitoring effort	-	-	-	-	-
Studies on kill rates/predation rates	Medium/Long	2	2	2-3	1-2
Ideal camera design and development	Medium	2	1	1	5 ($200k)
ID species to monitor	-	-	-	-	-
eDNA cat predator & prey develop as monitoring technique	Medium/Long	2	3	2	2
National workshop on (cat predator & prey) monitoring methods	Short	3	1	3	5
Detection probabilities (developed, camera traps, spotlighting)	Medium	2	1	2	3



NATIONAL TARGETS

1) An effective national monitoring network development (with sufficient precision) to detect trends in 40 key threatened species and cats by 2016.
2) New data management and analysis techniques used by X% practitioners to assess the effectiveness of cat management by 2016.
3) By 2018, low cost and readily available tools based on existing and novel technologies for both broad-scale and localised intensive monitoring effectiveness of cat management.

Control tools

Common understandings

Gaps

- Test all control tools against humane index – inform transparent development of tools
- New baiting technologies/toxins
    - Humane/effective
    - Continue development and broaden scope across jurisdictions
- Scoping opportunities for local people/communities stewardship

Areas for future work

1) Scale critical
2) Species specific techniques – address individual target animals
3) Range of tools available; optimum ways of using multiple tools at single time
4) Biocontrol options – hugely expensive development and regulation hurdles (ideas outside box for funding/support)
5) Technological solutions – document and comms for increased funding (grooming traps, implants, lethal collars etc)
6) Cost effective and easy for landholder/manager implementation
7) Decision support tools for maximum efficiency of tool application > strategic tool use
8) Identifying multiple Achilles heels/biological windows (e.g. floods)
9) Exploring indirect strategies to target cats e.g. RHVD on rabbits > effect on cats/meso predator release
10) Flow-on effects from removal of other target species
11) Marriage/Integration of cat control with fox control
12) Control tools that tell how many animals > contribute to monitoring: biocontrol tools require increased monitoring programs
13) Test all control tools against humane model – inform transparent development of tools
14) New baiting technologies/toxins
    - Humane/effective
    - Continue development and broaden scope across jurisdictions
15) Scoping opportunities for local people/communities/stewardship

MUST HAPPEN

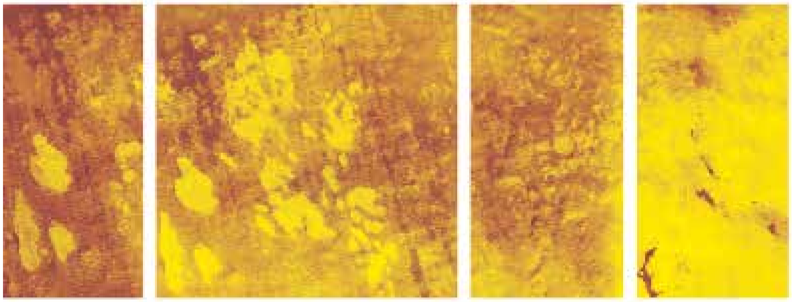
- Rabbit biocontrol support
- Dingoes for cat control
    - In management techniques
- Facilitator
- Links with other species management
    - In management techniques

Decision Matrix (1=highest, 5=lowest)

Future work projects	Timeframe short ≤12 mths medium 2-5 yrs long ≥5 yrs	Overall ranking (1-5)	Feasability (1-5)	Benefit (1-5)	Costs (1-5)
Small scale tools or follow-up with other techniques					
Grooming trap (+visual recognition)	medium	1 (3)	2 (3)	1 (3)	$1m (+$0.8m)
implants	medium	2	2	2	$0.3m
Lethal collars	medium	2	2	2	$0.3m
1080 (other toxin) feeders (hoppers to make baits on legs)	long	3	4	2	$2m
Kill traps		2	4	2	$0.6m
Large scale tools					
Biocontrol: a) gene drive	long	1	3?	1	>$5m
b) feasibility of gene drive (new technology (lab, ecological, social)	Short/medium	1	1	1	$1m
c) review of other potential biocontrols (disease)	short	1	1	1	$0.1m
Baiting: a) smart baiting	short	1	1	1	$0.4m
b) finalising elements of R&D	short	1	1	1	$0.2m
Environmental windows for control "Manual"	short	1	1	1	$0.1m
Support tools update SOP and additional multi-media (incl. landscape > control decision support)	medium	2	1	2	$0.8m
Fencing – sustainability (islands)	long	3	1	3	$1m

NATIONAL TARGETS

1) 2 new tools targeting feral cats within 3 years (to boost current control)
2) 10 year research program into gene drive technology to stop feral cats breeding (biocontrol, new emerging technology)
3) New feral cat bait available for landscape-scale delivery in 2 years



Management

Common understandings

Gaps

Areas for future work

1) Need broad long term national mgt strategy driving collaboration across different approaches in different environments
2) Development of key criteria to determine sites for fencing mainland islands/offshore islands (BIOSECURIUM)
3) Predetermine conservation goals – what are we trying to save
4) Cost benefit analyses of mgt strategies (including grazing mgt)
5) Increased focus on environment controls and assessment of efficiency
6) Continental scale evaluation/prioritisation of islands for mgt targets
7) Better coordination and integration across tenure
8) Experimental assessment in field. Trials for better understanding of which habitat manipulation advantages which spp (across different landuses/tenure)
9) Research on use of fire to manipulate landscapes scale/ecological trap
10) Further research on effect of grazing/woody weeds on cat/prey interactions
11) Assessment and roll-out of control strategies in context of rapid immigration of feral cats
12) Develop key messaging/communications to Minister on known (positive effects) environmental manipulation > priorities for interventions e.g. fence movement in Sturt NP
13) Assessment effectiveness of community based mgt
14) Focus on collaboration with traditional owners in cat mgt
15) Incorporate domestic/settlement cat mgt/communications strategies; collaboration between feral/domestic mgt (particularly considering indigenous communities)
16) Decision-making process to turn tools into mgt-strategies
17) Building predator-proof fences
18) Eradicate cats from a # of islands

Decision Matrix (1=highest, 5=lowest)

Future work projects	**Timeframe short ≤12 mths medium 2-5 yrs long ≥5 yrs**	**Overall ranking (1-5)**	**Feasability (1-5)**	**Benefit (1-5)**	**Costs (1-5)**
Need broad long term national mgt strategy driving collaboration across different approaches in different environments	Short	1	1	1	5
Islands (eradication of cats from islands)	Long	1	2	1	1
Fenced enclosures	Medium/long	1	2	1-2	1
Open landscapes					
Positive predation mgt	Medium	2	3	3	
Baiting	Short	2	3	3	3
Fire	Medium	2	3	2	3
Grazing	Medium	2	3	3	2
Rabbits	Medium	2	3-4	3	2
Trapping	Short	4	4-5	4	1
Tenure (co-ordination/integration)	Medium	3	2	2	3-4

Inherent "direction"/"assumption": Strategic adaptive management framework.

NATIONAL TARGETs 2020

4) Cats eradicated from 5 new islands (offshore)
5) 10x new fenced areas each greater than 25 km^2 with cats eradicated
6) In open landscapes:
   C) 20,000 km^2 of commonwealth land with strategic cat control
   D) 10x open-landscape sites each greater than 10,000 ha with strategic cat control, prioritised by
      - Extant threatened or high priority species
      - Recent loss that is reversible

Engagement

Common understandings

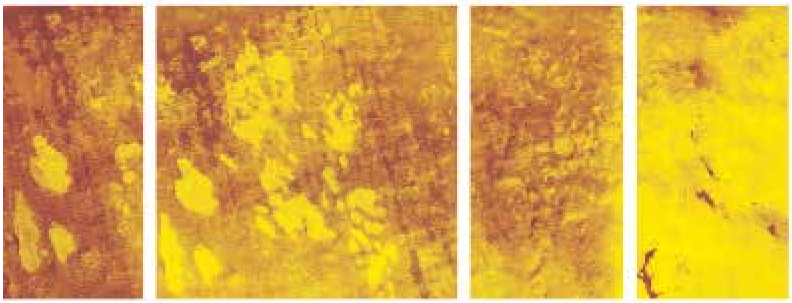
Gaps

Areas for future work

1) Involving local government to 'clean up' high density populations around tip/dump sites near settlements, tip sites around key nature reserves
   - Reinvigorate 'Who's for cats' – resource
2) Develop systems to qualitatively analyse programs such as cat scan
3) Facilitation of knowledge sharing
   - Experts working together/trusting
   - Overcoming competition for $
4) Harnessing social media technology
5) How do we maintain and build social licence/social marketing
6) Maximise public/social licence and budget usage by collaboration across jurisdictions > enable effective engagement and two way information with community
7) Identify and harness opportunities for broad collaboration across all partners
   - Engagement strategy?
   - National feral cat facilitator?
8) Identify and overcome institutional barriers – social science
9) Explore community perceptions of feral cat issue
   - Attitudes may be different to perceptions
   - Coupled social/ecological modelling
10) Merging of research methods with new citizen science data collection (replacing tradional research methods e.g. mouse monitoring project)
11) Indigenous engagement
12) Community needs analysis
    - Barriers to action (e.g. Tools to euthanize cats)
13) Private $$ support and crowd sourcing
14) Integrated pest control, engage other segments
15) Harnessing volunteers

Decision Matrix (1=highest, 5=lowest)

Future work projects	**Timeframe short ≤12 mths medium 2-5 yrs long ≥5 yrs**	**Overall ranking (1-5)**	**Feasability (1-5)**	**Benefit (1-5)**	**Costs (1-5)**
Knowledge needs: 1) Community needs research (sample: nation-wide key segments) 2) Identify institutional barriers 3) Community perceptions; coupled social/ecological modelling	Short medium	2	1	1	3 ($0.5m)
Strategic Engagement/Comms. Framework: 1) National stakeholder engagement strategy: who: managers/communities/stakeholders what a) support for and b) engagement in national feral cat mgt initiative a) stakeholders: RSPCA, welfare groups, conservation NGOs, local gov., AVA, Invasive Species Council, threatened species groups, IA CRC b) Engagement: indigenous land managers/ Animal Management in Rural and Remote Indigenous Communities (AMRRIC); volunteers/Green Army; landmanagers; local government; ACAC	Short	1 Prep 1 Impl./ roll-out	1	1	Prep 4 ($0.1m) Impl 2 ($2.0m)
Communication Channels / Strategies: a) social media/social marketing b) Who's for cats (urban/peri-urban)	a)short/medium b) medium/long		a) 1 b) 2	1	5 3-4 ($0.1m)
Collaboration: Leveraging from other spp. Mgt > integrated pest mgt Facilitation of knowledge sharing Feral cat scan: analyse data/investigate best ways to relate expert and citizen data National cat facilitator	Medium short Short / medium short	1	1-2 2	1 1	3-4 4 4 3
Action strategies – engage/promote Local government clean-up of tips	medium		1-2	1	5



(legislation)					
Financing: Crowdsourcing Philanthropies Collaboration National Landcare Program competition tied funding by Comm, Priority to NRM groups	Short/medium / long		1	1	4-5 ($0.1m)

NATIONAL TARGETS

Outcome > Strong support for and engagement in the national feral cat managment initiative (NFCMI)

Target > Increase in support for NFCMI by key stakeholder groups by X% by 2017

    - o Sign onto plan
    - o Feral cat management and community initiatives recorded on Feral Cat Scan
- Ø Increase in collaborative engagement for NFCMI by stakeholders by X% by 2017
    - o Involvement in database
    - o Linkages to investors
    - o Feral cat management and community initiatives recorded on Feral Cat Scan
- Ø Announce feral cat facilitator by July 2015 (summit)
    - o Taskforce and governance

Finance Target - 20% of National Landcare Program (NRM) competitive funding (up to 5 years) tied to cat management and threatened species conservation

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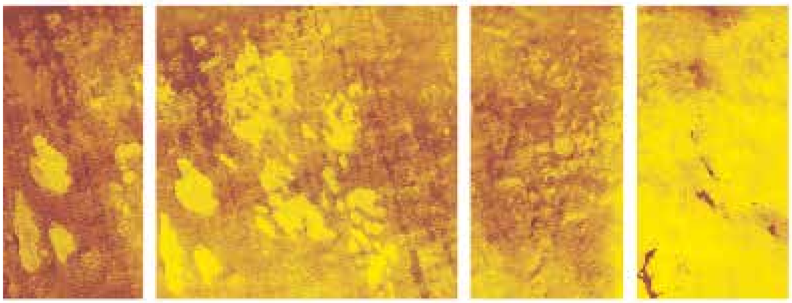

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