The Western Australian Biodiversity Science Institute

INCREASING KNOWLEDGE TO MITIGATE CAT IMPACTS ON BIODIVERSITY

A research program for Western Australia

These days there a lot of cats. They are killing all the desert finches and other things too, like bilbies. We have to save the bilbies. They are only left here and a few other places. That's why we are hunting and killing the cats, but there are more and more, so many now out here. What do they call them? Predators. Because they cheat. And the ones that were here before are now all gone.

JOHN TJUPURRULA WEST, Kiwirrkurra

Desert Aboriginal people have been hunting feral cats as a food resource for many generations and Indigenous Tracking Experts have detailed knowledge of cat behaviour and ecology. Adopting a Two-way Science approach to cat control that combines Indigenous knowledge and perspectives with contemporary science and technology is the most effective and efficient way of reducing the impacts of cats in the desert.

DR RACHEL PALTRIDGE, Indigenous Desert Alliance

Dedicated research by many scientists and managers over recent decades has led to major advances in knowledge of the ecology, impacts and management of feral cats. But there remain many major gaps that constrain our ability to effectively control feral cats, and across most of Australia their significant impacts remain unabated. Ensuring that knowledge gaps are identified, prioritised, communicated and addressed is a critical part of getting improved conservation outcomes for our native wildlife.

PROFESSOR JOHN WOINARSKI, Charles Darwin University

We urgently need a unified effort to reduce the devastating impact of feral cats on our native wildlife. The Western Australian Biodiversity Science Institute is leading the way by addressing key research priorities to improve feral cat control across tenures.

PROFESSOR PETER KLINKEN, Chief Scientist, Western Australia

Feral cats are a significant threat to our native animals and their devastating impact is a national issue. We need improved knowledge for better control so we can safeguard the future of our vulnerable wildlife.

DR SALLY BOX, Threatened Species Commissioner

THE WESTERN AUSTRALIAN BIODIVERSITY SCIENCE INSTITUTE

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A research program for Western Australia

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The Western Australian Biodiversity SCIENCE INSTITUTE

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Karlamilyi National Park
Photo courtesy: Judy Dunlop, DBCA

1. EXECUTIVE SUMMARY

Domestic cats (*Felis catus*), introduced to Australia over 200 years ago, now cover the entire mainland and many offshore islands, and represent a significant threat to native fauna across Western Australia. The numbers of animals lost to cat predation each year are astonishing in their magnitude – in excess of 2.2 billion birds, reptiles and mammals across the country. They have been a major factor in 27 animal extinctions in Australia and continue to threaten many more. Cats are also known to spread disease that can adversely affect humans and other animals. While at certain times and in certain places we are able to undertake cat control that mitigates this significant threat to biodiversity, the reality is that for the vast majority of Western Australian landscapes, and for most of the time, the control of cats (or lack thereof) remains ineffectual.

Where cats have been effectively controlled in the State there have been noticeable benefits for native fauna. Western Australia is a global leader in the control of feral cats, including island eradications, ambitious lethal baiting programs, Indigenous-led management, and large exclusion fencing areas to protect prey species. As for the control of all introduced animals, these programs need to weigh up the efficiency, effectiveness, and animal welfare concerns to ensure that the multiple benefits from management outweigh the costs.

Even so, managing cats remains challenging, with no single, consistently effective control method available, and local context being critical to management outcomes. There remains considerable scope for improving existing management programs, to develop and refine existing and novel control methods, and to ensure that the public is more informed on the issue of cat management to underpin social licence.

In the last 10 years, significant momentum has been building to improve outcomes for native animals by better control of feral cats. In Western Australia, the recent listing of feral cats as declared pests in the *Biosecurity and Agriculture Management Act 2007* opens up new opportunities for land managers to control cats in a more collaborative, cross-tenure approach. While the financial cost of controlling cats remains high, there is increasing public awareness of the need to address the issues that are holding back more effective and enduring mitigation of the significant threat that cats represent to our native animals.

Photo courtesy: Bruce Webber, WABSI

IDENTIFICATION OF KNOWLEDGE GAPS

Building on momentum from the 2018 Western Australian Feral Cat Symposium, improving outcomes for biodiversity from managing feral cats emerged as a high priority for The Western Australian Biodiversity Science Institute (WABSI). It was identified that a prioritised program of research was needed to address knowledge gaps that would improve on-ground outcomes. The initial end user need was identified as a program that was restricted to feral cats. However, as the program was developed, it became clear that end users, as well as the research community, demanded a program that dealt more broadly with the impact of cats on biodiversity.

To achieve this goal, a series of three facilitated workshops were held with end-users and research providers, representing many of the organisations at the forefront of research and management related to cat control in Australia. Consensus was reached on five focal areas under which research topics were considered, prioritised, refined and scoped:

- Improving existing management (feral cats only);
- Developing novel management (feral cats only);
- Quantifying impacts of cats on native animals;
- Social licence and value proposition; and
- Population ecology and behaviour.

There was a diversity of perspectives voiced from among the range of stakeholders engaged. Similarly, there was a diversity of views expressed on the current state of knowledge for managing feral cats, and which of the five focal areas required more extensive investigation. Despite the range of opinions among stakeholders, what remained undisputed was recognition of the significant impact that cat predation has on native wildlife and the urgent need to do more to improve management outcomes.

A PRIORITISED RESEARCH FRAMEWORK

The vision of this program is to enhance the conservation of native species in Western Australia through improved management of cats, by addressing priority knowledge gaps through new research and facilitating the translation of this insight into effective on-ground outcomes. The framework as outlined here will provide a guide for the development of research activities and will facilitate complementarity and collaboration, rather than duplication of research effort. When delivered, the program will help Western Australia to strengthen its role as a national leader in delivering innovative solutions for cat control, and will facilitate a unified approach to addressing knowledge shortfalls for what is truly a cross-tenure issue of relevance to the entire nation.

NEXT STEPS

The implementation of this research program is going to require a strong governance structure and significant resources. Significant headway has been made in parallel regarding the establishment of a Western Australian feral cat working group, which when active, could provide oversight to ensure the program is delivered by researchers in a collaborative way and to ensure that end-user expectations are being met. In its absence, a dedicated steering committee would be required to provide the same function. Strong alignment with research initiatives underway in other states and with relevant regulatory and policy bodies will enhance outcomes and reduce the risk of overlapping effort. Multiple sources of funding, including Commonwealth and State Government funding schemes, Lotterywest, Natural Resource Management grants and philanthropic sources, are all realistic options that support end-user driven research. Cash and in-kind support from project participants (researchers and end-users) will increase the likelihood of the success of these funding submissions.

KEY BENEFITS

ENVIRONMENTAL

- Greater knowledge of feral cat ecology, behaviour and impacts to inform better decision-making.
- Reduced threats to native species leading to enhanced conservation efforts.

ECONOMIC

- Greater understanding of the effectiveness and efficiency of cat control methods, enabling more efficient use of resources.
- Improved conservation efforts provide greater opportunities to develop tourism focused on Western Australia's unique biodiversity.

SOCIAL

- Greater public confidence and trust in policy and practice, leading to stronger social licence for feral cat control.
- A greater understanding of the social elements of cat ownership, and how cat impacts on biodiversity influence matters of cultural significance, particularly for Indigenous people.

BENEFITS OF THE RESEARCH PROGRAM

A range of stakeholders will benefit from the outcomes of this research program, including:

LOCAL, STATE AND COMMONWEALTH GOVERNMENT ORGANISATIONS

- A clearer financial impetus to invest resources into effective and cost-efficient control programs that reduce threat to native animals and improve environmental outcomes.

REGULATORS

- Enhanced policy relevance and effectiveness, improving biodiversity conservation outcomes.

CONSERVATION ORGANISATIONS

- More efficient use of resources for on-ground work such as the re-introduction of species.

INDIGENOUS LAND MANAGERS

- Better outcomes for managing biodiversity values and conservation of culturally significant species especially, in areas where there is high impact from feral cats.

AGRICULTURAL SECTOR

- Greater control over productivity, with less impact from feral cats and associated diseases.

RESEARCHERS

- A prioritised framework of focal issues are addressed to enable the improvement of cat management outcomes.

PEST MANAGEMENT INDUSTRY

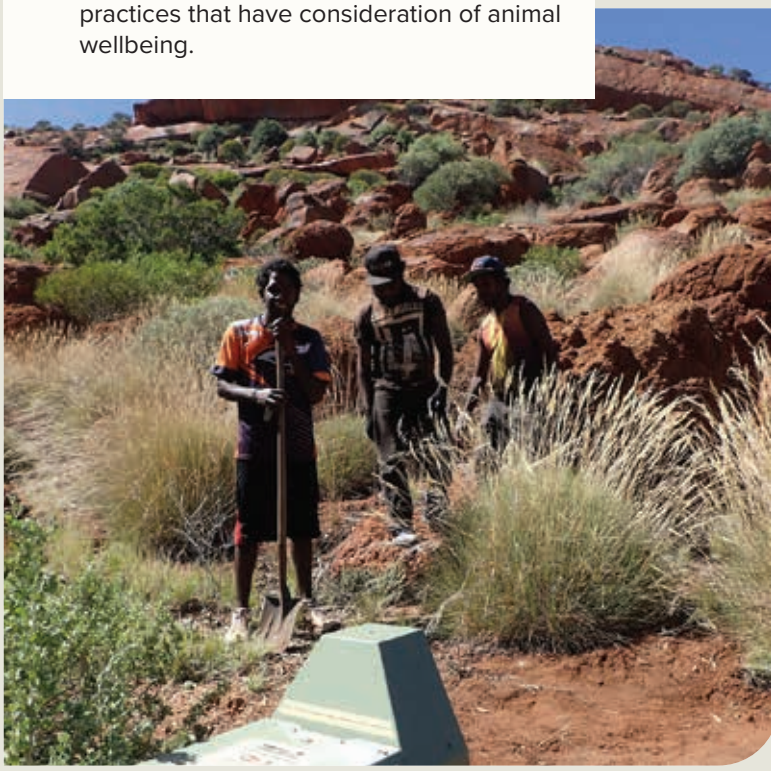
- Improvements in control options and practice that deliver better outcomes.

MINING INDUSTRY

- Enhanced outcomes from cat management programs to help achieve offset conditions.

COMMUNITY

- Better biodiversity conservation from reduced threat to native species.
- Greater trust and confidence in control practices that have consideration of animal wellbeing.



Anangu men installing Felixer traps in the Wamitjara mountains to protect warru (black-footed wallaby, *Petrogale lateralis)*

Photo courtesy: John Read

Fixing a GPS collar to a feral cat

Photo courtesy: Judy Dunlop, DBCA

ABBREVIATIONS

ABS	Australian Bureau of Statistics
AVA	Australian Veterinary Association
BAM Act	*Biosecurity and Agriculture Management Act 2007*
BC Act	*Biodiversity Conservation Act 2016*
Cat Act	*Cat Act 2011*
CISS	Centre for Invasive Species Solutions
CRC-P	Cooperative Research Centres Projects
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBCA	Department of Biodiversity, Conservation and Attractions
DLGSC	Department of Local Government, Sport and Cultural Industries
DPIRD	Department of Primary Industries and Regional Development
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
IK	Indigenous knowledge
LCDC	Land Conservation District Committee
NACC	Northern Agricultural Catchments Council
NESP	National Environmental Science Program
NGO	Non-government organisation
NRM	Natural Resource Management
PHCC	Peel Harvey Catchment Council
RBG	Recognised Biosecurity Group
RSPCA	Royal Society for the Protection of Cruelty to Animals
SWCC	South West Catchment Council
TSR	Threatened Species Recovery Hub
WABSI	The Western Australian Biodiversity Science Institute

Photo courtesy: Hugh McGregor

2. INTRODUCTION

BACKGROUND CONTEXT

Invasive alien species are one of the greatest threats to native biodiversity, and also threaten human livelihoods via impacts on agriculture, health and recreation (Cresswell and Murphy 2016). Managing invasive species in Australia across natural, urban and agricultural ecosystems has been the focus of considerable policy, research and management effort. However, despite the significant impacts of invasive species, and the billions of dollars being spent every year on preventing further incursions and controlling existing introductions (Pimentel 2011; Hoffmann and Broadhurst 2016), there is an increasing mismatch between the threat from invasive alien species in Australia and the solutions deployed to adequately address the problems they create. There is an urgent need to increase the effectiveness of existing invasive species control, through addressing knowledge shortfalls together with prioritising and coordinating management.

Domestic cats (*Felis catus*) are considered one of the most threatening invasive alien species worldwide. They were first introduced into Australia by European settlers in the late 18th century, and had become feral in Western Australia by 1840 (Dickman 1996; Abbott 2002; Abbott 2008). By 1890 cats occupied over 90% of the continent, and they now occur pervasively across mainland Australia and on about 100 offshore islands (Figure 1; Abbott 2008, Legge *et al*. 2017).

Domestic cats *(Felis catus)* are considered one of the most threatening invasive alien species worldwide.

Photos courtesy (From top: Sue Robinson and Luke Gadd, and John Augusteyn)

A detailed synthesis for cats in Australia with regard to their ecology, their impacts on biodiversity, relevant policy and management methods has been covered from an Australian context by a trio of recent reviews. Woinarski *et al*. (2019a), Read (2019) and RSPCA Australia (2018) provide a detailed insight that for the first time synthesises decades of research, going well beyond the overview provided here. These reviews build on earlier syntheses on cat ecological impacts and management in Australia (e.g. Dickman 1996; Denny and Dickman 2010; Doherty *et al*. 2017). Here we build on these syntheses, and the recommendations they contain, to inform the development of this research program.

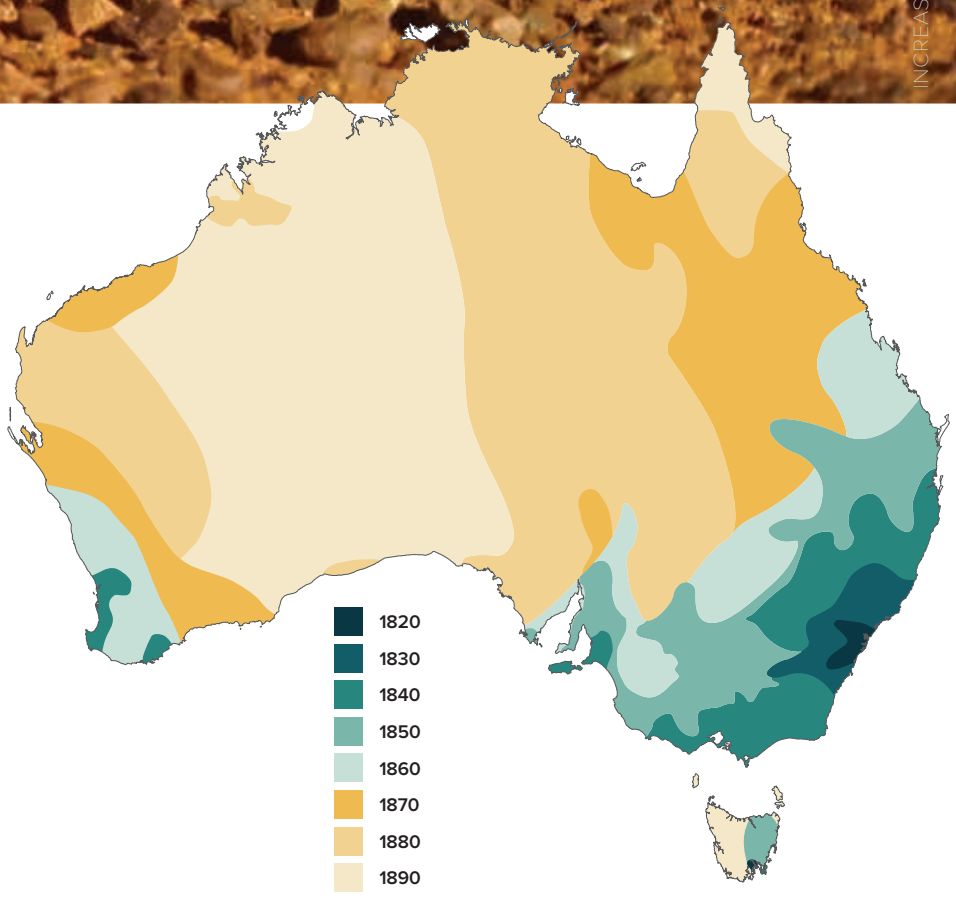


FIGURE 1. The estimated expansion over time of cats across Australia.
Source: Modified from Abbott (2008)

TERMINOLOGY MATTERS:

Pet, owned, domestic, non-domestic, stray, semi-owned, free-roaming, semi-feral, unowned, feral

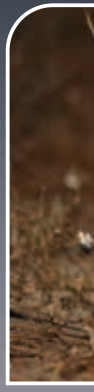
Domestic cats (*Felis catus*) can be grouped into categories based on where and how they live (RSPCA Australia 2018). In reality, these categories of cats are more or less arbitrary designations along a continuum (Crowley *et al*. 2019). Individuals may move from one category to another, although it is not clear how frequent or context specific this movement is. Unfortunately, a lack of consistent terminology for these categories causes confusion and disagreement, creating inconsistencies in legislation and challenges with implementing management strategies and enforcing regulations.

In Western Australia, cats are generally assigned from a management perspective to one of three categories: domestic, stray and feral, although all prey on native fauna. Feral and domestic categories are used by the *WA Biosecurity and Agriculture Management Act 2007* and the policy statement that supports it provides further definitions (DPIRD WA 2019).

Elsewhere, cat category terminology is applied in contrasting and often inconsistent ways. For example, in Queensland legislation cats have been classified as either *domestic*, or *non-domestic*. In the USA and Europe, *free-roaming* and *feral cats*, respectively refer to what Western Australia terms '*stray cats*'. This terminology mis-match creates problems – when Australian content uses the term *'feral cat'*, it frequently attracts criticism from international cat welfare agencies, which can result in misdirected propaganda.

There is a clear need for consistency of terminology nationally in Australia, which will allow for recognition of the issue internationally. To achieve this consistency, there is a need for a balanced, evidence-based and fully inclusive conversation around the pros and cons of chosen terminology, and the implications for management that this choice creates. For clarity and in alignment with Western Australian legislation, this document will use three categories – *pet*, *stray*, *feral* – where differentiation is appropriate. When no category is mentioned, it should be assumed the statement is inclusive of all three categories.

- **PET CATS** (domestic, owned) live with and are generally dependent on humans for food and habitation; they are socially important and are legally permitted in Australia. There is legislation in most states regarding ownership and variable requirements to register, sterilise and identify (i.e. microchips, collars) the animal.
- **STRAY CATS** (semi-feral) are often found in and around urban areas, rural properties, industrial areas, refuse tips and wastelands. They are either in self-sustaining populations or become stray following neglect or irresponsible pet ownership; some depend on resources provided by humans, but they are generally not registered. Most strays are not desexed or vaccinated but some may have been a pet cat at some stage of their life.
- **FERAL CATS** live as wild animals in self-sustaining populations in natural habitats of all types, detached from humans and survive exclusively by hunting and scavenging.



Australian fairy tern (*Sternula nereis nereis*)
Photo courtesy: Claire Greenwell

Across Australia, feral cats kill 272 million birds, 466 million reptiles and 815 million mammals every year.

The primary rationale for more effective management of cats relates to their impact upon native animals. Regardless of their categorisation, all cats are the same species, *Felis catus*, and all will kill prey, given the opportunity. Predation by cats has been a significant factor in 27 of the 47 extinctions of Australian reptiles, birds and mammals (Woinarski *et al*. 2019a), and threatens 75 critically endangered and near threatened mammal species (Woinarski *et al*. 2015), as well as 40 threatened birds, 21 reptiles and four amphibians (Department of the Environment 2015a). Estimates of the number of feral cats in Australia vary, but empirical modelling suggests approximately 2.1 million feral cats in natural environments (range c. 1.4 to 5.6 million), with mean feral cat density at approximately 0.27 cats per km^2 (Legge *et al*. 2017). Whilst the density of feral cats in Australia appears low, they are estimated to consume 272 million birds, 466 million reptiles and 815 million mammals every year (Woinarski *et al*. 2017; Woinarski *et al*. 2018; Murphy *et al*. 2019). Together with the prey of stray and pet cats, this translates into 2.2 billion birds, reptiles and mammals killed by cats in Australia every year. Focusing on impact in Western Australia, this represents around 720,000 feral cats annually consuming 544 million birds, reptiles and mammals across the State, with an additional 224 million birds, reptiles and mammals killed by stray and pet cats (J. Woinarski, pers. comm.). As concluded by Woinarski *et al*. (2019a), "apart from the influence of humans alone, it is likely that – because of their pervasiveness, abundance and hunting effectiveness – cats have subverted Australian nature more than any other species."

In addition to direct predation, cats can also impact native species through competition and indirect impacts. Cats may compete with other native predators for prey and territory. Glen *et al*. (2011) showed the diets of the feral cat and endangered spotted-tail quoll (*Dasyurus maculatus*) overlap, which could result in competition should resources become scarce. Cats are host to a number of disease-causing bacteria and viruses, with more than 100 pathogens recognised, 30 of which are also recorded in native mammal species (Moodie 1995; Denny and Dickman 2010). These diseases can also have detrimental impacts on human health and livestock production (Dubey 2009b; Dubey 2009a; Fancourt and Jackson 2014; Taggart *et al.* 2019). In Australia, there are four significant diseases of humans and livestock for which cats are the most important vector: toxoplasmosis (caused by *Toxoplasma gondii*), cat roundworm (*Toxocara cati*), cat scratch disease (*Bartonella henselae*) and sarcosporidiosis (caused by *Sarcocystis* spp.; Woinarski *et al.* 2019a).

Where feral cats have been effectively controlled, there have been noticeable benefits to native fauna (Risbey *et al*. 2000; Moseby *et al*. 2011; Frank *et al*. 2014). For example, in the Dryandra Woodlands, an extensive baiting program by the WA Department of Biodiversity, Conservation and Attractions (DBCA), in conjunction with additional shooting and trapping by landholders, coincided with a local increase in woylie (*Bettongia penicillata*) and numbat (*Myrmecobius fasciatus*) detections (DBCA, unpublished data). Similar native animal increases in abundance were seen after feral cat control at Heirisson Prong near Shark Bay (Risbey *et al.* 2000).

Feral cat control in the Dryandra woodland area is mitigating the threat of predation to species such as the woylie (*Bettongia penicillata*) (far left) and numbat (*Myrmecobius fasciatus*) (left)

Photos courtesy: Robert McLean

EXAMPLES OF SPECIES AFFECTED BY CAT PREDATION

Brush-tailed mulgara (*Dasycercus blythi*)

Photo courtesy: Judy Dunlop, DBCA

Spinifex hopping mouse (*Notomys alexis*)

Photo courtesy: Judy Dunlop, DBCA

Boodie (*Bettongia lesueur*)

Photo courtesy: Robert McLean

Western pygmy possum (*Cercartetus concinnus*)

Photo courtesy: Robert McLean

Greater bilby (*Macrotis lagotis*)

Photo courtesy: Robert McLean

Western ground parrot (*Pezoporus flaviventris*)

Photo courtesy: Alan Danks DPaW

Australian fairy tern (*Sternula nereis nereis*)

Photo courtesy: Claire Greenwell

Northern spiny-tailed gecko (*Strophurus ciliaris*)

Photo courtesy: Judy Dunlop, DBCA

Wailing Frog (*Cyclorana vagita*)

Photo courtesy: Greg Harold, Lochman Transparencies

Fitzgerald National Park

Photo courtesy: Megan Hele

While it is clear that controlling stray and feral cats is one of the highest priorities for conserving biodiversity across all Australian states and territories, exactly how they are controlled is critical for positive biodiversity outcomes due to direct and indirect ecosystem effects (Bergstrom *et al*. 2009; but see Springer 2018). For example, more complex community interactions involving cats, such as mesopredator release, are less clear in terms of their outcomes for native biodiversity (Marlow *et al*. 2015; Kinnear *et al*. 2017). It has been suggested that dingoes (*Canis dingo / familiaris*) could suppress foxes (*Vulpes vulpes*) and feral cats (Letnic *et al*. 2009; Moseby *et al*. 2012; Wang and Fisher 2012). Other studies suggest that this finding may be highly context specific and not likely to be widely generalisable, at least not for feral cats (Allen *et al*. 2015; Fancourt *et al.* 2019).

Dingo (*Canis familiaris*)

Photo courtesy: Judy Dunlop, DBCA

European fox (*Vulpes vulpes*)

Photo courtesy: Jiri Lochman, Lochman Transparencies

EXISTING MANAGEMENT SOLUTIONS

Managing cats is challenging with no single, consistently effective control method available for the resources that are being allocated to the issue. Compared to foxes and rabbits (*Oryctolagus cuniculus*), research on the control of cats is less advanced and extensive, with most research on impact and management taking place in the last 30 years, with momentum building considerably in the last 10 years (Read 2019; Woinarski *et al*. 2019a). Currently, the primary options available for the direct control of feral cats are baiting, shooting and trapping. Exclusion fencing and isolation of prey species on islands provide physical isolation from predation pressure. These control options are often used in combination to manage feral cats. In urban and peri-urban regions, cage trapping is generally deployed for stray cats to avoid impacting pet cats in these areas. Some of these control solutions, however, are currently not available for private landholders; regulations constrain the private use of lethal baits and some traps, and the expense of exclosure fencing may be prohibitive for many land managers.

Lethal baits are recognised as a practical and cost-effective method that currently provide the greatest population reductions for feral cats at the landscape scale (Algar *et al*. 2013; Department of the Environment 2015a; Comer *et al*. 2018). However, the scale of bait deployment required and the resources (costs, time) this entails mean that baiting is generally targeted to locations that support species of significance that are threatened by feral cat and/or fox predation, or where conservation outcomes may be most critical (Doherty and Ritchie 2017) and there is minimal risk to non-target species. Importantly, sustained conservation benefit deriving from baiting in these areas depends upon the ongoing implementation of baiting programs. Baiting programs are designed to maximise bait encounter for cats and aim for an optimal deployment of c. 50 baits/km^2 for aerial baiting programs (Algar and Burrows 2004). Baiting programs, when combined with shooting and trapping, have proven to be effective at eradicating feral cats from all Western Australian islands that formerly supported cats, including the 628km^2 Dirk Hartog Island (the largest island in the world from which cats have been eradicated). Variable effectiveness is achieved on the mainland and is influenced by a range of factors (Algar and Burrows 2004; Clausen *et al*. 2015; Comer *et al*. 2018).

At present, lethal baiting options in Western Australia are restricted to the *Eradicat®* bait and any management with this bait remains tightly controlled. The bait uses 1080 (a derivate of sodium fluoroacetate), a toxin that naturally occurs in the endemic flora of the south-west of the State. Species that have coevolved in the presence of these plants have a

At present, there is no landscape scale control that is consistently effective for managing feral cats.

Setting traps for feral cats
Photo courtesy: Judy Dunlop, DBCA

ABOVE: Lorna Glen (Matuwa) fauna enclosure

Photo courtesy: Judy Dunlop, DBCA. INSET: John Read

naturally high tolerance to 1080 (Twigg and King 1991; Armstrong 2004; Comer *et al*. 2018). Consequently, large areas of conservation land in Western Australia can be aerially baited with baits containing 1080 with limited or no lethal impact on native species. However, the density and level of toxicity for flora species containing the toxin declines in northern portions of the State. Fauna populations that persist in areas outside of the natural distribution plants containing sodium fluoroacetate have a lower tolerance to the toxin. Therefore at present, landscape scale management using 1080 products is primarily limited to areas in the south-west of the State. For example, baits containing 1080 are the primary management technique used by DBCA's Western Shield program to manage predation of native fauna species by feral cats and foxes (Box 1, page 24). Improving bait uptake by cats, reducing bait uptake by non-target species, and improving bait palatability remain a high priority for further research.

At a local scale, shooting and cage trapping remain the primary forms of control that are accessible and affordable to all land managers. Trapping with leghold traps and smart traps (e.g. Felixer) are not prescribed control techniques and cannot be used unless for research purposes with an ethics committee approval. The use of exclusion fencing is often the only viable option for cat control in some areas and for some highly imperilled (i.e. cat sensitive) mammal species. Western Australia has nine of Australia's 23 mainland exclosures that are cat-free (Legge *et al*. 2018). However the installation cost and ongoing maintenance requirements of these exclosures have meant that they are only being installed on a relatively small scale (currently to 123km^2; Legge *et al*. 2018), being usually more expensive than island eradications (Scofield *et al*. 2011). There is some concern that exclosures are creating predator-naïve populations (Jolly *et al*. 2018). This is not a problem *per se*, if the animals remain in exclosures, but may be an issue if they are being used for founder populations outside fences elsewhere. These species also require active management to combat genetic founder effects, small populations and the disruption of gene flow, which is a problem of their rarity irrespective of whether or not they are within exclosures. In some circumstances exclosures may result in over-population of some enclosed mammal species, with consequent environmental degradation.

Felixer grooming traps target feral cats' grooming behaviour by squirting a toxic gel onto their fur
Photo courtesy: Judy Dunlop, DBCA

EMERGING MANAGEMENT SOLUTIONS

The ongoing challenges in mitigating the impacts of cat predation on biodiversity emphasises the need to improve available control methods, including novel control methods, and better understand and be able to apply these in the right combination. Progress toward developing new methods has focused primarily on two areas: more effective delivery of toxins via baits and traps designed to exploit behavioural traits of cats and genetic pest control. Guardian and detection dogs are also showing promise as control methods in certain contexts, the latter particularly for 'problem' cats (Glen *et al*. 2016; McGregor *et al*. 2016a; Allen *et al*. 2019; Woinarski *et al.* 2019a).

Enhancing toxin delivery by exploiting behavioural traits is a way in which the efficiency, effectiveness, non-target impacts and humaneness of current control methods can be significantly improved. With an increasing focus on animal welfare, the humaneness of toxins is also an important consideration. Baits are currently under development or in approval stages, which contain the lethal toxin within a tough acid-soluble plastic pellet (hard shell delivery vehicle; HSDV). These encapsulated baits offer improved protection to many (but not all; Buckmaster *et al*. 2014; Johnston *et al*. 2018) native species by exploiting differences in the feeding strategies between cats and non-target species. That is, cats have a propensity to swallow chunks of flesh or whole prey, whereas most native species will eject the capsule after consuming a bait. In addition to 1080 capsule baits (*Hisstory®*), the toxin para-aminopropiophenone (PAPP) is being developed as a bait (*Curiosity®*), to allow baiting in areas where 1080 is unsuitable for use due to non-target impacts. PAPP is highly toxic to cats as well as some native species, so a capsule bait is required to reduce non-target impacts. Risks of non-target take can be reduced further (e.g. for veranids) by baiting in temperate areas during cooler months when the reptiles are in torpor.

Felixer grooming traps identify cats (from other animals) and deliver a toxic gel onto their fur as they pass in front of the traps. These devices are examples that circumvent the limitation that cats are less interested in inanimate baits, while also helping to reduce non-target impacts (Read 2010; Read *et al.* 2015; Read *et al*. 2019). Ongoing improvements to the Felixer device are being trialled in several Australian states, including Western Australia, but costs are currently prohibitive for broad-

scale deployment. In limited situations, 'population-protecting' implants ('PPIs': toxic capsules implanted into individuals of prey species in a manner that causes no harm to the host animal, but then kills any predator that eats it) are another way to more effectively deliver toxins to feral cats, especially for individual cats that selectively hunt highly imperilled species (Read *et al*. 2016). These devices target situations where an individual predator can be responsible for significant faunal mortalities in a small region (Hardman *et al.* 2016). Such cases may be common in mammal reintroduction programs, which are particularly resource demanding (Moseby *et al*. 2015). Using a toxic collar or implant (i.e. a toxin-containing capsule stable in subcutaneous tissue that dissolves at a lower pH when digested), predators can be selectively targeted before they have had a chance to decimate a local population. Unless the mode of delivery or cost of deployment is changed, these methods remain local in scale and are unlikely to achieve landscape-scale impacts on cat numbers.

Gene editing technology is considered one of the most potentially effective future control options under development for invasive alien species where self-dissemination of the gene drive enables longer-lasting effectiveness of control. While the theory behind this approach is quite well advanced, the controversial nature of gene-editing has led to an early focus of research on risks, public acceptability and regulatory implications (Webber *et al*. 2015; Moro *et al*. 2018). The social licence aspects of such a control solution are arguably just as important as the technology itself, which is why this is a high early research priority. Synthetic gene drives could be used to force deleterious traits (many are being considered) through target populations or lead to male-only progeny. Alternatively, gene shears could be carried within germ cells that shred a sex chromosome to achieve the same result. Other potential approaches are still under development, including safety mechanisms to prevent uncontrolled spread to other species and the theory and understanding of their likelihood of success. Gene-editing technology is delivered and spread only through sexual reproduction, and therefore cannot spread into populations via sexually incompatible (or spayed/neutered) individuals.

For feral cats, gene editing has challenges relating to deployment at a national level into a large existing cat population with relatively long lifespans. Yet it would make pest eradications theoretically possible in a completely humane way. Australia is a unique location in which to consider such a control strategy for a number of targets, and particularly for cats, as there is a large evolutionary distance between native species and feral cats, although there are some knowledge gaps to close (Moro *et al.* 2018). In Australia, development of the technology is currently focused on the house mouse (*Mus musculus*; for rodent eradications on islands), and is likely to be at least 15 years away for cats. Moreover, we are lacking critical genome information in cats (particularly on the sex chromosomes to apply gene-editing that results in sex-ratio distortion) and much of the fundamental reproductive biology and population ecology knowledge within an Australian context to refine a gene editing control solution. Community acceptability and engagement of such a control solution remains just as important as the technology itself, and represent a high priority for progressing this emerging management solution. It is important to note that much of the information to address knowledge shortfalls for gene editing applications would also assist in more effective deployment of other control approaches.

At present there is little prospect for effective biological control of cats on mainland Australia using known cat diseases (Moodie 1995), reflecting concerns around the possible impact on pet cats and social acceptability of possible disease options (Strive and Sheppard 2015). Feline leukaemia virus, feline immunodeficiency virus and feline panleucopaenia virus are all present in Australia, but have low transmission rates where cat density is low. However, feline panleucopaenia virus was successfully used as part of an integrated control program against feral cats on one small sub-Antarctic island (Van Rensburg *et al.* 1987; Saunders *et al.* 2010) and, if social acceptability changes, may be effective as a control solution where cats occur at higher densities. If this approach was given further consideration, effective vaccinations are available for all three viruses to protect the pet cat population. As with any disease-causing biological control agent, humane aspects will also need to be considered to meet community expectations regarding animal welfare.

RELEVANT POLICY AND LEGISLATION

Commonwealth

At the national level, 'predation by feral cats' is listed as a Key Threatening Process under section 188 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Once a Key Threatening Process is listed under the EPBC Act, a threat abatement plan may be put into place if it is 'a feasible, effective and efficient way' to mitigate the threatening process and may be reviewed every 5 to 10 years. The first threat abatement plan for predation by feral cats was produced in 1999, and subsequently updated in 2008 and 2015 (Department of the Environment 2015a).

In July 2015, Commonwealth, State and Territory ministers endorsed a national declaration of feral cats as pests, after tackling feral cats was highlighted as an action area in the Threatened Species Strategy (Department of the Environment 2015b). This declaration placed feral cat management as a priority in threatened species recovery programs, required ministers to remove any unnecessary barriers to the effective and humane control of feral cats, and resolved to develop a national best practice approach to keeping pet cats.

State

Feral cats are now (since June 2019) declared pests in Western Australia under Section 22(2) of the *WA Biosecurity and Agriculture Management Act 2007* (BAM Act), administered by the Department of Primary Industries and Development (DPIRD). Feral cats have been designated to the unassigned-control-category, meaning that there is no obligation on individuals or agencies to undertake management of feral cats. Under this declaration, landholders will not be required to manage or control feral cats on their property. The main purpose for making the feral cat a declared pest is to remove unnecessary state-legislative barriers to the effective and humane control of feral cats in wildlife restoration and management programs and for consistency with the national declaration of feral cats as pests in 2015. The declaration allows for greater opportunity from a wider variety of land managers to control feral cats. However, the management of cats, for any reason, must be carried out in accordance with Commonwealth and State animal welfare requirements. This requirement has

Cat predation impacts on a wide range of animals

Photos courtesy: Michael Johnston INSET: John Read

not changed with feral cats becoming a declared pest under the BAM Act. DPIRD, in conjunction with DBCA, has developed the *Feral Cat Policy – Minimising Impacts to Domestic Cats* to address concerns that pet cats will be impacted by the declaration of feral cats as pests in Western Australia.

The *Biodiversity Conservation Act 2016* (BC Act) and *Biodiversity Conservation Regulations 2018* provide greater protection for biodiversity in Western Australia, and have recently replaced the *Wildlife Conservation Act 1950* and its regulations. The BC Act provides for not only listing threatened species by public nomination, but also for listing threatened ecological communities, critical habitats, and 'key threatening processes'. Key threatening processes are eligible to be listed if they meet the criteria in Section 35 of the BC Act, or the listing is otherwise in accordance with *Ministerial Guideline No. 6 – Key threatening processes criteria and listing*. Key threatening processes are generally identified in recovery plans prepared under Part 6 of the BC Act, which identify the factors that contribute to the listing of a species or ecological community as threatened. The impact of cats has not been listed as a key threatening process under the BC Act. While there are provisions in Part 9 of the BC Act that provide for environmental pest management and complement the BAM Act, these have not yet been proclaimed and are therefore not in force at this point in time.

There is additional Western Australia state legislation that pertains specifically to the pet (domestic) cat. The *Cat Act 2011* (Cat Act) came into force in 2013 to enforce responsible cat ownership and reduce unwanted pregnancies that can lead to kitten dumping. The Cat Act is presently undergoing a review with considerable opportunity for improvements in relation to mitigating predation impacts on native animals. The Act requires cats over six months of age to be sterilised, microchipped and to wear an identification tag (registered breeders can obtain exemptions from mandatory sterilisation). Cat curfews and penalties for dumping unwanted animals are also available at the discretion of local councils. The Act is administered by the Department of Local Government, Sport and Cultural Industries (DLGSC) and generally enforced by local governments. The Act does not require cat owners to keep cats contained, and therefore pet cats are still a threat to native wildlife when allowed to roam. The Cat Act is very rarely enforced, and so remains largely a theoretical solution in regard to mitigating the threat to biodiversity from roaming pet cats. Declaration of feral cats under the BAM Act does not impact on requirements under the Cat Act.

WHY WESTERN AUSTRALIA?

Western Australia is already a national leader in the management of feral cats, with a range of successes such as the eradication of feral cats from all offshore islands known to support cat populations and the Western Shield program led by DBCA (which includes a bait development program; Armstrong 2004) that delivers feral cat management to over 1.5 million ha (see Box 1). Western Australia leads the nation in island eradications, with cats extirpated from 770 km^2 across nine islands (Legge et al. 2018; Woinarski *et al.* 2019a). Some of the nation's most ambitious and extensive baiting, trapping and exclusion fencing programs are taking place in Western Australia, led by DBCA, non-government organisations (NGOs) and local Indigenous groups, and community initiatives. The issue of cat impacts on biodiversity is particularly pertinent in Western Australia because the State has responsibility for the last few natural populations of many animal species that have disappeared from the rest of their national range (e.g. numbat (*Myrmecobius fasciatus*), banded hare-wallaby (*Lagostrophus fasciatus*), golden-backed tree-rat (*Mesembriomys macrurus*), rufous hare-wallaby (*Lagorchestes hirsutus*)) or otherwise have become particularly imperilled (e.g. Gilbert's potoroo (*Potorous gilbertii*), night parrot (*Pezoporus occidentalis*), western ground parrot (*Pezoporus flaviventris*)) largely because of predation by cats (and foxes).

BOX 1

The Western Shield program – conservation through threat mitigation

Western Shield is the lead wildlife recovery program of DBCA's Parks and Wildlife Service.

It is one of the biggest wildlife conservation programs ever undertaken in Australia and aims to recover and sustain wild populations of Western Australian native fauna threatened by foxes and feral cats. Western Shield does this through:

- Ongoing effective landscape scale management of foxes and feral cats (primarily baiting, over a footprint of 3.7 million hectares most of which is conservation reserve);
- Native fauna population enhancement through translocation;
- Adaptive management informed by scientific evidence from research and monitoring; and
- Collaboration with industry, non-government organisations and community to promote native fauna conservation.

Monitoring of native species and target animals (feral cat and fox) allows DBCA to track fauna trends and the effectiveness of management. Initially, management of foxes was the predominant strategy put in place to achieve fauna recovery. Research has allowed for the development of new bait type variants like *Eradicat®*, which is now being integrated as part of baiting prescriptions to address the threat of both foxes and feral cats.

Recent initiatives to improve the management of cats in Western Australia have included a workshop focused on introduced predators in the Pilbara (Moro *et al*. 2016), a meeting amongst the NRM sector in 2016 focused on feral cat control, a Western Australian-led publication on the knowledge gaps relating to improving management using gene drive technology for selected introduced species in Western Australia (Moro *et al*. 2018), and the Western Australian Feral Cat Symposium led by Peel Harvey Catchment Council in 2018 (Peel Harvey Catchment Council 2018). Taken together, this is evidence of clear momentum toward improving cat management in the State. However, there is a great deal of opportunity still to be realised from the foundations laid by these earlier events. As such, the long-established successes by Western Australian scientists and agencies in the management of feral cats and the conservation of cat-threatened species, more recent initiatives and some nationally recognised management leadership, places Western Australia in an ideal position to lead the nation in regard to improving feral cat management outcomes.

Momentum around the case for establishing a Western Australian Feral Cat Working Group provides an ideal platform to ensure research outputs generated by a WABSI research program are effectively shared amongst stakeholders and effectively translated into on-ground outcomes. The need for a state-wide group to facilitate improved management of feral cats in Western Australia was the highest priority recommendation to emerge from the first workshop held to develop this research program. Furthermore, the concept of a working group has now been endorsed by the National Feral Cat Taskforce and the Western Australia Biosecurity Council.

Any initiatives developed in Western Australia are likely to have clear relevance to the management of cats and predator-susceptible threatened native species elsewhere in Australia. As with the management of all invasive species, this matter is a tenure blind issue that crosses administrative boundaries. To maximise relevance, the initiatives proposed as part of this program would need to align with existing strategies, such as the national Feral Cat Threat Abatement Plan, and existing research initiatives, such as the program taking place as part of the Australian Government's National Environmental Science Program (NESP) Threatened Species Recovery Hub.

Management solutions for mitigating feral cat impacts

Photos courtesy: DBCA

Photo courtesy: Hugh McGregor

3. PROGRAM OBJECTIVES

There is growing momentum on the need to improve outcomes from feral cat management programs in Australia, and a recognition that research to address knowledge gaps, with associated funding provision, is a critical part of that need. Current direct control options have considerable scope for improvement, as well as integration with indirect control methods, such as the management of fire, grazing and apex predators (e.g. dingoes), and biosecurity provisions to constrain the introduction of cats to islands on which they are not yet established. Furthermore, emerging control methods require more development before they can be considered for wide scale deployment.

Significant knowledge gaps remain, relating to cat ecology, impacts and management, particularly that relate to local context in the range of environments across Western Australia (Moro *et al.* 2018; Read 2019; Woinarski *et al.* 2019a). Such knowledge is equally relevant to improving existing control methods as it is to developing new technologies. Moreover, with an increasing focus on investigating the potential for new and ideally more effective control techniques while improving animal welfare outcomes, there is an increasing need for research that focuses on community engagement and social licence.

Current direct control options have considerable scope for improvement.

This program recognises the:

- Importance of addressing the threat cats represent to the conservation of biodiversity in Western Australia;
- Need to address knowledge gaps as a critical component of this desired outcome; and
- Importance of retaining and improving social licence for cat control.

It is also recognised that there is significant complementarity to the program, particularly in regard to better defining and quantifying the impacts of cats on agriculture and on human health, and improving the awareness of responsible and ethical pet cat ownership. A program of prioritised research to address these knowledge gaps will help to improve management outcomes, and assist the national conversation on the impact of cats on native fauna. As such, the objective of this research program is to provide a prioritised framework for increasing knowledge to improve cat management in Western Australia. This program will encourage complementarity and collaboration, will help to identify the resources and funding required, and will provide clarity on how best to translate research findings into improved on-ground outcomes.

VISION

Address priority knowledge gaps through new research, facilitate the translation of insights into effective on-ground outcomes to enable the improved management of cats, thereby enhancing the conservation of native species in Western Australia.

OUTCOME

An increased understanding of how to mitigate the impact of cats on native species through improved control programs to facilitate the recovery of threatened fauna in Western Australia.

BELOW: Cat control programs assist in the management of threatened species such as the spectacled hare-wallaby (*Lagorchestes conspicillatus*)

Photos courtesy: Gregory Andrews (left) and Judy Dunlop, DBCA (right)

4. PROGRAM STAKEHOLDERS

Stakeholders of this research program include:

- The research community, in Western Australia, nationally and internationally, whose members are working towards developing more effective, efficient and humane solutions for managing cats;
- Government organisations (local, state and federal), some of whom invest resources into the conservation of threatened species, through controlling feral cats and who are actively involved in the deployment, research and outreach elements of cat management;
- Natural Resource Management (NRM) organisations, Recognised Biosecurity Groups (RBGs), Land Conservation District Committees (LCDCs) and other organisations who frequently lead community conservation or biosecurity initiatives by bringing together rural landholders and stakeholder groups;
- Indigenous land owners and managers, including Aboriginal Corporations and ranger groups with an interest in managing their country for biodiversity values (including areas where feral cats are having considerable impact);
- Non-government conservation organisations (NGOs) dedicate considerable time and resources towards re-introducing native species and controlling cats;
- The animal welfare sector, including the Royal Society for the Protection of Cruelty to Animals (RSPCA) and the Australian Veterinary Association (AVA), who represent the interests of target and non-target animals by promoting and advising on best practice to safeguard animal welfare;
- Cat owners, who have a moral imperative to improve the management of pet cats to deliver considerable benefits beyond those relating to native biodiversity, including their own health and that of their pet cat;

Photo courtesy: Judy Dunlop, DBCA

- The compliance and regulatory sectors, including government at the local, state and federal levels, that are working to ensure cat management policy remains relevant for biodiversity conservation;
- The agricultural sector, whose ability to productively manage their land may be impacted by cats, their diseases and their control;
- The environmental consulting and contractor sector, including pest management technicians, that are implementing cat management programs and who would benefit from improvements to control options;
- The mining sector, through offset and policy driven requirements, as well as best practice environmental management and restoration efforts, is undertaking cat management programs on land under their tenure;
- The tourism sector, which relies on Western Australia's natural environment, often including animals directly threatened by cats, for a significant component of their appeal to visitors;
- The Australian Defence Force, committed via the Australian Threatened Species Strategy and the Threat Abatement Plan for predation by feral cats and is undertaking best practice cat management on their extensive military training areas in the State;
- Animal rights organisations, that have a focus on advocating for issues relating to the morals and ethics of animal 'use' and 'value'; and
- The general public, which has an interest in the general wellbeing of animals and the conservation of native biodiversity.

5. VALUE PROPOSITION

Australian fairy tern (*Sternula nereis nereis*)
Photo courtesy: Claire Greenwell

The benefits of this research program for feral cats can be broadly grouped into three categories: environmental, economic and social. Conversely, and of equal importance to the value proposition of a research program on feral cats, is the need to examine impacts if such a program does not exist (i.e. the counterfactual).

ENVIRONMENTAL CONSIDERATIONS

Predation by cats is responsible for population declines across a broad spectrum of native vertebrate species, including birds, mammals and reptiles, many of which are classified as threatened. Cats are likely to have been a significant factor in 27 of the 47 extinctions since European settlement of reptiles, birds and mammals native to Australia, and a contributor to an additional seven extinctions (Woinarski *et al*. 2019a). Many surviving mammal species (and some bird and reptile species) continue to decline because of cat predation, with some of these species now perilously close to extinction. Alarmingly, it is currently estimated that on average cats consume over 2.2 billion birds, reptiles and mammals every year in Australia (Woinarski *et al*. 2017; Woinarski *et al.* 2018; Murphy *et al*. 2019). Although unquantified, it is likely that cat predation has negative impacts on invertebrate species too (Woinarski *et al*. 2019a). If nothing is done to mitigate these impacts, in all likelihood more of Western Australia's iconic and endemic vertebrate species will be made extinct in the near future (Geyle *et al*. 2018). These species are not only unique, but also are thought to perform vital ecosystem functions and services that can benefit us as a society (e.g. increased agricultural productivity as a result of soil bioturbation and ecosystem engineers supporting floral diversity; Fleming *et al*. 2014; Ryan *et al*. 2019).

ABOVE: Painted button quail (*Turnix varia*) and mottled ground gecko (*Diplodactylus squarrosus*)

Photos courtesy (From L–R): Robert McLean and Megan Hele

Cats are likely to have been a significant factor in 27 of the 47 extinctions since European settlement.

Improving our understanding of the behaviour and ecology of feral and stray cats, as well as the impact current control methods have on cats and non-target species, will provide an evidence-based system for comparing control outcomes in terms of their effectiveness, cost and humaneness, including non-target and unintended impacts (Doherty and Ritchie 2017). There are differing views amongst stakeholders as to how much of an issue these impacts have, suggesting that detailed quantified insight could improve the consensus. Together with improved insight on the impacts of cats on prey species, we will then be in a position to understand animal welfare issues from all dimensions. Such knowledge is equally relevant to refining existing control methods as it is to developing new technologies, such as those based on gene editing. Ultimately, improved knowledge that can inform decisions for managing cats will translate into improved conservation outcomes for Western Australia's – and indeed Australia's – unique biodiversity.

ECONOMIC CONSIDERATIONS

From an economic standpoint, this research program has the potential to improve funding opportunities for the management of cats by providing clear evidence of the efficacy of each control option and the likely positive outcomes for threatened species. Limited funds for managing cats can be targeted more precisely while also articulating a stronger value proposition for increasing resourcing as appropriate.

Control costs

By robustly comparing the efficacy of different control options for managing cats, this program of research will help to clarify which management options are likely to be most cost-effective for controlling cats within a given local context, for a given conservation objective and over short- and longer-term time scales. Unlike other pests that have well-resourced control programs due to their economic impacts on agriculture (e.g. wild dogs, rabbits, foxes; Wool Producers Australia 2014; Cox *et al*. 2019), prioritising and resourcing cat control has been harder to achieve because of a perceived lack of financial impetus. From a control perspective, a 'cost per cat kill' figure is alluring to monetise control and identify efficiencies. Such a figure can be misleading, however, because it is removing the cats that pose the biggest threat to wildlife that is the primary concern (Moseby et al. 2015). For example, a starving cat dying from baiting is far less important for mitigating predation impacts on biodiversity, relative to taking out a healthy cat that is less likely to consume a bait, because these suboptimal hunters are likely to die regardless.

Also more important than the numbers of cats killed is the need to enduringly reduce cat density below levels at which they have significant impact. Because baiting programs in mainland areas do not eradicate cats, the baiting programs (and their expense) need to be maintained more or less perpetually. Even so, current estimates suggest that for each feral cat killed via aerial baiting, DBCA spend around $250, with an overall spend of approximately $500,000. It is likely that further research to improve the effectiveness of baiting programs could see even greater returns on this investment.

Current alternatives to baiting programs are also expensive. Island eradications have been costed at between $600 per km^2 (Faure Island, 2010) and $26,000 per km^2 (Macquarie Island, 2009). For example, the cat eradication program on Dirk Hartog Island in Western Australia cost approximately $6.3M (Department of Biodiversity Conservation and Attractions 2019). Exclosures, on average, cost $30,000 per linear km of fencing with subsequent eradication costs of $2,000 per km^2, as well as relatively high ongoing maintenance costs as a proportion of the area protected (reviewed in Woinarski *et al*. 2019a). Exclusion areas and islands have an initial high capital expenditure, but a relatively low ongoing cost (compared to the cost of perpetual baiting programs). While their overall costs reduce with time, exclosure fences need to be regularly patrolled for maintenance and there is often an ongoing cost of management of the animals within the exclosure. The fences can also impact on the movement of some native wildlife, leading to injury or mortality from fence strike and disrupting gene flow (Hayward and Kerley 2009).

The cost of trapping and shooting is highly variable, according to the density of cats, the features of the landscape and the skillset of the hunter. Molsher (2001) studied the use of leghold and cage traps on feral cats over a two-year period, and averaged 1.3 cats per 100 trap-nights. Costing such activity is notoriously challenging (but see Ruykys and Carter 2019). Moreover, shooting and trapping are generally deployed as part of an integrated management program; on their own they rarely result in a significant decrease in overall cat numbers (Parkes *et al*. 2014).

Looking further ahead, this program of research will also provide both the data and the incentive to develop new approaches for controlling feral cats that may not only be more cost-effective but also more humane (e.g. gene editing solutions).

Control gains

There is a certain link between Australian identity and native wildlife, which has untold social value and mental health benefits. In addition to what could be viewed as a moral imperative to respond to ecological threats, there are also financial and legislative drivers to conserve biodiversity. By encouraging the recovery of charismatic native species, effective feral cat control will translate into more opportunities to develop a strong tourism industry centred around Western Australia's unique biodiversity (e.g. quokkas (*Setonix brachyurus*) on Rottnest Island which have prospered since feral cats were eradicated; Algar *et al*. 2011; see Box 2). A functional suite of native fauna in Western Australia has a specific dollar value that is most pronounced in tourism, and is directly threatened by feral cat predation. Woinarski *et al*. (2019), using data on the economic value of birds, estimate a cost of over $30 billion per year for predation of our native birds, mammals and reptiles by cats.

Feral and stray cat populations also present a considerable disease risk to both agriculture and human health. This includes toxoplasmosis, which can threaten lifelong mental health in addition to pregnancy issues, and sarcosporidiosis impacts on livestock (Torrey and Yolken 2013). These costs have been estimated at well in excess of $1.2 billion per annum for toxoplasmosis, and around $1 million for sarcosporidiosis on Kangaroo Island alone, and could be far higher if particular diseases not yet in Australia were to arrive (Woinarski *et al*. 2019a).

BOX 2 – CASE STUDY

The value of quokka selfies

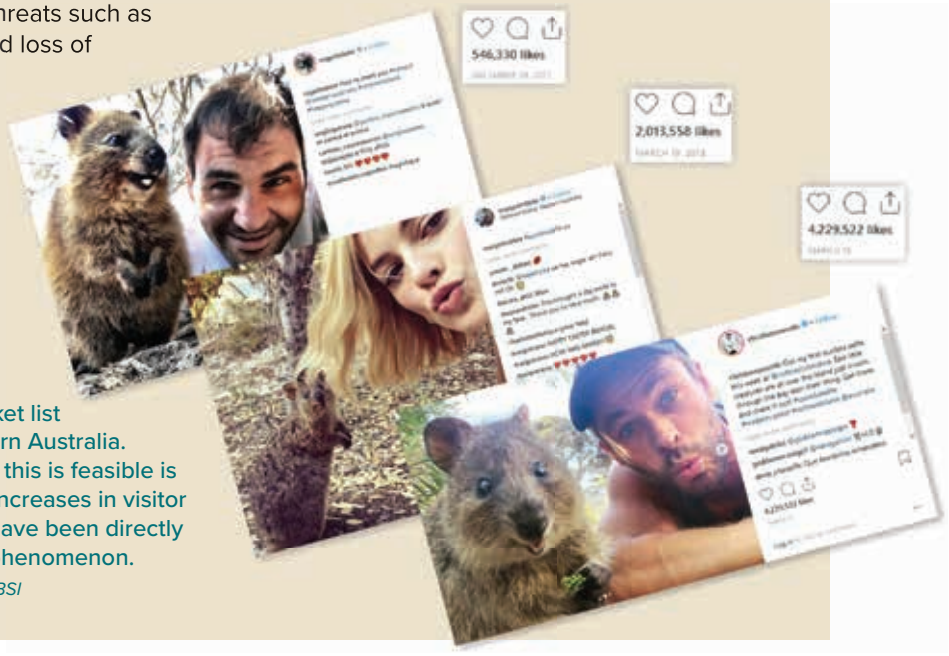
The global appeal of natural landscapes and our native flora and fauna is a tourism drawcard for Western Australia. Cats not only represent a direct threat to this significant source of revenue and employment for the State, but arguably limit what could be a considerably greater appeal if cat predation of native animals was mitigated. A case in point is the broad appeal of interacting with quokkas (*Setonix brachyurus*) as an essential part of a visit to Rottnest Island. Yet the 'bucket list' priority of getting a quokka selfie may never have developed had it not been for the management of feral cats on the island.

Cats were present on the island since European settlement, and the island's management authority started removing feral cats in the 1960s. In 1980, all pet cats (c. 20 individuals) were removed from the island. Feral cats were finally eradicated from the island in 2002 with a trapping removal program (Algar *et al*. 2011), with subsequent increase in quokka numbers and 'tameness'.

International visitors and the 'quokka selfie' have been associated with a 25% increase in visitors to Rottnest Island since the campaign began in 2015/16. With Rottnest tourism valued at $34.73M in 2015/16 and $42.25M in 2018/19, feral cat control on the island could be credited for providing a return of over $7M per annum to Western Australian tourism.

As a driver of missed revenue, if the broad tourism appeal of quokkas extended to the other equally appealing critical weight mammals of Western Australia, then the State is foregoing a potentially very large revenue stream. For example, high likelihood sightings of bilbies (*Macrotis lagotis*), numbats (*Myrmecobius fasciatus*) and boodies (*Bettongia lesueur*), as well as quokkas, could easily promote tourism in other parts of the State.

While recognising that other threats such as climate change, foxes, pigs and loss of habitat are also key threats to our native fauna, feral cats represent a direct threat to this significant source of existing (and potential) revenue and employment for the State.



The 'quokka selfie' is rapidly gaining acceptance as the bucket list thing to do when visiting Western Australia. Currently, the only place where this is feasible is on Rottnest Island, and recent increases in visitor numbers to Western Australia have been directly attributed to this social media phenomenon.

Photo courtesy (top): Bruce Webber, WABSI

SOCIAL CONSIDERATIONS

From a social point of view, this research program will play a key role in driving and informing the discussion around how to most effectively approach cat management in Australia. The key to ongoing social licence for cat control is enabling an open and informed forum for discussion among all relevant stakeholders. This discussion needs to convincingly address why there is a need to control stray and feral cats, including the animal welfare consequences of inaction, but also how this can be done as humanely as possible and without impacting in a negative way on the benefits of keeping cats as pets. In doing so, it will also pave the way for future discussions surrounding emerging technologies, including gene editing, as additional solutions to improve the management of cats in a way that is more effective and humane.

Animal welfare

It is beyond dispute that cats are a serious pest in Australia and have severe to catastrophic effects on native fauna (Woinarski *et al*. 2015). There is also little debate about the need to protect native fauna from cat predation (Travaglia and Miller 2018). However, there are some sections of the community that continue to express concerns about the welfare of animals impacted by feral animal control, and through advocacy and lobbying can bring about financial and political barriers to feral animal management. Proactively sharing accurate information, countering misinformation, and retaining trust by being transparent are all issues that need to be considered to ensure social licence is retained for research on and management of cats across Australia.

In 2011, the Australian Government produced a humaneness assessment model aimed evaluating the impact of a pest animal control method on individual animals. There is scope to further expand the humaneness model for feral cat control methods not already included (Sharp and Saunders 2011). All control, however, should consider the suffering of prey targeted by cats and non-target animals impacted by control programs alongside any suffering of the cats themselves.

Social fulfilment

Cats have significant impacts on human society, both positive and negative. This research program will ensure that those benefits that cats provide to humans as a companion animal remain, while also working towards reducing negative social impacts.

Many of the small to medium mammals, reptiles and birds that are threatened by feral cats are culturally significant to Indigenous people, both as an intrinsic part of people's connection to country, and as a food source. Reducing the impact of feral cats on these species as part of broader Indigenous land management programs will contribute to improved wellbeing for Indigenous people, particularly in remote Australia. On the other hand, feral cats have also become a food for some Indigenous communities (most likely replacing animals that have become extinct or rare). Keeping Indigenous land managers at the forefront of research and management programs on their lands will help maintain a social licence and ensure positive social and cultural impacts of feral cat management.

Volunteers checking traps in the Pilbara
INSET: Feral cat caught on a camera trap
Photos courtesy Judy Dunlop, DBCA

Yellow-footed antechinus (*mardo; Antechinus flavipes*)
Photo courtesy: Robert McLean

THE COST OF BUSINESS AS USUAL

Australia holds the record for the highest number of mammal species extinctions since 1500, with 34 mammal extinctions over that period (Woinarski *et al*. 2019b). Cats are likely to have been a significant factor in 27 of the 47 extinctions since European settlement of reptiles, birds and mammals native to Australia, and a contributor to an additional seven extinctions (Woinarski *et al*. 2019a). But these extinctions do not mean that the losses and declines have ceased: more than 140 extant species of mammals, reptiles, birds and frogs remain threatened by feral cats. Cats also represent a disease and predation risk to agriculture, and a disease risk to humans. Despite these clear threats and negative impacts, there has not, as yet, been a willingness to invest substantially in a state-wide program of research and management to mitigate the impacts of feral cats on native animals.

Failing to mitigate this significant and ongoing threat would impact in at least four ways:

1. Not enacting more effective management for cats would lead to an increasing extinction risk (and would reduce the likelihood of recovery) for many native fauna species. Not investing in either improving existing controls or developing novel controls is likely to lead to further extinctions;
2. Not addressing knowledge gaps to improve cat management will mean that the State must invest in ongoing funds to control cats without necessarily achieving satisfactory conservation outcomes for threatened species;
3. A lack of effective management to control cats would allow the heightened risk of transmission of toxoplasmosis (for humans and livestock) and sarcosporidiosis (for sheep) to remain prevalent, albeit largely unquantified in terms of impact; and
4. The indirect impacts of doing nothing flow onto a variety of areas where there are opportunity costs due to declining native biodiversity values. Native species diversity in many areas of Western Australia is a significant draw card for tourism. Without improved feral cat control, these visitation rates could fall, reducing tourism revenue for the State.

Photo courtesy: Judy Dunlop, DBCA

6. CURRENT RESEARCH IN WESTERN AUSTRALIA

Research on feral cats in Western Australia has a long history, with a broad remit of research focusing on cat ecology, impacts and control. This section highlights just some of the past and current research as it applies to Western Australia.

DEPARTMENT OF BIODIVERSITY, CONSERVATION AND ATTRACTIONS

The Department of Biodiversity, Conservation and Attractions (DBCA) has been involved in a variety of research to improve outcomes from managing feral cats. DBCA's predecessor agencies commenced lethal bait development in Western Australia in an endeavour to develop a smaller and more palatable bait medium that would be attractive to feral cats. The bait also had to be capable of carrying a toxin, relatively easily and cheaply manufactured and could be deployed aerially over broad-scale areas. The focus of the earlier research was to improve acceptability via changes to the physical form and type, as well as with flavour enhancers (Algar and Burrows 2004). Research was also undertaken to optimise baiting frequency, baiting density and timing of baiting programs (Algar and Burrows 2004; Algar *et al*. 2007). These earlier trials resulted in the development and subsequent registration of the *Eradicat*® feral cat bait. Current research is focussed on examining various additives that may potentially enhance bait palatability (e.g. Scaffidi *et al*. 2016) and therefore bait consumption and also avenues for improving bait longevity in the field. DBCA is also a partner

DBCA has been involved in a variety of research to improve outcomes from managing feral cats.

in a collaborative research program investigating alternative bait types with the Department of the Environment and Energy and Scientec Research Pty Ltd. This research has led to the development of *Curiosity®* and *Hisstory®* baits that use encapsulation technologies to target feral cats and mitigate impacts on wildlife species, which will be important where *Eradicat®* may not be suitable to deploy. As a part of developing all three bait media, a comprehensive assessment of the potential risk of the feral cat bait to non-target species has been undertaken and, where necessary, the development of methods to reduce exposure to the toxin (Algar 2006; Hetherington *et al*. 2007; Buckmaster *et al*. 2014). For example, the *Hisstory®* bait can minimise non-target impacts on varanid populations. To refine the bait further, particularly in areas where feral cats co-occur with canids, DBCA is currently investigating several rapid-acting emetics, which cause dogs to vomit but have no effect on cats; and could be used in the polymer coating of encapsulated baits.

Beyond baiting methods, DBCA is also working to refine other current control techniques. DBCA is currently examining refinements to these methodologies, including lures, to improve their utility as well as other options to complement existing techniques. Trapping programs are being refined to improve the trapping technique to reduce the impact on the target species while maintaining trapping efficiency and minimising risk to non-target species. An example of this work is the development of a technique where traps are set on a raised platform to minimise the capture risk to ground-dwelling fauna (e.g. as part of the cat eradication program on Christmas Island; Algar *et al*. 2019a). Similarly, DBCA has refined trap sets for wet weather conditions that allows the traps to still work efficiently under heavy rainfall without the action being impaired. Investigations are also being conducted into the possibility of luring male cats by exploiting the promiscuous mating behaviour of cats via the '*Femme fatale*' cat (adult female feral cats that are injected with an external source of hormones). On release into the landscape, they will provide continuous attraction to male cats and create a number of avenues to control male cats across the landscape. Preliminary trials have recently been completed and have demonstrated the potential of this methodology, particularly given that cats that survive baiting programs are invariably the larger males that are more adept at hunting.

Quantifying the impact of control programs on feral cat presence and density is an essential component of refining methods. Such monitoring has been a part of mainland operations, as well as eradication programs successfully conducted from five Western Australian offshore islands: Serrurier Island (Pilbara; Moro 1997); Hermite Island (Montebello Islands; Algar *et al*. 2002), Faure Island (Shark Bay; Algar *et al*. 2010), Rottnest Island (Algar *et al*. 2011), and Dirk Hartog Island (Algar *et al*. 2019b). These feral cat control programs enable the reconstruction of the original fauna or protection of extant species. Globally, the Dirk Hartog Island National Park project is the largest successful island feral cat eradication campaign attempted to date and the last island off the Western Australian coastline where feral cats were present.

TOP LEFT: Attaching a Global Positioning System (GPS) monitor to research feral cat movement

RIGHT: The Dirk Hartog Island National Park ecological restoration project has successfully eradicated feral cats from the island

Photos courtesy: Judy Dunlop, DBCA

MURDOCH UNIVERSITY

Murdoch University has undertaken almost two decades of research on feral, stray and pet cat management. Several research projects, some in collaboration with DBCA or CSIRO have focused on measuring the impact of feral cats on wildlife (Short et al. 1999; Risbey *et al*. 2000), feral cat diet (Crawford 2010) and predation on threatened species (Hardman *et al*. 2016). Numerous studies of pathogens in feral cats have been carried out on mainland Australia and several islands (e.g. Dybing *et al.* 2016; Dybing *et al*. 2017) revealing that feral cats carry substantial, mixed parasite loads that threaten the health of cats, humans and other wildlife. Assessments have also been made of bycatch in cat trapping programs and ways to mitigate the problem (Surtees *et al*. 2019).

Several Murdoch University studies have made inroads on stray cat management issues, including attitudes of Western Australians to cat control legislation (Grayson *et al*. 2002; Grayson and Calver 2004). An examination of stray cat diet and demographics in Perth, Western Australia, point to substantial welfare issues that arise for cats living on the streets (Bissett *et al.* 2009) and underpin a recommendation to trap stray cats from urban areas and placing them in shelters (Crawford 2019). Findings of much of the Murdoch University research on stray cats is integrated into a case for precautionary management of pet cats to protect the environment (Calver *et al.* 2011) and in a rationale not to trial trap-neuter-release of stray cats in Australian cities (Crawford *et al*. 2019).

Murdoch University research has documented the rates of predation by pet cats (Robertson 1998) and have demonstrated the effectiveness of collar devices to reduce predation rates (Calver and Thomas 2010; Hall *et al.* 2016). Other studies have established that pet or stray cats can cause rapid local extirpation of native fauna (Bamford and Calver 2012; Greenwell *et al*. 2019). Studies of citizens' attitudes have established the willingness of Perth residents to accept increased regulation of cat ownership (Grayson *et al*. 2002; Lilith *et al*. 2006).

OTHER WESTERN AUSTRALIAN ORGANISATIONS

Research carried out in the Kimberley region, in a collaboration between the University of Tasmania and the Australian Wildlife Conservancy demonstrated that feral cat impacts were amplified by intense fire and heavy cattle grazing (McGregor *et al.* 2014; Leahy *et al*. 2016; McGregor *et al.* 2016b). The work demonstrated how interactions between cats, fire and grazing can lead to small mammal decline in the northern savannas, and how appropriate management to mitigate feral cats impacts can stop these declines (Legge *et al.* 2011a; Legge *et al.* 2011b; Legge *et al.* 2019).

Edith Cowan University undertook research on the impacts of feral cats on native fauna and their interactions with dingoes at Charles Darwin Reserve from 2012–15. Camera trap data showed that dingoes and cats preferred woodlands and very long unburnt shrublands, respectively, but spatial overlap between the two species was still common (Doherty 2015b). Mean diurnal activity time for feral cats was two and a half hours later than that of dingoes. The diet of feral cats was more diverse than that of dingoes and dietary overlap between the two carnivores was relatively low (Doherty 2015a). An experimental trial of track-based *Eradicat* baiting (2013–19, in collaboration with Bush Heritage Australia and DBCA) showed that baiting reduced cat occupancy in some years, but not others (Doherty and Algar 2015; BHA unpublished data).

LEFT: Feral cat predation of a native rodent

Photo courtesy: Michael Johnston

The Western ringtail possum (ngwayir; *Pseudocheirus occidentalis*) has a recovery plan in place that includes addressing the threat of feral cats

Photo courtesy: Robert McLean

A range of organisations are involved in the control programs that also include varying degrees of monitoring. Mining companies in remote areas bait for introduced predators (including feral cats) as part of their environmental commitments to manage biodiversity and impacts due to their mine activities. For example, Roy Hill bait along their rail corridor in the Pilbara for introduced predators to support bilby populations. Environmental offset projects now consider feral cat baiting (among other introduced predators) as an important part of their activities to address their objectives. On-ground works undertaken by the NRM and Landcare communities are having localised success that is informing further improvements to control. These programs include the Wheatbelt NRM black-flanked rock-wallaby (*Petrogale lateralis lateralis*) project, Rangelands NRM's public education campaign and control program across the North West Cape, South Coast NRM's feral animal baiting with DBCA for the protection of the western ground parrot, SWCC's feral cat program in the protection of western ringtail possums (*Pseudocheirus occidentalis*), Perth NRM's threatened species program, and Peel Harvey Catchment Council's Farmers 4 Fauna program that works with farmers to control feral cats to primarily protect the numbat within and around the Dryandra Woodlands.

INTERSTATE RESEARCH AND EXPERTISE RELEVANT TO WESTERN AUSTRALIA

The considerable research undertaken on feral cats across Australia has recently been reviewed in Woinarski *et al.* (2019a) and Read (2019). As noted in both publications, momentum has picked up considerably on addressing the impacts of feral cats on native biodiversity. A great deal of the research being conducted in other states and by expertise based elsewhere is directly relevant to Western Australia. This work includes national-scale assessments of the toll taken of wildlife by cats, national assessments of spatial variation in cat density, assessments of predator naivety in some threatened species (and the extent to which it can be manipulated), research on interactions between cats, foxes and dingoes and the consequences of targeted management of part or all of this predator assemblage, research on the interactive relationships of cats with fire and grazing regimes, the opportunities to manage cats with manipulation of fire and grazing, and artificial refuges that protect prey from cat predation. Additional research is progressing on cat diseases.

7. PROGRAM DEVELOPMENT AND FRAMEWORK

THE PROGRAM DEVELOPMENT PROCESS

A process to scope, define and prioritise research needs was undertaken following the WABSI program development pathway. Originally developed for the Subterranean Fauna Research Program, this framework was further refined by WABSI during 2018 and endorsed by the WABSI Board. The approach follows an iterative model with stakeholder engagement — both end users and research expertise — as the driving force for defining the program scope and priorities (Figure 2).

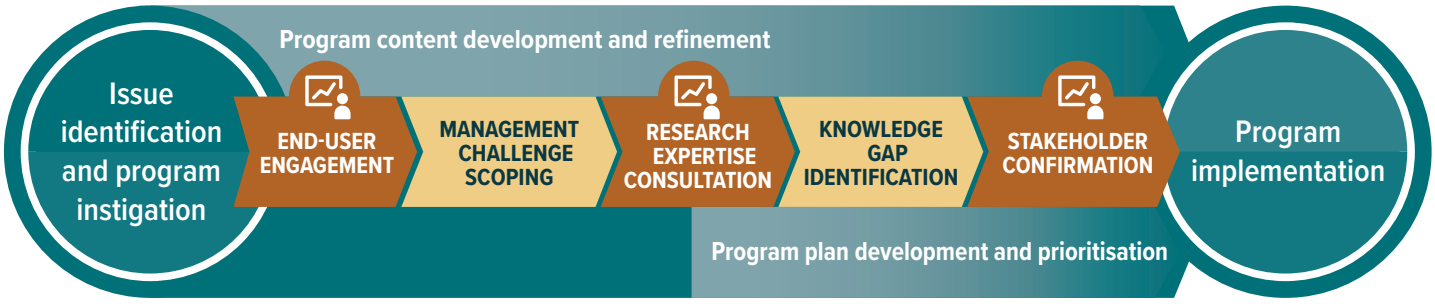


FIGURE 2. The program development pathway followed to develop a research program for increasing knowledge to mitigate cat impacts on biodiversity. Dark brown boxes highlight the three workshops held to develop the program.

PREVIOUS PAGE: Brush-tailed mulgara (*Dasycercus blythi*) *Photo courtesy: Judy Dunlop, DBCA*

ABOVE: (From L–R) Rufous hare-wallaby (*Lagorchestes hirsutus*), noisy scrub-bird (*Atrichornis clamosus*)
Photos courtesy: Robert McLean and Alan Danks, DBCA

In the process of consulting with stakeholders to identify issues that could improve management outcomes, it was recognised early on that a range of underlying factors can be responsible for positive change, either alone or in concert. Factors including further research, improved management, policy change, improved communication, and increased or better targeted funding can all improve outcomes for biodiversity conservation (Figure 3). To define the remit of this research program, and therefore which priorities would be taken forward for development, it was deemed that research needed to be an element (not necessarily the sole element) of delivering the outcome (Figure 3).

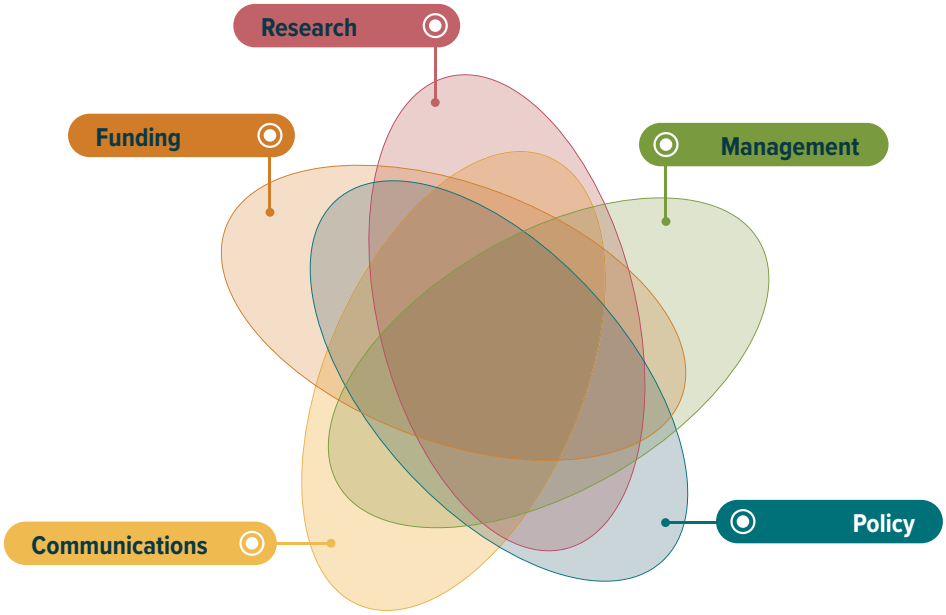


FIGURE 3. Factors for improving the outcomes of feral cat management can fall into one or more solution components: (1) research addressing a knowledge gap; (2) altered management; (3) policy change; (4) increased or better targeted funding; and (5) improved communications, including education, teaching, lobbying and advocacy. The remit for activity against this program is restricted to the region encompassed by the red research circle.

PROGRAM WORKSHOPS

WORKSHOP 1 was held on 1 June 2018 in Mandurah in conjunction with the Western Australian Feral Cat Symposium, a public event to share the latest knowledge, frameworks, legislative context, biodiversity impacts and control options for the management of feral cats in Western Australia. This one-day workshop, co-developed with Peel Harvey Catchment Council, brought together 19 stakeholders, with a focus on end-users, particularly from the NRM and State Government sectors. The workshop had three primary objectives:

1. Develop a refined understanding of current and near future issues relevant for the management of feral cats;
2. Identify the key actions that are most important to achieving effective feral cat management in Western Australia; and
3. Establish a collaborative vehicle for driving effective feral cat management in Western Australia.

To help develop this program, the group identified knowledge gaps for addressing objectives 1 and 2. A set of 54 topics subsequently emerged and were identified as those that could be addressed by further research (Appendix 3). These topics were not prioritised by the group. The full group was clear that the highest priority to improve management outcomes was to form a collaborative vehicle to improve cat management. Part of the role of this group would be to identify, prioritise and communicate research needs. It was felt that such a need could be one and the same as a WABSI-led research program.

Based on the content generated in workshop 1, and in consultation with key stakeholders – leading university-based researchers, DBCA staff involved in management and research, and the NRM sector – five focal areas of research were proposed:

1. Improving existing management;
2. Developing novel management;
3. Quantifying impacts of cats on native animals;
4. Social licence and value proposition; and
5. Population ecology and behaviour.

These focal areas were developed into a framework that was floated and tested at workshops 2 and 3 (Figure 4). Some minor refinement to the titles was suggested and incorporated, but the overall structure was supported by all stakeholders at both latter workshops.

WORKSHOP 2 was an invitation-only event held on 12 March 2019 in Perth. Specifically focused at bringing together the community of researchers from across Australia working on feral cat management, this full day workshop was attended by 28 people, seven from interstate (Appendix 1). At this workshop, the full list of 54 topics from workshop 1 was considered, along with outputs from two other publications that dealt, at least in part, with improving feral cat management (Moro *et al*. 2016; Moro *et al*. 2018). The group was tasked with (i) assessing and revising the program framework, (ii) considering the 54 topics and adding further topics as appropriate, (iii) merging topics where necessary (discarding topics was not an option) and aligning them to the five focal areas of the framework, (iv) prioritising the topics, and (v) high level scoping of those topics identified as high priority. Workshop 2 identified an additional 27 research topics, before coming up with a prioritised list of 16 consolidated topics spread across the five focal areas (Appendix 3).

WORKSHOP 3 was an invitation-only event held on 13 March 2019 in Perth. This full day workshop brought together all stakeholders – both researchers and end users – to refine and confirm the outputs from the first two workshops. Forty people attended, with some overlap on the first two workshops, but with a more diverse group of end users (Appendix 1). Attendees were tasked with:

- Refining and finalising the program framework and scope;
- Refining and finalising the research knowledge gap priorities;
- High level scoping of the identified priorities; and
- Identifying funding opportunities and likely risks that the program would need to mitigate.

No further topics were added to those already identified, although further refinement was undertaken, including merging of some of the topics that had not been scoped in workshop 2. The workshop also considered and provided feedback on the proposed Western Australian Feral Cat Working Group as a structure to help with governance of the research program (see Governance section).

An important change in scope was floated, discussed at length and unanimously supported by attendees at workshop 3. Coming into the development of this program, there was a clear desire to keep the scope of this program strictly constrained to feral cats, with pet and stray cats excluded. After deliberations, it was decided by stakeholders at workshop 3 that focal areas 1, 3, and 5 ('social licence and value proposition', 'quantifying impacts' and 'population ecology and behaviour') would be expanded to recognise the impacts all cats have on biodiversity outcomes. However, focal areas 2 and 4 ('improving existing management' and 'developing novel management') would remain focused on feral cats for the development of this Research Program.

An earlier draft of this research program was subsequently sent around for stakeholder feedback. To avoid scope drift, a boundary was set that all priorities would remain as per workshop 3, and no major modifications (inclusions or exclusions) would be undertaken. Attendees at all three workshops, together with an extended list of stakeholders were invited to provide feedback on the program. Initial feedback was provided by 42 individuals as well as de-identified aggregated feedback from two organisations, while a smaller group of 21 stakeholders and one organisation provided further feedback on a near-final draft (Appendix 2).

BELOW: Chief Scientist of Western Australia, Professor Peter Klinken opening the WABSI workshop

Photo courtesy: Preeti Castle, WABSI

The black-flanked rock wallaby (warru; *Petrogale lateralis lateralis*) is threatened by cat predation

Photo courtesy: Bruce Webber, WABSI

8. RESEARCH PROGRAM STRUCTURE

RESEARCH PROGRAM FRAMEWORK

From across the three workshops, consensus was reached on the most pressing knowledge gaps to prioritise in this research program. Research priorities were grouped into five focal areas that were, in turn, formed into a framework for the research program (Figure 4). Social licence and value proposition were together recognised as an overarching focal area with relevance to all other focal areas. Similarly, the underpinning nature of cat population ecology and behaviour focal area was based on the knowledge being broadly applicable across other focal areas.

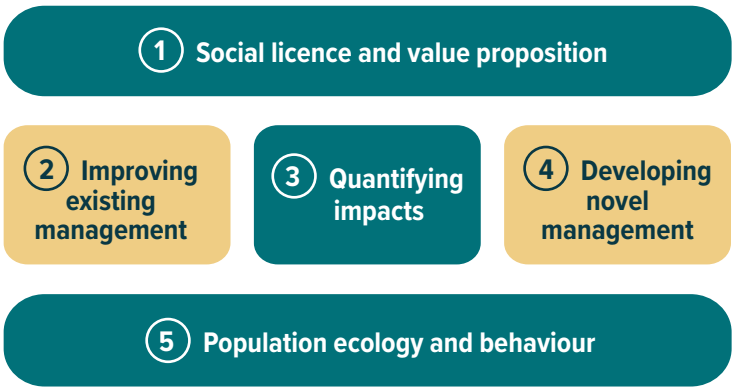


FIGURE 4. Five focal areas were identified under which to group research to address knowledge gaps for improving cat management in Western Australia.

Against these five focal areas, 16 prioritised research topics were considered, refined and scoped by stakeholders into 14 priority projects (Table 1). While gene editing as a novel management solution was scoped as a single entity, it was noted by the group that this topic would almost certainly involve multiple projects when scoped in detail.

TABLE 1. Prioritised topics from workshops 2 and 3. Topics identified in these were prioritised during workshop 2. The 14 top priorities were developed up as projects and grouped according to focal area.

FOCAL AREA 1	**Social licence and value proposition**	**(Focus: All cats)**

- **Project 1:** Improving community understanding and involvement
- **Project 2:** Social licence to support existing and novel control
- **Project 3:** Economics of cat management and control

FOCAL AREA 2	**Improving existing management**	**(Focus: Feral cats)**

- **Project 4:** Assessing and prioritising existing control strategies
- **Project 5:** Refining lethal technologies, lures and deterrents
- **Project 6:** Land management practices, including Indigenous knowledge
- **Project 7:** Integrated introduced predator control

FOCAL AREA 3	**Quantifying impacts**	**(Focus: All cats)**

- **Project 8:** Cat density impact targets and biodiversity response thresholds
- **Project 9:** Understanding disease prevalence and impacts

FOCAL AREA 4	**Developing novel management**	**(Focus: Feral cats)**

- **Project 10:** Gene editing: molecular studies on genes of interest
- **Project 11:** Other novel control solutions

FOCAL AREA 5	**Population ecology and behaviour**	**(Focus: All cats)**

- **Project 12:** Indirect management measures
- **Project 13:** Cat behaviour (bait avoidance, social structure, reinvasion)
- **Project 14:** More effective cat population monitoring

It was recognised that while certain projects were rated a higher priority than others, this did not necessarily reflect the temporal order in which they needed to take place. Working with the shortlist of prioritised projects (Table 1), stakeholders created a temporal framework to show project delivery requirements, in particular those with short, medium and long-term delivery horizons (Figure 5).

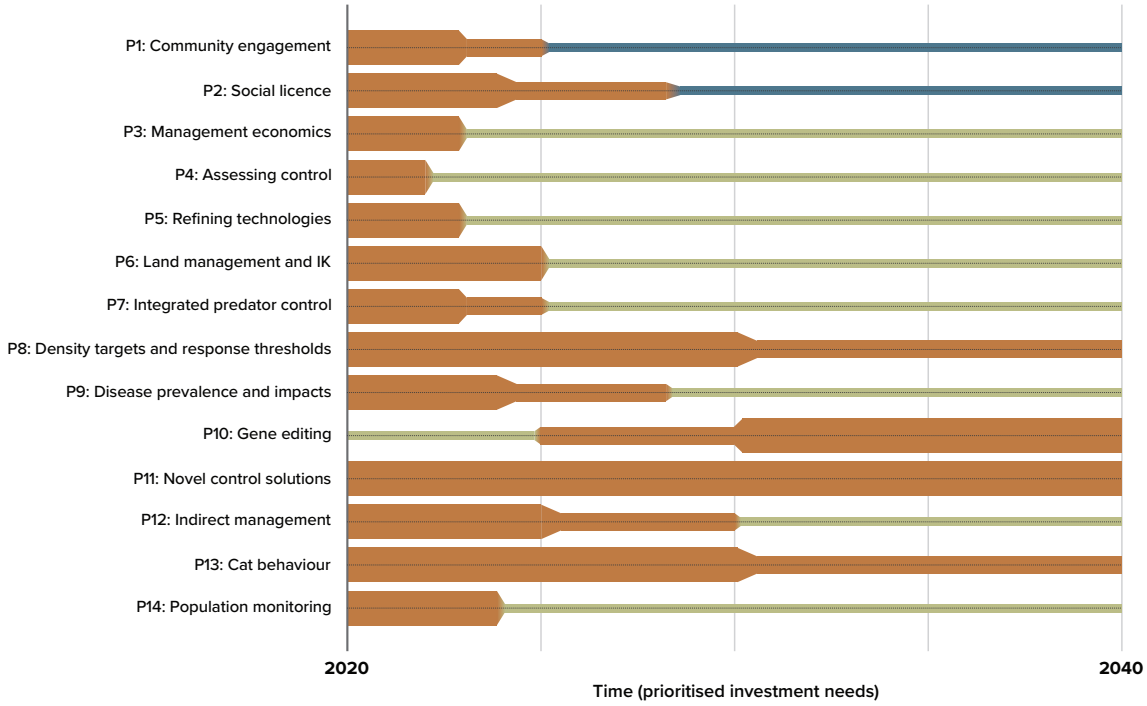


FIGURE 5. A proposed timeline for a program of investment in the Research Program designed to indicate the order and duration of projects, partitioned between active research (orange), possible research (light green), and adaptive management informing the need for any further research (blue). Relative required resources (labour, funding) are depicted across the range of prioritised projects (P), as identified in Table 1.

FOCAL AREA 1 SOCIAL LICENCE AND VALUE PROPOSITION

Rationale

Social licence to operate refers to the community's acceptance and approval for an initiative to exist or take place, and is an extension of the concept of corporate responsibility (Widmar *et al.* 2018; Hampton and Teh-White 2019). With increasing attention paid to the human dimensions of wildlife management in recent decades (Dubois *et al*. 2017), it has become apparent that, to gain and maintain public support, wildlife managers need to respect and proactively take into consideration the variety of views in society in relation to animal welfare (Lunney 2012). This approach is particularly important for the management of feral cats, as there are members of the community that have a strong emotional connection with cats, whether as pets or strays. Many of these people do not associate cats with causing harm to native fauna (Woinarski *et al.* 2019a). Equally, there is a growing appreciation of the welfare of animals that are preyed on by cats. Despite the large number of native animals killed by feral cats in Australia, welfare-related criticism of management is currently weighted towards concern for feral cat welfare, overlooking native animal welfare.

Broadening the value proposition of improved management of cats will help this conversation. We know that the cost of feral cat control varies greatly with environment and landscape scale, and can be measured, but what are the costs of doing nothing? Can 'ecological accounting' assign a value to threatened species or the harm caused by feral cats to native animals, and then determine the value of saving a species? If so, can any change in that value as a function of management

inputs, cat density and impact be disaggregated? Can this insight be used to link in with philanthropic and corporate investment frameworks that are using ecological accounting to inform investment?

> Despite the threat to native animals, welfare-related criticism of management is currently weighted towards concern for feral cat welfare, overlooking native animal welfare.

Control programs for cats are increasingly likely to be a collaborative activity between governments and other stakeholders. Many landowners and other stakeholder groups are capable of, and interested in, contributing to this management. Improving stakeholder engagement, a more informed dialogue and a more clearly articulated value proposition would benefit from research addressing knowledge shortfalls in regard to (i) the ethics of managing cats, (ii) the relative humaneness and non-target impacts of existing control techniques, (iii) more awareness of the harm and suffering, and increased extinction-risk, caused to wildlife by cats, and (iv) the costs and health risks posed to people and livestock by the cat-vectored transmission of varied pathogens and diseases. Such insight can be used to systematically build consensus that would underpin informed dialogue and subsequently, the decisions regarding which approaches are deemed acceptable and appropriate, and those which are not pursued or require refinement (Susskind *et al.* 1999).

Public confidence in control that involves new technology requires that risks be properly assessed and managed, the public engaged, and gaps in knowledge identified and clarified. For example, gene editing technology is one option currently being proposed as a potential future solution for controlling invasive alien species. Proactive engagement with the community via communication, education and extension needs to be implemented to address scientific as well as social and cultural concerns (Saunders *et al*. 2010; Mehmet *et al.* 2018; Kirk *et al*. 2019). This engagement needs to include Indigenous Australians who may contribute unique cultural heritage as well as knowledge of, and attitudes to, cats in the Australian landscape (Hudson *et al*. 2019).

Objectives:

- Determine how to address and manage the issues that impede the widespread acceptance of cat control, including definitions and control targets, the lack of awareness of cat predation impacts on native fauna, and the lack of awareness of the health impacts of cat-vectored diseases;
- Assess the value and impacts of cats to Indigenous culture, and the role of the Indigenous community in cat management;
- Determine the current extent of social licence to support current and emerging methods to control feral cats in Western Australia and then either secure and maintain it or develop and maintain it; and
- Achieve a clearer value proposition via a cost-benefit analysis of different control methods that examines efficiency, effectiveness and animal welfare.

Outcomes:

- Broad acceptance of cat management approaches and their justification, leading to more effective contributions by the public and stakeholder groups in cat management;
- Evidence-based information to support links between feral, semi-domestic and domestic cats underpins social licence and public acceptance of the importance of responsible pet ownership;
- Improved understanding of the significance of cats to Indigenous communities and land managers;
- Increased awareness of the impact of cat predation on native fauna, including incorporating the welfare of native animals preyed upon by cats into the assessment of feral cat management; and
- An improved understanding of the economics of feral cat management, taking into account variation in control methods, landscape context and impact variability, and financial impact on stakeholders.

FOCAL AREA 2 IMPROVING EXISTING MANAGEMENT

Rationale

There is still substantial scope for improving current feral cat control methods by either developing modifications that improve efficacy and/or integrating these methods with new techniques. From the options currently available for feral cat management, many can only be used effectively in some ecosystems, by some land managers, or are only suitable on relatively small scales. Although there have been some notable recent enhancements in toxins and their delivery, which are aimed at minimising off-target impacts and increasing their humaneness and cost-effectiveness, there is a need to improve our understanding of how localised context impacts on the efficacy of each control method. Research on alternative poisons and delivery mechanisms and refining technologies that enhance uptake of baits by feral cats whilst reducing non-target uptake will improve the efficacy and cost-efficiency of current baiting programs.

More research is also desirable for indirect techniques to manage feral cats, such as through habitat manipulation that reduces suitability for (and hence density of, or hunting efficiency by) feral cats but increases habitat suitability for native wildlife. For example, there is evidence that feral cats are attracted to recently burnt areas due to the higher hunting success they experience there (McGregor *et al*. 2015; McGregor *et al.* 2016b), resulting in greater predation of small mammals (Leahy *et al.* 2016). Understanding the environmental conditions that lead to this behaviour to focus lethal control on recently burnt areas may be an effective means of targeting cats and reducing their impacts post-fire. Could seasonal 'burn-lines' or other forms of linear path creation in dense understory focus cat activity to where they can be controlled? Landscape-scale management of fire in northern Australia can increase the abundance of native mammals (Kutt and Woinarski 2007; Legge *et al*. 2011b; Radford *et al*. 2015; Legge *et al*. 2019), probably in part because retained ground cover reduces the impacts of cats (McGregor *et al.* 2014; Leahy *et al.* 2016). However, grazing by livestock (including feral stock) can negate the benefits of appropriate fire management (Legge *et al.* 2019), thus supporting the need for integrated land management approaches. How applicable these findings are to non-savanna systems remains unknown and requires further research. Close collaboration would be beneficial with Indigenous land managers who undertake widespread fire management programs in these regions. Importantly, these habitat alterations can be implemented as part of existing land management plans, if appropriate, and do not require new technologies. They can also be implemented on large scales. However, there remain some constraints on uptake, such as assessment of costs and benefits, the willingness of landowners to reduce livestock densities in over-stocked areas, the costs of enduring programs to reduce feral stock densities, and the practical mechanisms that can be used to reduce extensive high-intensity fires.

Further research is needed to understand the responses of cats to the control of other introduced predators, as well as to the interactions between introduced predators where they co-occur. This research is particularly important given that dingoes are inconsistently controlled and even put forward as a way to reduce cat impacts on native fauna. Dingoes are susceptible to cat baiting, which may have unintended cascading outcomes that ultimately increase the risk of predation for native animals by feral cats (M. Wysong, pers. comm.; Brook *et al*. 2012). While there is substantial dingo and wild dog research in this field currently being undertaken elsewhere in Australia, and past work that has been done on cat interactions with foxes in Western Australia, further understanding of local context and how this insight may be transferrable will be critical for cat management in Western Australia.

Indirect methods can be used to manage feral cats, including habitat manipulation by burning

Photo courtesy: Judy Dunlop, DBCA

Objectives:

- Evaluate cat control methods by multiple measures of success, including the welfare of prey and non-target impacts, and provide options for management with a local context;
- Optimise the use of existing control methods by improving the acceptance of lethal baits to feral cats and developing alternative delivery mechanisms, lures and deterrents that enhance feral cat uptake while reducing non-target consumption;
- Enhance existing feral cat management by integrating control measures and indirect land management practices (e.g. fire, grazing management);
- Quantify the efficacy of Indigenous feral cat control and determine if this knowledge can be integrated into other cat control methods to improve efficacy; and
- Establish a clearer understanding of how best to include cat control in integrated management programs for introduced predators.

Outcomes:

- The efficacy of options for feral cat management are improved, based on evidence-based prioritisation of optimum methods taking into account local context, resource availabilities and conservation objectives;
- The efficiency and effectiveness of currently available control methods for cats are enhanced while minimising non-target impacts and optimising humaneness;
- Improvements in baiting delivery mechanisms result in less non-target impacts and better uptake by feral cats; and
- The extent of land (and the number of wildlife populations) benefitting from effective cat management is significantly increased.

FOCAL AREA 3 QUANTIFYING IMPACTS

Rationale

Beyond islands and fenced exclosures, it is currently near impossible to remove feral cats completely with the resources available. Hence cats continue to exert strong predation pressure on many wildlife species across most of Australia. It is, therefore, important to determine what level of predation pressure that the prey community as a whole, and individual threatened species, can tolerate, as well as the broader ecological community, in different contexts. Whilst there is some research that suggests the presence of a single cat can contribute to the decimation of a local prey population (Moseby *et al*. 2015), there is limited data available on thresholds of cat density or predation pressure above which populations of particular native species decline, and below which populations of those species are stable or increase (Radford *et al*. 2018). Understanding the relationships between population densities of introduced predators and their prey is urgently needed if these threatened species are to recover or be re-established at landscape scales (Sinclair *et al*. 1998). Such thresholds may vary among native wildlife species, regionally, with different weather conditions, and in response to other threatening factors. Without such knowledge of cat predation thresholds and corresponding population-level responses of wildlife, control programs may be futile (i.e. they do not reduce cat density sufficiently to result in native fauna increases) or overkill (and hence result in over-expenditure) (Hone *et al.* 2010). This insight would also allow for prioritisation as to where, and for what species or systems, resources should be preferentially allocated.

There have been few studies in Western Australia of the incidence of disease in pet, stray and feral cats, and the extent to which cat-borne disease may have impacts on wildlife species and other values (e.g. livestock production); and of options for mitigating such impact if it is found to be significant. Some targeted studies into key knowledge gaps in this field would be desirable. There have also been few studies on potential beneficial impacts of cats (e.g. through their predation on agricultural pests, such as rabbits and rodents). Although there is little evidence that cats effectively reduce the numbers of introduced rodents and rabbits (Parsons *et al.* 2018), there is often still strong sentiment in the bush that cats are beneficial pest controllers. Research to generate an evidence-based assessment may help better inform societal valuation of cats, and of the net consequences of cat control.

Objectives:

- Quantify the interactions and outcomes of cat predation and the impact of other threatening processes on native fauna conservation;
- Understand the context-specific circumstances that can allow cats and native fauna to co-exist, including establishing threshold tolerances of different native species to feral cat predation pressure to facilitate the maintenance or recovery of prey populations;
- Quantify relationships between feral cat densities and their prey; and
- Determine the extent of, and how to best mitigate, the prevalence and impact of cat-borne disease on biodiversity, with flow on benefits to agriculture and human health.

Outcomes:

- The relationship between feral cat density and impact is understood in a manner that allows for management to most effectively and sustainably result in the recovery of native fauna across varying landscapes;
- The extent of land (and the number of wildlife populations) benefitting from effective cat management is significantly increased; and
- The impact of cat-borne disease on human health and agriculture is understood and minimised.

FOCAL AREA 4 DEVELOPING NOVEL MANAGEMENT

Rationale

Investing in the development of additional novel control technologies remains a high priority to ensure there is an integrated approach to feral cat management in Western Australia. Significant knowledge gaps exist in developing and refining new methods, as well as ensuring social and policy-based support for their deployment. While there is a clear need for improved feral cat control in Australia, any sustainable and economically viable landscape-wide alternatives to the current methods of feral cat control must consider the ecological, conservation and societal risks.

A key focus for novel management is genetic technology, which presents significant opportunities for conservation, particularly for the control of invasive pest animals using gene drives. Scientists, ethicists, biosafety experts, government regulators and non-governmental organisations have already been engaged in a great deal of international debate over concerns emerging from the potential power of gene drives. International frameworks are being adopted – for funding agencies and regulatory authorities through to research institutes – with a particular focus on the environmental risk of this work and the containment of animals carrying gene drives. For the appropriate development of gene drive solutions, we need to first understand the wider environmental implications of gene drives aimed at feral cat control, which in turn depends on addressing ecological knowledge gaps within the Australian context to support future risk assessments should gene drives be pursued (Moro *et al*. 2018). Environmental risk assessments require a high level of knowledge about the genetics and ecology of a target species (and of some potential non-target species). This knowledge is the foundation on which risks can be assessed with confidence, mitigations understood, and future trials undertaken.

Other emerging methods, including novel or improved toxin delivery systems may provide improved outcomes for cat control at a range of scales. Support for further development of these tools, including understanding how they can most effectively be deployed alongside existing control measures, remains a priority for future research.

> Any sustainable and economically viable landscape-wide alternatives to the current methods of feral cat control must consider the ecological, conservation and societal risks.

Objectives:

- An annotated genome for *Felis catus*, with genes of interest identified for gene editing control solutions; and
- Develop and refine the use of emerging control technologies, particularly in regard to increased efficacy with new contexts.

Outcomes:

- Knowledge gaps specific to feral cats within the gene drive context are addressed to support future gene editing approaches as a novel control proposition;
- Alternative (enhanced and more sustainable) novel toxins (or toxin delivery mechanisms) are available for cat control;
- Development and operationalisation of novel control tools; and
- The extent of land (and the number of wildlife populations) benefitting from effective cat management is significantly increased.

FOCAL AREA 5 POPULATION ECOLOGY, GENETICS AND BEHAVIOUR

Rationale

The relatively low densities at which feral cats occur in Australia present some challenges for research aimed at understanding their ecology. However, basic knowledge on cat population ecology, genetics and behaviour underpins the potential to improve both current and emerging control methods, including an essential pre-condition for the assessment and implementation of gene-drive based approaches. Young cats are more susceptible to predation, disease and malnutrition, with the potential for these biological characteristics to be used to improve the efficacy of control programs. Furthermore, understanding the structure and connectivity of cat populations is a prerequisite for defining spatial management units. For example, the extent of dispersal of cats influences the effective size of areas subject to control programs, with likely ongoing recruitment from peripheral areas.

Understanding the population structure and movements of cats could potentially lead also to another management strategy: the identification of ecological traps within the landscape where cat control could be focused. In arid areas, for example, cats often move to sheltered parts of the landscape or to sites with easy access to food and water resources. If these sites can be identified, cat control could be focused at these sites when cats are most likely to be concentrated within them. Such sites are likely to be fixed within the landscape and defined by topographic, riparian or other features. However, temporary ecological traps may occur at sites that have recently burned; influxes of cats can often be anticipated at these sites, and could again be targeted for cat control. A priority may be to undertake research on the extent and pace of immigration of cats to areas in which cat densities have been reduced by control programs, and hence the size of control area required to ensure benefits can be prolonged. Another may be to identify the potential to use ecological traps as a management tool.

Objectives:

- Improved techniques to effectively monitor feral cat populations (abundance, range, dynamics);
- Quantify how cat ecology and behaviour responds to control methods and outcomes, landscape attributes (including prey species' dynamics), land use (e.g. grazing) and events such as fire;
- Characterise the genetic structuring and gene flow within cat populations to understand spatial movements, metapopulational structure and effective population sizes; and
- Understand the extent of recruitment across the spectrum of cat groupings (pet, stray and feral), and mechanisms that can be used to disrupt the ingress of pets to strays and strays to feral cats.

Outcomes:

- The impact of landscape attributes, land use, fire and grazing on cat ecology and behaviour is understood and used to refine and improve control techniques;
- The population dynamics of cats, including abundance, densities, social structures and gene flow, is understood in regard to predation threat and cat control efficacy and can subsequently be used to improve control options;
- Fewer pet cats become strays; and fewer strays become feral; and
- The extent of land (and the number of wildlife populations) benefitting from effective cat management is significantly increased.

BELOW: Understanding cat responses to fire is a research priority

INSET: Release of a spinifex hopping mouse (*Notomys alexis*)

Photos courtesy: Judy Dunlop, DBCA

Martu rangers setting camera traps Karlamilyi National Park
Photo courtesy: Judy Dunlop, DBCA

9. IMPLEMENTATION

FUNDING STRATEGY

As the scope of the research program is large and the nature of individual components varies, a number of funding models are likely to be targeted. The research program is likely to involve a combination of short (1-year), mid (5-year) and long (>10 year) term projects.

ARC Linkage Projects

The Linkage Projects scheme promotes collaboration and research partnerships between key end-users in research and innovation including higher education institutions, government, business, industry and end-users. Research and development is undertaken to apply advanced knowledge to problems, acquire new knowledge and as a basis for securing commercial and other benefits of research. The Linkage Projects scheme provides funding to eligible organisations (higher education institutions) to support research and development projects which are collaborative, are undertaken to acquire new knowledge and involve innovation. Proposals for funding under the Linkage Projects scheme must include at least one partner organisation. The partner organisation must make a contribution in cash and/or in-kind to the project. The combined (cash and in-kind) partner organisation contributions must at least match the total funding requested from the ARC. The Linkage Projects scheme provides project funding of $50,000 to $300,000 per year for two to five years.

Cooperative Research Centres Projects (CRC-P)

CRC-P grants support short-term (up to 3 years) industry-led partnerships to develop new technologies, products and services that will solve problems for industry and deliver tangible outcomes. At least one of the two required industry partners must be a small to medium business enterprise (SME: up to 200 employees). At least one research organisation is required to complete the partnership. CRC-Ps must also demonstrate education and training opportunities between industry and research partners. Aligning project outcomes with strategic priorities identified through relevant Growth Centres is also encouraged.

A maximum of $3 million of Australian Government funding is available for each CRC-P. All partners in a CRC-P must contribute resources, with the total contribution including cash and in-kind matching the amount requested from the CRC Program. The matching resources can be cash or in kind, but cash contributions, particularly from industry, will be viewed favourably. One of the clear advantages of a CRC-P includes the ability to leverage industry funds with Government and other funders.

Lotterywest

Lotterywest fund environmentally focused projects of a range of size and duration that help understand and/or preserve the Western Australian environment. Projects must be community focused, not-for-profit, end-user led, and involve a strong element of delivering on-ground outcomes.

Mining companies

As part of their offset conditions, mining companies can be required to control feral cats. For projects that are clearly focused on near term on-ground outcomes, there may be synergies to form with mining companies to provide resources, data or funding. Furthermore, environmental offset funds paid by mining companies for threatened species and feral predator programs is an obvious source of funding for research that would improve cat management. Initiatives such as the Pilbara Environmental Offset Fund, which will deliver strategic and lasting conservation benefits via transparent and accountable research projects, are a logical fit to this research program.

National Environmental Science Program (NESP)

The National Environmental Science Program (NESP) allocated $145 million over the six years from 2015 to 2021 of which $30 million was allocated to Threatened Species Recovery Hub. A number of feral cat research projects administered by universities and the Australian Wildlife Conservancy are partly or fully resourced through the Hub. The resource allocation for the current Threatened Species Recovery Hub is fully committed, and any contribution from the NESP initiative beyond 2020 is entirely contingent on whether the Commonwealth government continues the program and, if so, on the future research focus and Hub structure.

NRM grants

State NRM grants as well as NRM group small grants can be used to fund components of research, usually embedded in a bigger management program primarily focused on delivering on-ground management outcomes.

Philanthropy and strategic alliances

Collaborative alliances with land managers linked to NGOs or philanthropic partnerships are an option for co-investing in complementary research. Not for profit groups such as the Australian Wildlife Conservancy and Bush Heritage Australia, Indigenous ranger groups, and the Centre for Invasive Species Solutions (CISS) all present collaborative options in this regard.

A pet cat funding levy

Based on the number of pet cats in Australia (3.9 million; Animal Medicines Australia 2016) and the number of households in Western Australia (Australian Bureau of Statistics 2017), there are at least 429,000 pet cats in Western Australia. The figure is conservative, as the ABS data does not capture the number of households that have more than one cat (however, ABS data did suggest that 60% of pet owners have more than one pet).

Following the introduction of *Western Australian Cat Act 2011*, it became compulsory for pet cat owners to register, neuter and microchip their cat. The Minister for Local Government, Sport and Cultural Industries (DLGSC) is responsible for administrating the Cat Act and individual local governments are authorised to collect fees. The cost of pet registration may vary between individual local governments, but most have set the rate at $20/year, with discounts for multiple years of registration.

If $10 for biodiversity conservation was added to the annual cat registration process in Western Australia, and all cat owners complied with the legislation, it would raise over $2.5 million every year. Unfortunately, there is an issue with compliance, with only about 30% of households having registered their cats (DLGSC, unpublished 2017 survey data), with levels below 20% in some peri-urban and regional areas. Aside from the huge number of unregistered cats, local governments are missing out on lost revenue (>$3.5 million) by not enforcing the legislation.

There is a precedent for an impost on pet registrations to pay for mitigating cat impacts on biodiversity. In Victoria, a percentage (currently c. $4 per cat, indexed) of cat registration fees is payable to the State treasurer and may go toward cat education campaigns and staff to inspect breeding facilities. This raises approximately $900,000 annually (Agriculture Victoria 2019). A further opportunity to raise considerable funds is via adding a levy to the purchase of pet cats or their maintenance, such as food and insurance (Brink *et al.* 2019).

GOVERNANCE

The successful delivery of this research program for feral cats is contingent on an appropriate governance structure. At a higher level, and as unanimously called for at workshop 1, is a proposed establishment of a Western Australian Feral Cat Working Group. The concept of this working group has already been endorsed by the National Feral Cat Taskforce and the Biosecurity Council of Western Australia (Figure 6). It is proposed that the 'prioritised research' component of the Western Australian Feral Cat Working Group (Figure 6) would be led by WABSI and defined by this research program. Other working group components are planned to be led by other members.

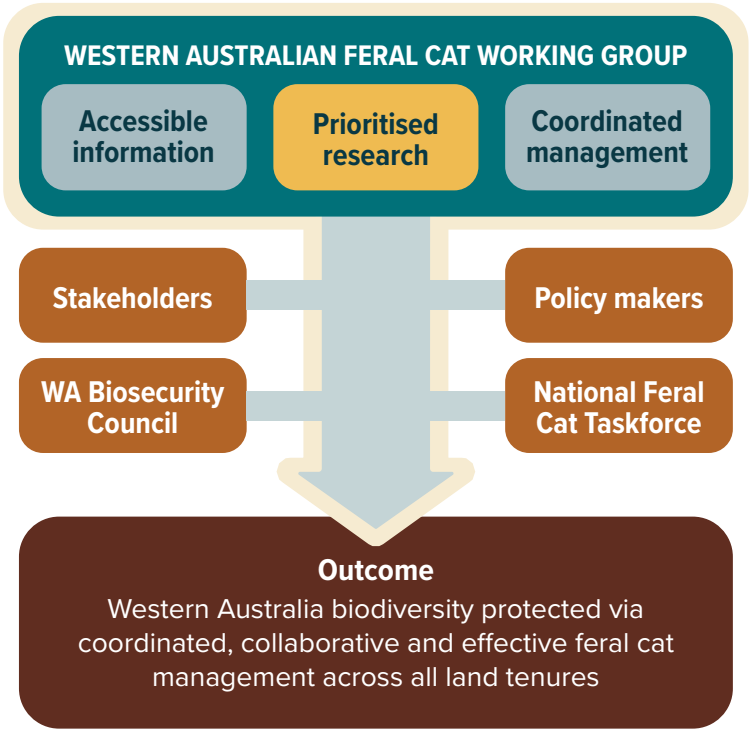


FIGURE 6. Draft framework for the Western Australian Feral Cat Working Group, showing the relationship of the proposed WABSI research program (yellow) in relation to the other activities being undertaken. A working group has already been endorsed by both the Biosecurity Council of Western Australia and the National Feral Cat Taskforce.

The WABSI research program framework specifies that a steering committee will be established to administer the program. Steering committees generally comprise key stakeholders, researchers and at least one representative from the regulatory sector to ensure that outcomes are consistent with policy objectives. A working group will become active in the near future and it is likely that a steering committee and working group will be one and the same. While WABSI will play an active role in the implementation of the research program, the appointed group will ensure that the research program endures, should WABSI involvement be either reduced or withdrawn.

The primary role of the group that will guide the implementation of the research Program is to ensure that:

- Projects developed under the research program are well integrated and will deliver on a shared vision;
- The scope of projects and intended outcomes meet the requirements of end-users;
- The science being delivered is of a high standard without duplication of research effort;
- Outcomes are able to be translated effectively to all end users with the knowledge to encourage adoption of research findings;
- The principles that WABSI has developed around cross-cutting themes are implemented within projects where appropriate;
- The research program plan is up to date and best reflects the current end-user needs and research capability;
- Activities are aligned to the National Feral Cat Taskforce and Biosecurity Council of Western Australia objectives; and
- Proposed outcomes are achieved.

Red-tailed phascogale (*Phascogale calura*)
Photo courtesy: Robert McLean

RISK MANAGEMENT

This section outlines key risks identified in relation to the research program.

Governance

Description	Likelihood	Impact	Mitigation action
Steering Committee not able to represent the interests of all stakeholders	Possible	Moderate	• Membership comprises key stakeholders who have a long-term interest in the intended outcomes of the program • Steering Committee membership overlaps with the Western Australian Feral Cat Working Group membership
Steering Committee not well linked to the Western Australian Feral Cat Working Group and the National Feral Cat Taskforce	Possible	Moderate	• Steering Committee membership overlaps with that of the proposed Western Australian Feral Cat Working Group membership • Steering Committee actively supports the formalisation of a Western Australian Feral Cat Working Group • Steering Committee actively engages with the National Feral Cat Taskforce, with the Western Australian delegate to the latter appointed as a member of the Steering Committee
Sub-standard collaboration and communication between research providers	Possible	Moderate	• Steering Committee liaises with project leaders throughout the projects to facilitate effective collaboration • Project agreements clearly indicate the collaborative nature of projects and communication requirements
Projects do not deliver against identified research priorities	Possible	Major	• Project planning to be established at project commencement and evaluated by the Steering Committee • External independent peer review of project proposals and reporting as appropriate, including representatives of the Western Australian Feral Cat Working Group
Aboriginal engagement is not conducted appropriately	Unlikely	Major	• Research projects are aligned with WABSI Aboriginal engagement principles • Research projects meet the requirements of their own organisation's Aboriginal engagement policy
Misuse of funds	Unlikely	Major	• Project proposals are clear as to how the funds will be expended against each milestone • Organisations managing project funds must provide evidence of appropriate financial management systems and protocols
Insufficient funds are realised to implement key components of the program	Possible	Major	• Program components are carefully and strategically prioritised • Options for funding are fully explored • Significant effort put into community outreach to justify the program and its implementation, and to chart its successes

Research delivery

Description	Likelihood	Impact	Mitigation action
Research outputs are of sub-standard quality	Possible	Moderate	• Steering committee maintains close oversight throughout research projects • External peer review of project proposals and reporting as appropriate
Research outputs do not directly address an information gap	Unlikely	Major	• Steering Committee maintains close oversight on research project scoping • Scope of work and path to impact are clearly articulated
Research outputs are not delivered on time or on budget	Possible	Major	• Adoption of a proactive project management process with Steering Committee involvement • Early interception of timeline deviations before milestones are missed • Clear contractual obligations relating payments to milestones
Research outputs are not shared appropriately with end users	Possible	Moderate	• Research proposals clearly articulate a path to impact approach, including how the research will be translated into a user-friendly format for all end users • Projects include a mandatory communication and adoption strategy to be endorsed by the Steering Committee, the Western Australian Feral Cat Working Group, ensuring links into the National Feral Cat Taskforce • Intellectual property and information sharing agreements are clearly articulated in project agreements • There will be an assumption that all results will be made public with open access publication unless there is sufficient justification for privacy
Research not able to deliver on objectives	Possible	Major	• Scope of work and risks are clearly articulated • The Steering Committee helps to find an optimal balance between aspiration and realism in regard to project scope • Mitigation strategies are included in project risk assessments
Research is being duplicated	Possible	Moderate	• Project scopes and outputs are communicated clearly and promptly to the research community • The Western Australian Feral Cat Working Group and the National Feral Cat Taskforce are kept informed of all new initiatives • The WABSI website (and others as appropriate) are kept up to date with information on all projects

Continues following page...

Research delivery (continued)

Description	Likelihood	Impact	Mitigation action
Loss of key personnel	Possible	Major	• Sufficient research depth in partner organisations allows for substitution of expertise • WABSI research provider network knowledge is leveraged by the Steering Committee and the Western Australian Feral Cat Working Group
Insufficient funds are realised to implement key components of the program	Possible	Moderate	• Program components are carefully and strategically prioritised • Options for funding are fully explored • Significant effort put into community outreach to justify the program and its implementation, and to chart its successes

INSET (From top): Malleefowl (*Leipoa ocellata*), Central netted dragon (*Ctenophorus nuchalis*), Quenda (*Isoodon obesulus fusciventer*)

Photos courtesy: (MAIN IMAGE) Bruce Webber, WABSI, (INSETS): Wikipedia, Judy Dunlop, DBCA; and Robert McLean

Impact and adoption

Description	Likelihood	Impact	Mitigation action
Communication plans do not address adoption of research outcomes	Possible	Major	• All projects to have a communication plan that includes an adoption strategy • The Western Australian Feral Cat Working Group is consulted when forming research adoption plans
Social licence is not secured, maintained and enhanced for all planned activities	Possible	Major	• All projects consider social licence issues in their scoping and risk assessment • All projects take a proactive approach to engagement with stakeholders and interested parties during project scoping and delivery
Active interference with research program goals by special interest groups	Possible	Moderate	• All projects take a proactive approach to engagement with stakeholders and interested parties during project scoping and delivery • Research projects take a proactive, neutral and respectful approach to communicating results and engaging with the public, including paying careful attention to language and framing
Research outcomes are not adopted by end users	Possible	Major	• All projects take a proactive approach to identifying end-users during project scoping • Project leaders to work with the Steering Committee and the Western Australian Feral Cat Working Group to ensure optimal adoption by end users • Adoption milestones are included in all projects, and developed in consultation with the Steering Committee and the Western Australian Feral Cat Working Group
Insufficient funds are realised to implement key components of the program	Unlikely	Major	• Program components are carefully and strategically prioritised • Options for funding are fully explored • Significant effort put into community outreach to justify the program and its implementation, and to chart its successes

Policy

Description	Likelihood	Impact	Mitigation action
Policy changes work against the research outcomes of the program	Possible	Moderate	• Ensure that the regulatory sector is represented on the Steering Committee • Ensure effective communication between the Steering Committee, the Western Australian Feral Cat Working Group, and policy makers/regulators • Ensure that policy makers and regulators have access to the latest evidence based knowledge
Policy changes alter the likely impact of the research outcomes	Unlikely	Major	• Ensure that the regulatory sector is represented on the Steering Committee • Ensure effective communication between the Steering Committee, the Western Australian Feral Cat Working Group, and policy makers/regulators

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Photo courtesy: Bruce Webber

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Appendices

Noisy scrub-bird (*Atrichornis clamosus*)
Photo courtesy: Alan Danks, DBCA

APPENDIX 1.
Workshop attendees

WORKSHOP 1: 1st June 2018

FIRST	SURNAME	INSTITUTION
Dave	Algar	Department of Biodiversity, Conservation and Attractions
Chris	Curnow	Rangelands NRM
Peter	Davies	The University of Western Australia
Owain	Edwards	Commonwealth Scientific and Industrial Research Organisation
Di	Evans	Royal Society for the Prevention of Cruelty to Animals
Rowan	Hegglun	Wheatbelt NRM
Win	Kirkpatrick	Department of Primary Industries and Regional Development
Elisabeth	McLellan	Bush Heritage Australia
Richard	McLellan	Northern Agricultural Catchment Council
Ashley	Millar	Department of Biodiversity, Conservation and Attractions
Jane	O'Malley	Peel Harvey Catchment Council
Luke	Rogers	Peel Harvey Catchment Council
Jessica	Stingemore	Northern Agricultural Catchment Council
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Graham	Thompson	Terrestrial Ecosystems
Bruce	Webber	The Western Australian Biodiversity Science Institute / Commonwealth Scientific and Industrial Research Organisation
John	Woinarski	Charles Darwin University
Natarsha	Woods	Wheatbelt NRM
Peter	Zurzolo	The Western Australian Biodiversity Science Institute

APPENDIX 1.
Workshop attendees *(continued)*

WORKSHOP 2: 12th March 2019

FIRST	SURNAME	INSTITUTION
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Kathryn	Batchelor	Commonwealth Scientific and Industrial Research Organisation
Margaret	Byrne	Department of Biodiversity, Conservation and Attractions
Heather	Crawford	Murdoch University
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Christopher	Dickman	University of Sydney
Tim	Doherty	Deakin University
Di	Evans	Royal Society for the Prevention of Cruelty to Animals
Lesley	Gibson	Department of Biodiversity, Conservation and Attractions
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Malcolm	Kennedy	Department of Primary Industries and Regional Development
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Hugh	McGregor	University of Tasmania / Australian Wildlife Conservancy
Elisabeth	McLellan	Bush Heritage Australia
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Dorian	Moro	Department of Biodiversity, Conservation and Attractions / Murdoch University
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Russell	Palmer	Department of Biodiversity, Conservation and Attractions
John	Read	Ecological Horizons / Arid Recovery
Craig	Salt	Sustainable Consulting
Mike	Smith	Australian Wildlife Conservancy
Nolia	Ward	Kiwirrkurra Indigenous Ranger Group
Jodie	Ward	Kiwirrkurra Indigenous Ranger Group
Bruce	Webber	The Western Australian Biodiversity Science Institute / Commonwealth Scientific and Industrial Research Organisation
John	Woinarski	Charles Darwin University
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APPENDIX 1.
Workshop attendees *(continued)*

WORKSHOP 3: 13th March 2019

FIRST	SURNAME	INSTITUTION
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APPENDIX 2.
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APPENDIX 3.
Workshops 1 and 2 priority issues list

During workshop 1 (1st June 2018), end-user stakeholders identified 54 topics where solutions for managing feral cats depended, either in full or in part, on further research. Workshop 2 (12th March 2019) identified a further 27 research topics of relevance. Topics from workshop 1 and workshop 2 are listed without priority and are grouped by five focal areas.

FOCAL AREA 1: Social licence and value proposition

Topics from workshop 1

a) Help Indigenous groups to tell their story about cat control to form/grow the broader public discussions

b) Help more people understand what things were like pre-cats (e.g. get access to enclosures)

c) Re-imagine the landscape to overcome generational amnesia (don't remember/ never seen a landscape thriving with diverse species)

d) Time is now to communicate gene drive potential and needs

e) Not all people have good understanding of numbers – how else to communicate?

f) Communicate humaneness model – relative humaneness of methods

g) Understand where threats are in landscape – why doesn't the Feralcatscan app work?

h) Animal welfare – actual vs perceived

i) Reduce reliance on less humane methods or change perceptions about relative humaneness

j) Be mindful of emotional connection to cats (a cat is a cat is a cat)

k) Reframe the conversation – it is about 'saving native animals' not 'war on feral cats'

l) Control of feral cats is a means to an end – positive reframe on biodiversity as the end goal

m) Avoid desensitizing (people get used to messages – it becomes normal to accept impact on animals)

n) Publish failures

o) Condemn cross-bow or other outright cruel actions

p) Emotive issue – personal feeling + attachment

q) Dispelling misinformation is important – limiting Calici release

r) How do we make communications more effective? Do we use data effectively?

s) What is impeding more widespread acceptance of cat control?

t) Why is mining seen as a problem but not cats?

u) Risk to loss of control techniques due to losing social licence

v) Need social science to help design strategy to engage the undecided

APPENDIX 3.

Workshops 1 and 2 priority issues list
(continued)

Topics from workshop 2

w) What is the best way to raise community understanding?
- Responsible owner behaviour
- Understanding the difference between feral cats and stray/domestic cats
- What are the variation in impacts between feral/strays?

x) How does variation across the community impact on their views in regard to feral cat management?

y) Comparing animal welfare indicators for all different management options (current and future), including no action

z) Surveys to understand social acceptability of planned management programs

aa) How does Indigenous cat control methods fit in with the humanness model of prioritising feral cat control?

bb) Prioritising all current control methods using the humaneness model, and integrating these outputs with other optimising tools (e.g. efficiency, effectiveness, off-target impacts etc.), including predator, prey and non-target animals

FOCAL AREA 2: Improving existing management

Topics from workshop 1

a) Integrated introduced predator control, including identifying which integrating techniques are going to give the best possible outcome (i.e. context specific, two+ techniques)

b) How do we improve bait specificity in N Australia? (possibly merge with c, g, h)

c) How do we avoid targeting dogs, goannas etc.?

d) How does feral cat control interact with fox and rabbit control?

e) Do fences create predator naïve animals? If this OK for future reintroductions outside fences?

f) Are fences the only option for predator naïve species?

g) Bait specificity – improving baits to minimize risk to dingos / farm dogs

h) Constraints on Eradicat bait in SW, Kimberley and non-target 'by-catch'

Topics from workshop 2

i) How do we improve non-direct control methods (e.g. fire and grazing)

j) How do we understand and optimise the humaneness of existing management options?

k) How do we get consensus around the metrics for success of management programs?

l) Can we be more informed about when to do different management approaches (or not do anything)?

m) How do we make fenced reserves better for the surrounding landscape? Can we increase the 'positive halo' of fenced areas?

n) What is the local context required to inform which management strategies are most appropriate across contrasting Western Australian landscapes?

o) How can we monitor cat populations more effectively?

p) How can we improve lures and deterrents?

APPENDIX 3.

Workshops 1 and 2 priority issues list

(continued)

FOCAL AREA 3: Quantifying impacts

Topics from workshop 1

a) Cost/benefit analysis needs to include impacts on non-biodiversity (e.g. disease threats)

b) Ecological accounting is needed ($120k to raise a numbat at Perth Zoo!)

c) Continuously update the humane model as more, particularly quantitative, information comes to hand

d) Hard to measure the value of a woylie to the general public

e) Mesopredator release issues

f) Indirect interactions need to be better understood

g) What about impacts of feral cat predation beyond mammals (e.g. birds, reptiles, invertebrates)?

h) Cat density impact targets – are there thresholds to aim for to get a biodiversity response?

i) Is species specific context too great to target specific densities?

j) Research economic impact on agriculture of feral cats

k) Cost efficiency – e.g. 100 yrs of annual action vs .....)

l) Economics of feral cat management needs to be researched

m) Understand the business case for various management actions

Topics from workshop 2

n) How can we get improved insights from long term intervention managements (lots of funding required)?

o) Quantifying the efficacy of feral cat baiting control in the forests of SW WA (e.g. influence of rainfall)

APPENDIX 3.

Workshops 1 and 2 priority issues list
(continued)

FOCAL AREA 4: Developing novel management

Topics from workshop 1

a) Continue research into *Eradicat*, grooming traps (e.g. *Felixer*), don't rely only on gene technology

b) Non-disease control methods for humane reasons

c) Electronic collars preventing access to parks etc.?

d) Ethics of working on cats in labs since they are difficult lab animals and dislike being caged (is this really an issue – knowledge synthesis on this is a priority)

Topics from workshop 2

e) More baseline research on gene editing, including the feasibility of the technique and the technique itself

f) How can we manipulate cat behaviour to improve management outcomes (e.g. manipulating rewards, reinvasion after control programs)?

g) Quantifying the impact of traditional practices/hunting on cat control (comparing areas where this happens with where it doesn't)

h) Population protection implants (PPIs, or 'toxic trojans')

i) Maximising productivity of native species to improve ecosystem resilience (e.g. ethnobotany, Indigenous knowledge)

APPENDIX 3.

Workshops 1 and 2 priority issues list
(continued)

FOCAL AREA 5: Population ecology and behaviour

Topics from workshop 1

a) Gaps in population ecology understanding of feral cats (specific to question/context)

b) Bait avoidance (could move into theme 4)

c) Mobility / dispersibility / connectivity research needed to underpin gene editing models (and generally informative to other controls too) (specific to question/context)

d) Research into toxoplasmosis spread on native wildlife (also human impacts) and onto stock (e.g. sheep on Kangaroo Island)

e) Predator prey interactions need research (specific to question/context)

f) What can we learn from Traditional Owners? Importance of 2-way science (could move into theme 2)

g) Landscape scale actions are critical – what are they?

h) Mating biology research, ecology, population genetics

i) Cat-dingo-fox interaction needs understanding

Topics from workshop 2

j) Better quantification of cat/fire/cattle interactions and habitat complexity more broadly

k) Understanding natural causes of mortality (i.e. death beyond control programs)

l) Understanding cat social structure and how this impacts on management effectiveness

m) Gene and individual flow between stray and feral cat populations

n) What are the landscape attributes that impact on cat ecology and behaviour

o) What is the response of cats to fire and fire-modified landscapes? (possibly merge with j)

RIGHT: Numbats (*Myrmecobius fasciatus)*
Photo courtesy: Robert McLean

BACK COVER: Mardo (*Antechinus flavipes*)
Photo courtesy: Robert McLean

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