

# Protecting Western Australia's unique biodiversity - controlling pest animals

**Dr Margaret Byrne**



Biodiversity and  
Conservation Science

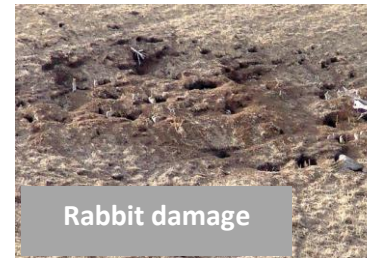
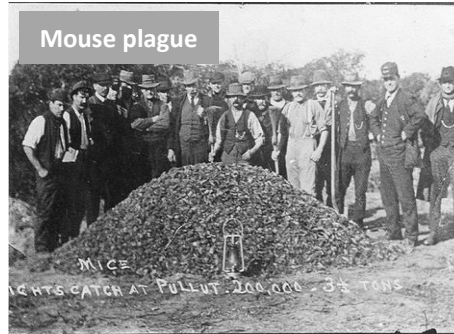
# Animal conservation - principles

- Maintain populations in the wild – recovery and reconstruction
- Manage threats (fox/cat predation, cane toads, black rats on islands, fire)
- Create secure new populations – translocations (wild, islands, enclosures)
- Captive breeding if required
- Multiple threats, multiple species
- Focus on conservation estate
- IUCN status, iconic species, stakeholder interest, regional context
- Work in partnership, Traditional Owners
- Science underpins conservation policy and practice



# Introduced and invasive animals

- House mouse
- European rabbits
- Feral foxes
- Feral cats
- Black rats
- Cane toads





# Biodiversity impacts of introduced invasive mammals



## Ongoing unraveling of a continental fauna: Decline and extinction of Australian mammals since European settlement

John C. Z. Woinarski<sup>a,b,1</sup>, Andrew A. Burbidge<sup>c</sup>, and Peter L. Harrison<sup>d</sup>

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This Feature Article is part of a series identified by the Editorial Board as reporting

Edited by William J. Bond, University of Cape Town, Cape Town, South Africa, and

The highly distinctive and mostly endemic Australian land mammal fauna has suffered an extraordinary rate of extinction (>10% of the 273 endemic terrestrial species) over the last ~200 y: in comparison, only one native land mammal from continental North America became extinct since European settlement. A further 21% of Australian endemic land mammal species are now assessed to be threatened, indicating that the rate of loss (of one to two extinctions per decade) is likely to continue. Australia's marine mammals have fared better overall, but status assessment for them is seriously impeded by lack of information. Much of the loss of Australian land mammal fauna (particularly in the vast deserts and tropical savannas) has been in areas that are remote from human population centers and recognized as relatively unmodified at global scale. In contrast to general patterns of extinction on other continents where the main cause is habitat loss, hunting, and impacts of human development, particularly in areas of high and increasing human population pressures, the loss of Australian land mammals is most likely due primarily to predation by introduced species, particularly the feral cat, *Felis catus*, and European red fox, *Vulpes vulpes*, and changed fire regimes.

conservation | biodiversity | marsupial | predation | feral animal

The world's biodiversity is in decline as humans increasingly use our planet's natural resources and modify its environments (1). Much of the current biodiversity decline is occurring in areas subject to the most rapid human population growth and highest rate of habitat loss and transformation, and in countries

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*'...the loss of Australian land mammals is ... due primarily to predation by introduced species, particularly the feral cat, Felis catus, and European red fox, Vulpes vulpes ...'*

### Earlier Losses

European settlement at 1788 marks a particularly profound historical landmark for the Australian environment, the opening up of the continent to a diverse array of new factors, and an appropriate baseline for measuring biodiversity change (9). However, the continent was not then paradisiacal: its mammal fauna had undergone profound changes before that date. The fossil record attests to appreciable change in the Australian mammal fauna over the previous hundred thousand years, most notably the loss of the continent's megafauna (10). The principal cause of these losses remains sharply contested but most likely involved a combination of rapid climate changes, environmental changes associated with the establishment of Aboriginal fire management, and hunting by Aboriginal people (who arrived on the continent about 50,000 y ago) (10–12). The arrival of the dingo, *Canis lupus dingo*, about 3,500 y ago (13) most likely caused further decline and change in the abundance of many species, although its role in broadscale extirpations at and since that time remains debated (14–16).

### Taking Stock: The Current Conservation Status and Outlook for the Australian Land Mammal Fauna

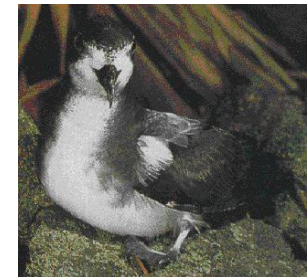
Our comprehensive review (7) concluded that 28 Australian endemic land mammal species have become extinct since 1788.





# Biodiversity impacts of introduced invasive mammals

**Feral cats - primary driver of extinction  
and current declines of >100 species  
(30% of Australia's mammal fauna)**



# Current control

Integrated chemical / physical management practices

- Poison baiting combined with habitat removal, fencing (rabbits, mice, rats)
- Poison baiting, shooting (fox)
- Poison baiting, trapping (feral cat)
- Biological control: rabbits: myxoma, RHDV1, RHDV1 (K5)



## Western Shield Fauna Conservation Program

fox and feral cat baiting  
over 3.8 m ha

- Varying levels of efficacy
  - Short-term results in population control
- Unintended ecological consequences (mesopredator release)





## Optimising control strategies

### Non target impacts – assess risk to non-target species

- Laboratory and field trials, adapt to minimise exposure

### Optimal deployment

- Determine the optimum time of year to conduct baiting and trapping programs to maximise efficiency
- Examine baiting intensity to optimise control
- Examine baiting frequency required to provide sustained effective control



## Fox bait

### ***Probait***<sup>®</sup>

- dried meat bait
- toxin sodium monofluoroacetate (1080)
- *Gastrolobium* plants
- native species tolerant, co-evolved
- bait every 3-4 months





## Cat baits

### ***Eradicat***<sup>®</sup>

- moist sausage bait
- 4.5 mg of the toxin sodium monofluoroacetate (1080)
- bait registered for operational use in Western Australia
- 16,000 km<sup>2</sup> aerially baited with *Eradicat*<sup>®</sup> baits
- bait annually in autumn



### ***Curiosity***<sup>®</sup>

- based on the *Eradicat*<sup>®</sup> bait medium
- acid-soluble encapsulated pellet - 'hard shell delivery vehicle' (HSDV)
- 80 mg para-aminopropiophenone (PAPP)
- HSDV contains toxin, reduces exposure



### ***Hisstory***

- same bait matrix as *Curiosity*<sup>®</sup>
- contains 4.5 mg 1080 in the HSDV
- currently being tested in field efficacy trials in northern Australia

# Ecological Restoration – Dirk Hartog Island



Island 63,000 Ha  
Ex pastoral lease,  
National Park

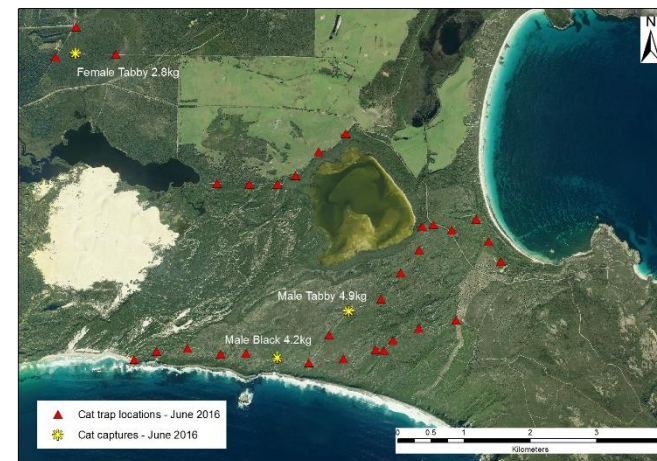
- Removal of sheep
- Eradication of goats
- Eradication of cats
- Reintroduction of 12 mammals

(Rufous hare wallabies,  
Banded hare wallabies)





# Emergency interventions





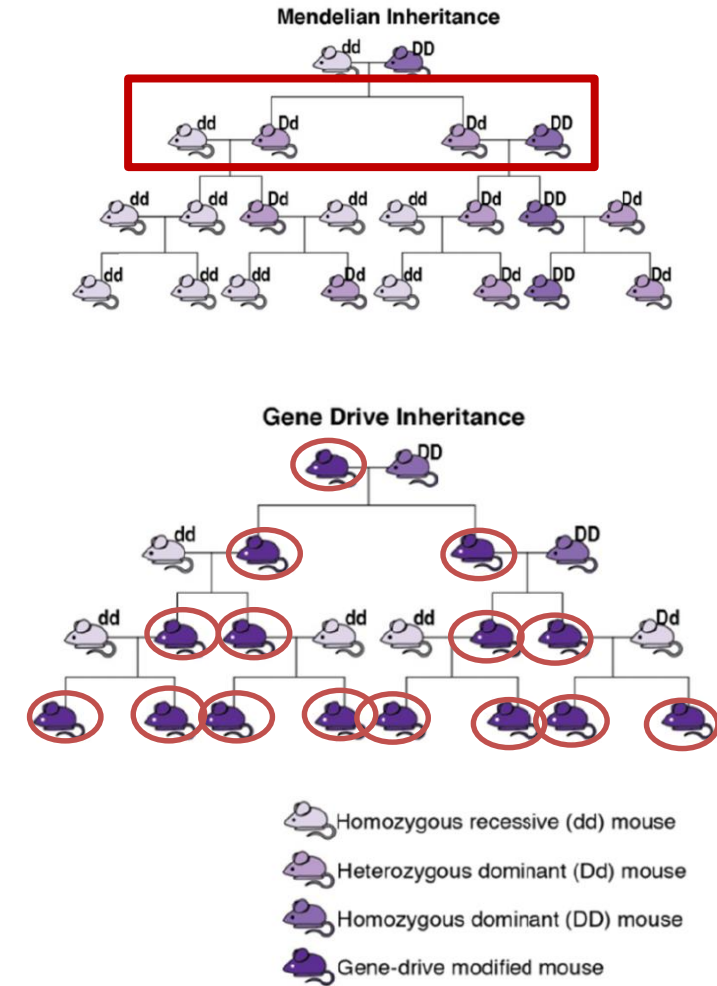
# Alternative practices

- Sterile males (invertebrates, carp)
- Virally vectored immuno-contraception
  - mice, rabbits, foxes
- Gene drives and gene editing (eg. CRISPR-Cas9)
  - species-specific
  - non-lethal
  - multiple applications
    - disease resistance
    - tolerance environmental toxins
    - reduce toxin production
    - disruption of a sex-determining gene to skew sex ratios to drive population suppression or extirpation



# Gene drive and Gene editing

- Normal rules of inheritance
  - one allele from female and one allele from male
  - pass on only one of these to each offspring
- *Meiotic drives* are unusual naturally occurring genetic elements that distort the normal inheritance and gene segregation, leading to (theoretically) full transmission of the character
- CRISPR/Cas 9 gene editing - creates precision breaks in DNA, repairing the break exploited to cause duplication of a gene drive cassette
- **Precise** editing of a **single gene** in the tens of thousands that make up an animal's DNA code



Duplicate sex determining gene – skew sex ratio – population extirpation

# Considerations - policy

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Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values

#### DETAILS

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Division on Earth and Life Studies; National Academies of Sciences,  
Engineering, and Medicine

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Working Party on Biotechnology, Nanotechnology  
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Directorate for Science, Technology and Innovation

This workshop aims to stimulate a wide-ranging discussion that involves scientists, business leaders, policy makers and opinion leaders. It will be a cross-disciplinary event to exchange information and approaches across countries on the science, governance, and economics of gene editing innovations in:

- Applications in Agriculture & Aquaculture
- Environmental Applications, and
- Applications in Human Medicine.

Working through breakout sessions and case studies, the meeting will highlight policy issues of applications in each sector. It will also explore the important issues shared across these sectors that are critical to economies, including issues of science policy, innovation and governance. In addition, the workshop aims to address certain economic questions raised by gene editing, notably IP issues and business and financing models, with a view to highlighting important aspects of responsible commercialisation.

## Workshop on Gene Editing in an International Context: Scientific, Economic and Social Issues across Sectors

29 – 30 September 2016

Sir Frederick G. Banting Building  
at Tunney's Pasture\*

\*251 Sir Frederick Banting Driveway, Ottawa, Ontario, Canada K1A 0K9



## IUCN Assessment of Synthetic Biology and Biodiversity Conservation

### GENE DRIVES IN AUSTRALIA

DISCUSSION PAPER, NOVEMBER, 2016

#### INTRODUCTION

Gene drive mechanisms cause a gene to spread throughout a population at a rate higher than would be predicted by Mendelian inheritance. Research on synthetic gene drives has accelerated recently due to significant advances in genome editing tools. Since 2015 scientists have published four proof of concept studies in yeast, mosquitoes and the fruit fly *Drosophila* to demonstrate the feasibility of using synthetic gene drives for purposes such as combating vector-borne disease, suppressing pest populations, or for introducing desired characteristics into target organisms. The potential applications are far reaching, as are the potential impacts—both intended and unintended—on public health, conservation and ecology. This rapidly developing area represents an additional method of manipulating populations alongside traditional and other methods as listed in Table 1.

The pace at which the science and technology field is moving has triggered international discussion on gene drives (Nuffield, 2016; NAS, 2016a). There is a need for governments and communities around the world to consider if, when and how it will be permissible to release organisms with synthetic gene drive mechanisms into the environment. Concerns have been raised in the scientific community as to whether organisms modified with synthetic gene drives should be released, and there is significant discussion amongst scientists on best practice and mitigation strategies.

This discussion paper is a contribution from the Australian Academy of Science, in which the Academy highlights: (i) the benefits and risks of synthetic gene drives; (ii) ways to minimise the potential risks of an unintentional release of a gene drive modified organism; and, (iii) ways to limit the duration of the expression of the modification in the environment. This report discusses ecological and environmental hazards, social and economic issues (including trade implications) and governance issues from an Australian and international perspective. Our unique Australian environment generates a number of issues specific to our country and this report reflects such benefits and problems. The Academy intends that this discussion paper will inform government and community thinking and decisions about gene drive technology in Australia.

#### Principles for Funders of Gene Drive Research

Claudia Emerson<sup>1</sup>, Stephanie James<sup>2</sup>, Katherine Littler<sup>3</sup>, \*Fil Randazzo<sup>4</sup>

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\*Corresponding Author

The recent outbreak of Zika virus in the Americas has renewed attention on the importance of vector control strategies to fight the many vector-borne diseases that continue to inflict suffering around the world. In 2015, there were approximately 212 million infections and a death every minute from malaria alone.<sup>1</sup> Gene drive technology has been proposed as a potentially durable and cost-effective strategy for controlling the transmission of deadly and debilitating vector-borne diseases that affect millions of people worldwide. Additionally, it has also been proposed for various applications in conservation biology, and as a highly specific and humane method for eliminating invasive species from sensitive ecosystems.<sup>2</sup> Gene drive is an emerging technology that promotes the preferential inheritance of a gene of interest, thereby increasing its prevalence in a population. A variety of gene drives occur in nature that can cause genetic elements to spread throughout populations to varying degrees, and researchers are studying how to harness these mechanisms to solve some of society's most intractable problems.<sup>3</sup> Aided by CRISPR gene editing technology, the rapid pace with which the technology is progressing is demonstrated by recent achievement of successful gene drives in the laboratory.<sup>4</sup>



# Considerations - scientific

Scienceexpress

Policy Forum

## Regulating gene drives

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Regulatory gaps must be filled before gene drives could be used in the wild

Genes in sexually reproducing organisms normally have, on average, a 50% chance of being inherited, but some genes have a higher chance of being inherited. These genes can increase in relative frequency in a population even if they reduce the odds that each organism will reproduce. Aided by technological advances, scientists are investigating how populations might be altered by adding, disrupting, or editing genes or suppressed by propagating traits that reduce reproductive capacity (1, 2). Potential beneficial uses of such "gene drives" include reprogramming

sal drives could overwrite unwanted drive or by conventional genome engineering. However, ecological effects. These and other RNA-guided gene drives have yet to be demonstrated in the laboratory.

Environmental and security aspects

A recent workshop examined key questions concerning effects of devel-

nome engineering that uses the CRISPR nuclease Cas9 to cut sequences specified by guide RNA molecules (5, 6).

This has more enabled editing in animals, but only under the strictest conditions and with appropriate safeguards.



org on July 17

## WORLD VIEW

A personal take on events

## Regulate gene editing in wild animals

The use of genome-modification tools in wild species must be properly governed to avoid irreversible damage to ecosystems, says Jeantine Lunshof.

Gene editing is a hot topic following a flurry of interest in the use of CRISPR tools to modify human embryos. As an ethicist in a genome-engineering lab, I am an eyewitness to these recent scientific developments and I do have concerns about the way gene

certainly be allowed, but only under the strictest conditions and with appropriate safeguards.

In less than three years, CRISPR has become a key tool for biologists. 'Should they stop before it is too late?' is therefore an immaterial question.

## Opinion: Is CRISPR-based gene drive a biocontrol silver bullet or global conservation threat?

Bruce L. Webber<sup>a,b</sup>, S. Raghu<sup>c</sup>, and Owain R. Edwards<sup>a,1</sup>

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Scientists have recognized the potential for applying gene drive technologies to the con-

but whether we should. Here we explore the implications of recent developments in

### Driven to Extinction

Gene drive technologies provide the ability to disperse engineered genes throughout target populations much more quickly than would be possible via simple genetic inheritance (5). In nature, selfish genetic elements use a similar strategy, generating multiple copies across the genome to improve the chances that they are inherited (6).

BIOSAFETY

## Safeguarding gene drive experiments in the laboratory

Multiple stringent confinement strategies should be used whenever possible

By Omar S. Akbari<sup>1,2</sup>, Hugo J. Bellen<sup>3,4</sup>, Ethan Bier<sup>5,\*</sup>, Simon L. Bullock<sup>6</sup>, Austin Burt<sup>7</sup>, George M. Church<sup>8,9</sup>, Kevin R. Cook<sup>10</sup>, Peter Duchek<sup>11</sup>, Owain R. Edwards<sup>12</sup>, Kevin M. Esvelt<sup>8,\*</sup>, Valentino M. Gantz<sup>5</sup>, Kent G. Golie<sup>13</sup>, Scott J. Gratz<sup>14</sup>, Melissa M. Harrison<sup>15</sup>, Keith R. Hayes<sup>16</sup>, Anthony A. James<sup>17</sup>, Thomas C. Kaufman<sup>10</sup>, Juergen Knoblich<sup>11</sup>, Harmit S. Malik<sup>18,19</sup>, Kathy A. Matthews<sup>10</sup>, Kate M. O'Connor-Giles<sup>14,20</sup>, Annette L. Parks<sup>10</sup>, Norbert Perrimon<sup>9,21</sup>, Phillip Port<sup>6</sup>, Steven Russell<sup>22</sup>, Ryu Ueda<sup>23,24</sup>, Jill Wildonger<sup>25</sup>

## PROCEEDINGS B

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### Research



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## Dodging silver bullets: good CRISPR gene-drive design is critical for eradicating exotic vertebrates

Thomas A. A. Prowse<sup>1</sup>, Phillip Cassey<sup>2</sup>, Joshua V. Ross<sup>1</sup>, Chandran Pfitzner<sup>2</sup>, Talia A. Wittmann<sup>2</sup> and Paul Thomas<sup>2,3</sup>

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Self-replicating gene drives that can spread deleterious alleles through animal populations have been promoted as a much needed but controversial 'silver bullet' for controlling invasive alien species. Homing-based drives comprise

# Potential for pest management

*Investigate gene editing as a sustainable and economic landscape-wide alternative to population control of invasive species*

*while understanding and addressing the ecological risks*

- Identify requirements of target species in risk framework
  - Knowledge
  - Desirable characteristics/features
- Identify knowledge gaps to aid future research priorities

## Target species

- House mouse
- European red fox
- European rabbit
- Feral cat
- Black rat
- Cane toad
- European starling

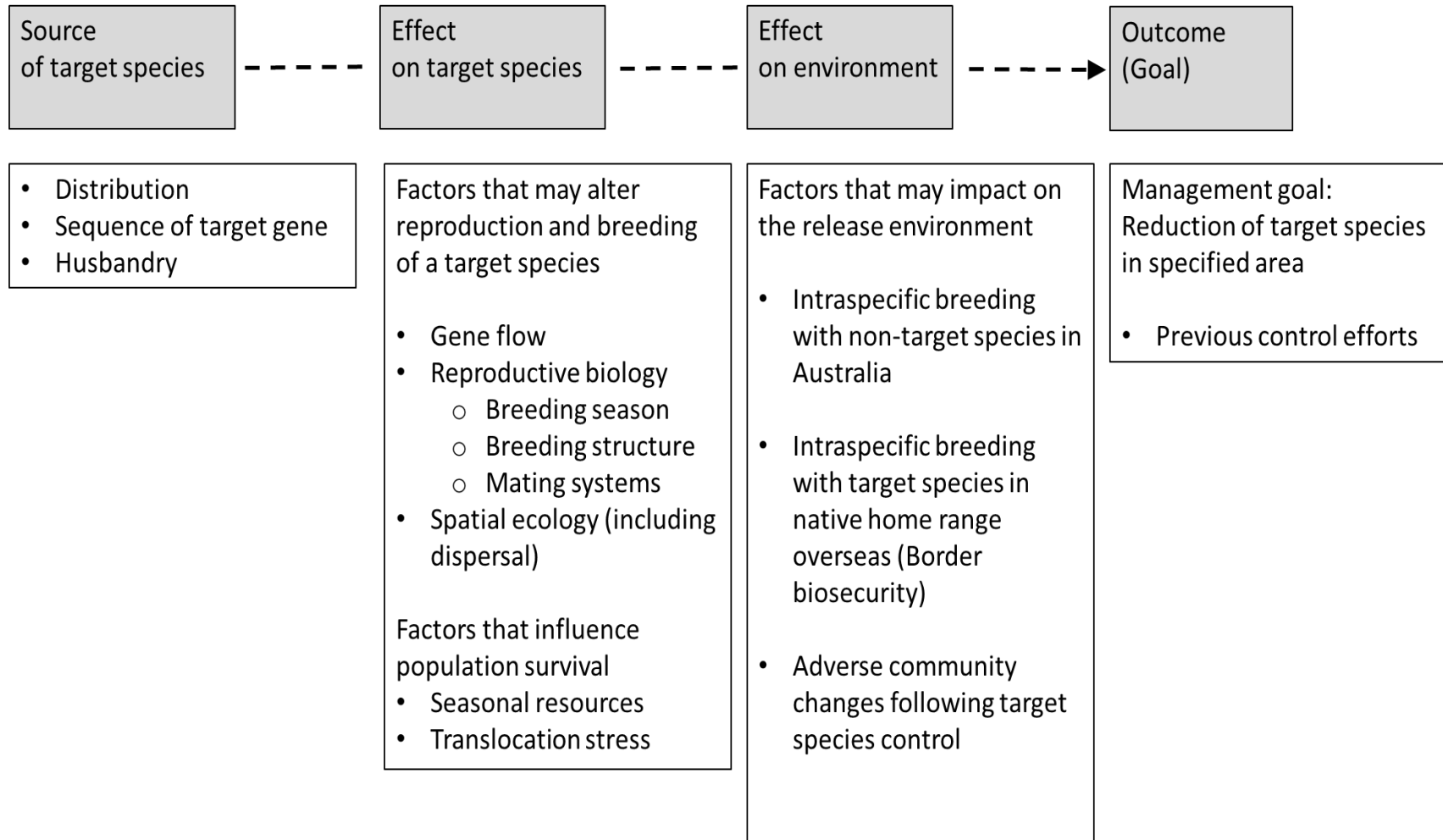


Review Paper

Identifying knowledge gaps for gene drive research to control invasive animal species: The next CRISPR step

Dorian Moro <sup>a,\*</sup>, Margaret Byrne <sup>a</sup>, Malcolm Kennedy <sup>b</sup>, Susan Campbell <sup>c</sup>, Mark Tizard <sup>d</sup>

# Risk framework



*Modified from 'Gene Drives on the Horizon.' National Academies of Sciences, Engineering, and Medicine 2016*



# Knowledge gaps

Species	Life history and fecundity data (age-specific and sex-specific)	Gene flow	Clarify sex-determining genes	Density dependant reproduction and mate selection	Border transport pathways	Community interactions	Invasion biology	Fertility control
House mouse	✓	Mate selection	✓	✓	X	✓	X	✓
Rabbit	✓	Mate selection	✓	✓	X	✓	X	✓
Feral cat	X	X	✓	X	X	✓	X	X
Fox	✓	X	✓	✓	X	✓	X	✓
Black rat	X	X	partial	X	X	minimal	X	X

## Considerations

- New control tools for controlling invasive mammals in Australia are urgently needed
- Gene editing/gene drive is worth investigating
- Open discussion and evaluation, Community acceptance
- Acknowledge risks of gene editing/gene drive technologies and options for mitigation
- Baseline information on the biology and ecology of target species is needed
- Risk assessment – framework for evaluation



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