Australian Government

Department of Climate Change, Energy, the Environment and Water

Background document for the threat abatement plan for predation by feral cats 2023

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Acknowledgement of Country

Our department recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge Aboriginal and Torres Strait Islander Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past, and present.

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1 Context

This background paper provides foundational information for the threat abatement plan (2023) for the key threatening process of *predation by feral cats*, as listed under Australia's national environmental legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Act's specifications for threat abatement plans are detailed in Appendix 1. Relevant legislation for states and territories is summarised in Appendix 2.

This background paper recapitulates and updates the background paper (Department of the Environment 2015a) linked to the previous (2015) iteration of this threat abatement plan (Department of the Environment 2015b). An earlier background paper (Department of the Environment Water Heritage and the Arts 2008a) accompanied the 2008 iteration of the threat abatement plan (Department of the Environment Water Heritage and the Arts 2008b).

Predation by feral cats was listed as a key threatening process in 1999 under the legislation preceding the EPBC Act, the *Endangered Species Act* 1992, and under the EPBC Act subsequently (Environment Australia 1999). Since then, and partly in response to this listing, there has been a substantial research effort in Australia aiming to understand the ecology and impacts of feral cats, and the efficacy of management options, and to apply such knowledge to enhance the control of feral cats to reduce their impact on biodiversity. The results and outcomes of such effort have been described in a large body of publications, and this background paper distils, rather than comprehensively details, that evidence base, with particular emphasis on information relevant to management. Other recent major compilations of information on the impact and management of feral cats in Australia can be found in two books on the subject – *Among the pigeons: why our cats belong indoors* (Read 2019) and *Cats in Australia: Companion and Killer* (Woinarski *et al.* 2019b) – and in a two volume issue of the journal *Wildlife Research* (Legge *et al.* 2020), and in a review of the impacts and management of feral cats in Australia (Doherty *et al.* 2017).

Consistent with the delineation of the key threatening process, the focus of this background paper is on the issue of predation on Australian fauna by feral cats. However, it also includes information on impacts that feral cats have on Australian biodiversity through the spread of disease, and through competition; some information on impacts of feral cats on cultural and economic values; and some information on impacts of pet cats on Australian biodiversity.

The management of feral cats across Australia is a complex and collaborative issue that involves the Commonwealth and state/territory governments, local governments, and many other groups including landholders, non-government conservation organisations, Indigenous groups, Natural Resource Management agencies, pet-owners and animal welfare groups. In many cases, these stakeholders have their own key information resources and policies: some of these are listed in Appendix 3.

2 Definitions

In general, all cats (i.e., including pet and feral cats) in Australia belong to the introduced species *Felis catus*, the domestic cat. The few exceptions may comprise some cases of hybrids bred in captivity between *Felis catus* and other felid species. Specifically, the Australian government allows importation of bengal cats – hybrids of *Felis catus* and the Asian leopard cat *Prionailurus bengalensis* – provided they are at least five generations removed from the Asian leopard cat; and some bengal cats are now present in Australia. In contrast, hybrids of *Felis catus* and serval *Leptailurus serval* ('savannah cats') are prohibited imports to Australia, due to their potential to compound the impacts of feral cats (Dickman *et al.* 2019).

- **Feral cats** are not formally owned, or cared for, by people. They survive by hunting or scavenging for themselves and live in diverse habitats. Most feral cats live in natural environments and have no or few interactions with people. A subset of feral cats is found in and around cities, towns and rural properties; these cats may rely on resources that are inadvertently provided by people, such as rubbish tips or abundant rodent populations. These cats are sometimes called 'stray cats'.
    - *Management interventions for feral cats seek to reduce their abundance or change their hunting behaviours; some actions for feral cats living in and around human infrastructure differ from those in scope in more natural environments.*
- **Pet cats** are owned by a person or people; their needs (food, shelter, veterinary care) may be wholly or partly supplied by their owners. Some pets are contained indoors, but others roam widely, and feed themselves.
    - *Management interventions seek to promote the uptake of principles for responsible ownership of pets, and to reduce the likelihood of pet cats from supplementing the feral cat population, and contributing to pathogen transmission.*

In this document, 'cat' is used to refer to pet and feral cats collectively, whilst the terms 'pet cat' and 'feral cat' are used to refer to those specific subsets of cats. Feral cats may be further described as those living in natural environments, and those living in or around human infrastructure or heavily modified environments.

This classification was also used in the 2015 feral cat threat abatement plan, although that document used the word 'stray' rather than 'feral cats living in or around humans'.

There are other definitional schemes. The RSPCA (RSPCA 2018) proposed a categorisation based also on the cat's degree of association and socialisation with humans:

- **Domestic** – all cats with some dependence (direct or indirect) on humans, with three sub-categories:
    - *Owned* – these cats are identified with and cared for by a specific person, and are directly dependent on humans. They are usually sociable although sociability varies.

- *Semi-owned* – these cats are fed or provided with other care by people who do not consider they own them. They are of varying sociability with many socialised to humans and may be associated with one or more households.
- *Unowned* – these cats are indirectly dependent on humans with some having casual and temporary interactions with humans. They are of varying sociability, including some who are unsocialised to humans, and some may live in groups (e.g., common aggregation sites including rubbish tips, food outlets, coastal fishing spots associated with urban environments etc).

- **Feral** – these cats are unowned, unsocialised, have no relationship with or dependence on humans, and reproduce in the wild.

A recent parliamentary inquiry into 'the feral cat pandemic' noted some inconsistency among states and territories regarding terminology, and definitions of cat categories (Table 1) (HoR SCEE 2020).

Table 1 Terminology used to define cats in each jurisdiction, as given in the House of Representatives Standing Committee Inquiry, 2020

Jurisdiction	Terminology
Commonwealth	Defines 'feral', 'stray' and 'domestic' cats
Queensland	Does not differentiate by 'feral' or 'stray'
New South Wales	Defines 'cat' as 'an animal of the species *Felis catus*, whether or not domesticated'
Australian Capital Territory	Groups all cats together as an example of 'domestic' animals
Victoria	Does not explicitly define 'feral' or 'domestic'
Tasmania	Defines 'stray and 'feral' cats
Northern Territory	Defines 'feral animals' but not specifically cats
South Australia	Defines 'cat' as 'an animal of the species *Felis catus*
Western Australia	Does not refer to 'feral', 'domestic' or 'stray' animals except in relation to powers to destroy 'feral' cats

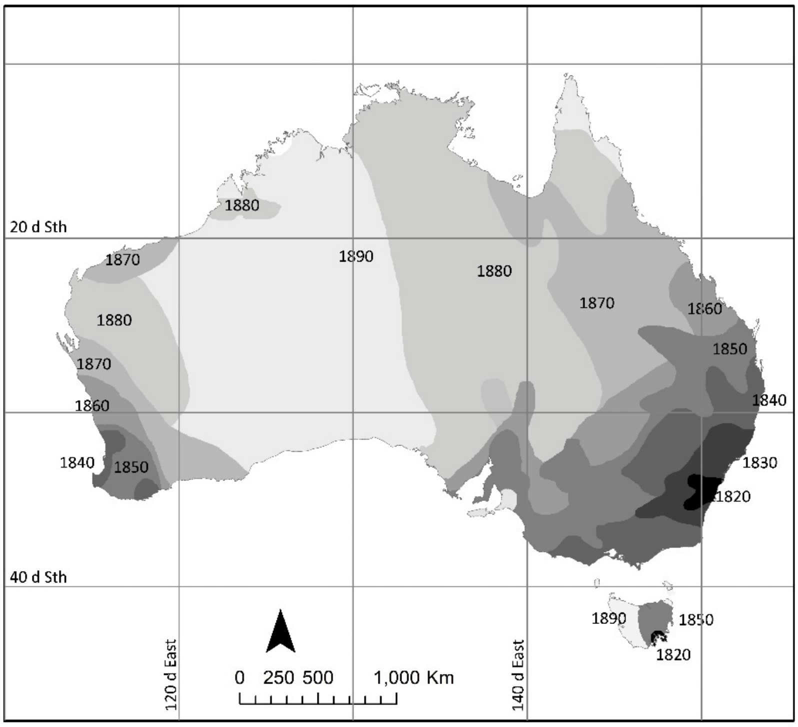
3 Feral cats in Australia

3.1 History

Cats *Felis catus* were domesticated from African wildcats *Felis lybica* about 4000 years ago, in north Africa. The domesticate is treated as a separate taxon from its wild ancestor. Cats have since been introduced to and spread widely across all continents other than Antarctica, and many islands.

Cats accompanied the first European colonists to Australia and have been repeatedly introduced as pets since then. The spread of feral cats across much of Australia was also aided by the deliberate release to the wild of many cats into rural areas in the second half of the nineteenth century as an attempt to reduce the proliferation of rabbits *Oryctolagus cuniculus* and 'plagues' of house mice *Mus musculus* following a series of introductions of these, mostly in the early nineteenth century (Rolls 1969; Woinarski *et al.* 2019b). The chronology of the spread of feral cats Australia is illustrated in Figure 1, based on the collation and interpretation of thousands of historical records (Abbott 2002; Abbott 2008b); note however that the timing of the introduction to offshore islands is in general far less well resolved.

Figure 1 The chronology of the spread of feral cats across Australia, adapted from Abbott (2008b)

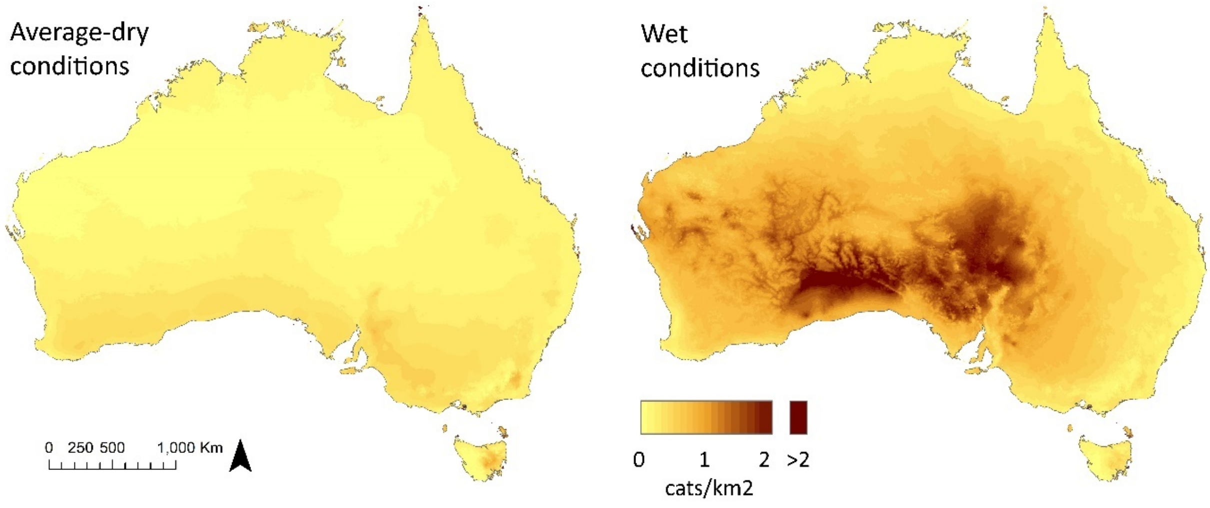


3.2 Density, distribution, population size, and variation in abundance

3.2.1 Density and total population

Since the previous iteration of the threat abatement plan, there have been considerable advances in knowledge of the density and population size of feral cats in Australia, with such advances due largely to the increasing deployment of arrays of remote cameras, recognition of individual cats in images produced from such cameras, and then application of capture-mark-recapture analysis (McGregor *et al.* 2015b). Legge *et al*. (2017) collated 91 estimates of the density of feral cats from widely spread locations across Australia, and modelled variation in these estimates relative to a suite of geographic and environmental factors. The density of feral cats varies significantly between mainland areas and islands (with higher density on islands, especially smaller islands), and rainfall conditions (with higher densities in arid and semi-arid areas in years following good rainfall). The average density of feral cats in Australia's natural environments is 0.27 cats per km^2, increasing to 0.73 cats per km^2 in good rainfall years. Based on the modelled spatial variation in density estimates, there are 2.07 million (95% confidence intervals 1.4 to 3.45 million) feral cats in Australia's natural environments, with this tally rising to 5.56 million (95% confidence intervals 2.5 to 10.9 million) in good rainfall years. Spatial variation in cat density is depicted in Figure 2, with densities notably highest in semi-arid and arid areas following years of good rainfall.

Figure 2 Modelled density of feral cats in Australia (in natural areas) in normal years and following good rainfall in inland Australia (Legge et al. 2017).



Based on fewer samples, Legge *et al.* (2017) also estimated the density and population size of feral cats in highly modified landscapes such as urban areas and other intensive development sites. The average density of feral cats in these highly modified landscapes is 8.2 cats per km^2, and the total size of this component of the cat population is 0.71 million cats.

The total population of pet cats has been estimated through household sampling. The most recent estimate based on these surveys is that there are 5.3 million pet cats in Australia (Animal Medicines Australia 2022), with this figure increasing rapidly, from 3.8 million in 2019 (Animal Medicines Australia 2019). Thus, in average years, the total population of cats in Australia is 8.1 million.

As context for these estimates of the numbers of cats in Australia, the United States has an estimated 100 million pet cats (Kitts-Morgan 2015) and 30 to 100 million unowned cats (Jessup 2004; Loss *et al.* 2013).

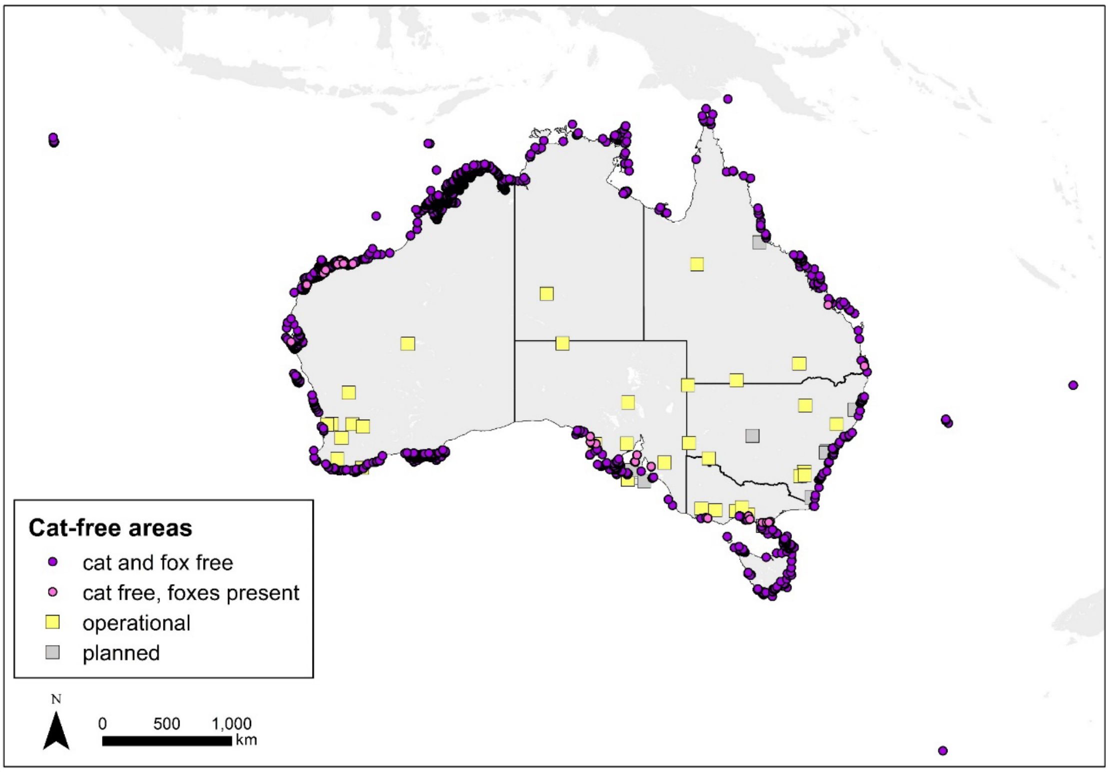
3.2.2 Distribution and cat-free areas

Feral cats are almost pervasive in Australia. They occur in all terrestrial habitats, from alpine areas to the most arid deserts, including rainforests, woodlands, heathlands, and grasslands. However, their persistence in some desert areas may depend upon the availability of refuges (such as burrows) that provide some protection from high temperatures (Briscoe *et al.* 2022).

Legge *et al*. (2017) collated information on the occurrence of cats on Australian islands, and on the extent of areas in mainland Australia where cats have been excluded (through predator proof fencing). Subsequent to that 2017 assessment, cats have been eradicated from Dirk Hartog Island, and from 14 additional mainland fenced areas; and some more information is now available on the occurrence of cats on islands.

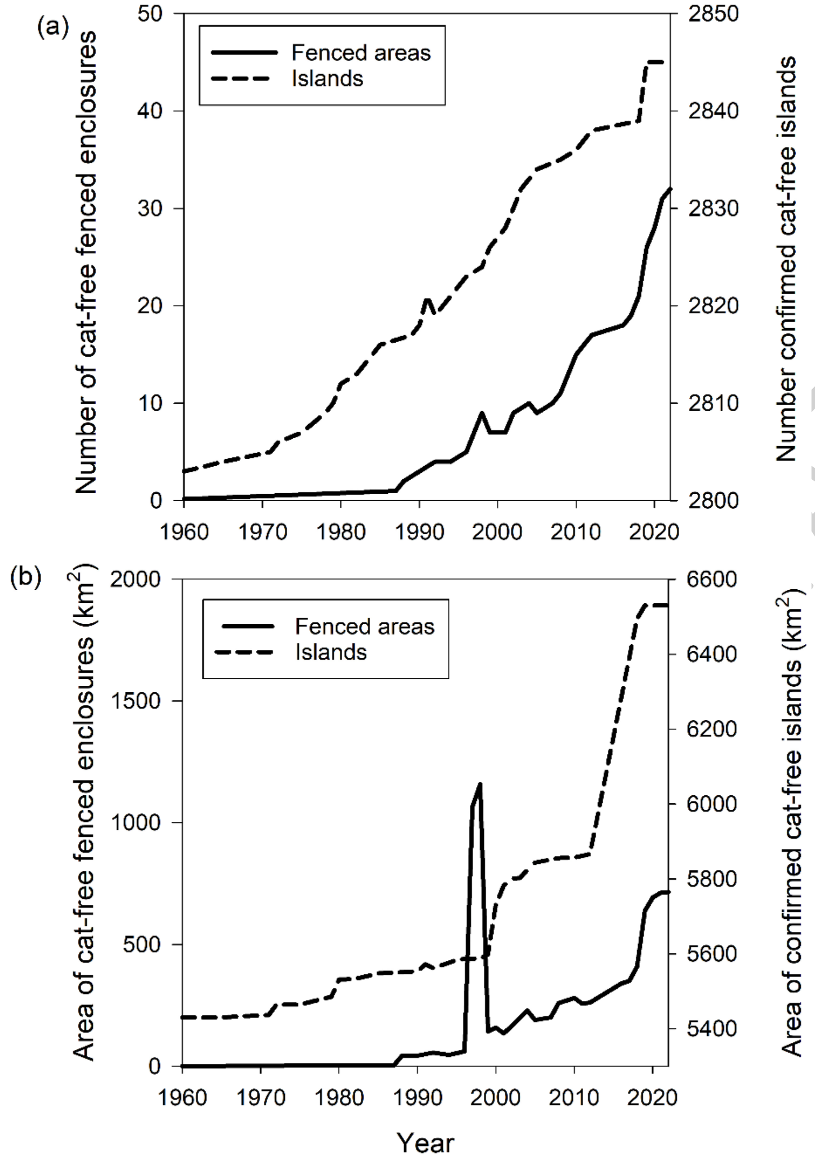
- Cats are known to be present on 96 Australian islands (including Tasmania; Appendix 4), covering 89,521 km^2, or 92% of the 5447 Australian islands that are larger than 1 ha. Excluding Tasmania these tallies are 25,002 km^2 (76% of the total area of all Australian islands other than Tasmania).
- Cats are known to be absent from 2845 islands, with a total area of 6530 km^2 (Fig. 3; Appendix 4)
- The presence or absence of cats is unknown for c. 2506 Australian islands (of >1 ha) covering 1436 km^2 (Appendix 4). However, most of these are small islands and unlikely to support cats. The total area of islands uninhabited by cats is therefore between 6530 and 7966 km^2, representing around 0.1% of Australia's total land area.
- Within the set of cat-free Australian islands, cats have been eradicated from 30 (Appendix 5). The largest of these is Dirk Hartog Island (628 km^2), with the eradication occurring in 2018 (Algar *et al.* 2020b). This is also the largest island in the world from which cats have been eradicated (Campbell *et al.* 2011). Cats died out on an additional 17 islands, and eradication programs are underway on nine islands (Appendix 5). The number and area of cat-free islands is therefore increasing over time (Fig. 4).
- As at December 2022, feral cats were excluded (by fencing) from 32 sites in mainland Australia, with a total area of 715.4 km^2, representing 0.01% of Australia's land area. The number and extent of such exclosures (established to protect threatened mammals from predation) is increasing (Fig. 4; Appendix 6).
- Based on the total areas of exclosures and the maximum number of islands without cats, the total extent of areas in Australia without feral cats is less than 8681 km^2, meaning that feral cats occur in 99.9% of Australia.

Figure 3 Locations of cat-free islands and mainland fenced enclosures, at December 2022.



Past enclosures not included on the map because they are no longer operational are Genaren Hill (NSW), Peron Peninsula (WA), Heirisson Prong (WA). Map based on Legge *et al*. 2018, with updated data.

Figure 4 Growth in the number and cumulative area of cat-free islands and fenced enclosures since the 1960s.



The data for islands are shown by the right axes and for fenced enclosures by the left. Reduction in areal extent denote when a haven 'failed (e.g. the fence of a fenced area was damaged and cats invaded). The pronounced spike in the areal extent of fenced enclosures in the late 1990s shows the creation then failure of Peron Peninsula as a cat and fox free area. Only confirmed cat-free islands are shown here; 4650 Australian islands (of >1 ha) covering 2173 km^2, may also be cat-free.

3.3 Cat ecology

The natural history of cats has been recently summarised in Woinarski *et al.* (2019b). That account is briefly parsed here. Cats are ambush predators and obligate carnivores, meaning they specialise on hunting live prey; they rarely consume carrion, and are unable to digest plant carbohydrates. Cats will hunt anything smaller than themselves (but usually < 200g) from all vertebrate classes and arthropods (see section 4.1 for more details). Prey is taken mostly according to their relative availability, although individual cats may develop hunting specialisations, and females may pass these preferences to their young. Cats are habitat generalists.

The social and spacing systems of cats are flexible and respond to food dispersion. When food is evenly dispersed, cats are mostly solitary, with females occupying home ranges that overlap only marginally with other females, and males occupying home ranges that overlap with one or more females. As food becomes clumped, females may coalesce into matrilineal groups around those resources, with much smaller ranges, and with males more loosely attached, potentially moving between female groups. At the other extreme, when food is very scarce, individual cats may leave their territories and range semi-nomadically in search of resources. Cats may move many kilometres to areas that support pulses of food availability or increased likelihood of hunting success, such as recently burnt patches (McGregor *et al.* 2016b). Tracking of individual feral cats has demonstrated that some may disperse over distances greater than 100 kilometres (Jansen *et al.* 2021; Roshier and Carter 2021). Cats from surrounding areas may readily and rapidly move into localised areas from which managers have removed resident cats (Lazenby *et al.* 2015).

The mating system varies with the social and spacing system – tending towards monogamy when males can monopolise access to a single female, to polygyny when male territories overlap with multiple females, and towards promiscuity (females mating with multiple males; males with multiple females) when cats are living at high density, and males are unable to monopolise access to females. Cats are sexually dimorphic, with males being larger than females (male weight averages 4.2 kg; females 3.3 kg).

Feral cats live for an average of 3-7 years, much less than pet cats. Offspring disperse away from their mother upon reaching maturity, with sons dispersing further than daughters. If cats are living in groups, daughters may be recruited into the matrilineal group. Young females can breed in their first year of life, young males usually breed from one to two years of age. Female cats have high reproductive potential, typically producing two litters a year, each of four kittens (but more litters and larger litter sizes are possible). Juvenile mortality is variable but can be high.

4 Cat impacts

4.1 Predation

Cats have had, and continue to have, a major detrimental impact on Australian biodiversity. The evidence for such impacts includes: (i) correlations over time and space in the spread of cats and the reciprocal decline and extinction of many native animal species (Dickman 1996; Lunney 2001; Abbott 2008a); (ii) persistence of susceptible native species on islands without cats compared to their extirpation on cat-occupied islands and the mainland (Woinarski *et al.* 2011; Burbidge *et al.* 2018); (iii) recovery of susceptible native species from sites where cats have been extirpated or intensively controlled (Miller and Mullette 1985; Paltridge *et al.* 2016; Springer 2018); (iv) success of many reintroduction programs for susceptible native species to sites where cats have been extirpated or intensively controlled, but general failure of such reintroductions where cat control has not been effective (Moseby *et al.* 2011b; Kanowski *et al.* 2018; Moseby *et al.* 2018); (v) tracking, experimental and other autecological studies of native animal species that demonstrate significant incidence and impacts of cat predation (Gibson *et al.* 1994; Moseby *et al.* 2015; Short 2016); and (vi) dietary studies of cats that demonstrate predation on cat-susceptible species (Woinarski *et al.* 2017a; Murphy *et al.* 2019). This evidence base for this impact is much stronger for mammals and some birds (especially on islands) than for other taxonomic groups of Australian fauna.

Cats have been implicated in the extinction of many Australian animal species, including as a primary cause of most of the 33 Australian mammal species that became extinct since European settlement (Woinarski *et al.* 2015). Of 60 Australian animal species formally recognised as extinct (or extinct in the wild) over this period, cats are thought to have been a contributing factor to one of 10 invertebrate extinctions, none of one fish extinction, none of four frog extinctions, three of three reptile extinctions, two of nine bird extinctions, and 26 of 33 mammal extinctions (Woinarski *et al.* 2019a).

4.1.1 Susceptibility of native species to cat predation

Based on the evidence outlined above, it is possible to recognise a gradient in the susceptibility of native animal species to cat predation (Radford *et al.* 2018), although for many native species, the available evidence is too meagre to position them on this gradient. At one extreme are species that cannot persist with cats even when cats are at low densities. Because of cat predation, many such species have been rendered extinct (e.g., southern pig-footed bandicoot *Chaeropus ecaudatus*, lesser bilby *Macrotis leucura*) or have suffered major declines and persisted only on islands to which cats have not been introduced (e.g., banded hare-wallaby *Lagostrophus fasciatus*, burrowing bettong *Bettongia lesueur*, greater stick-nest rat *Leporillus conditor*). Of the 37 native mammal species considered by Radford *et al*. (2018) to have such extreme susceptibility to introduced predators, 25 are now extinct, 10 are threatened and only two are not threatened. Other native species are still susceptible to cat predation but can persist with cats in some areas or where cats are at low densities (e.g., woylie [brush-tailed bettong] *Bettongia penicillata*). Of 52 native mammal species considered to have high susceptibility, one is extinct, 36 are threatened and 15 are not threatened.

Other native species are relatively unaffected by cats, in part because they have ecological, behavioural or morphological traits that render them relatively infrequently preyed upon by cats, or because they have life history characteristics (e.g., high reproductive output) that allow them to tolerate some level of cat predation without marked reduction in population viability. Using the definitions outlined in Radford *et al.* (2018) the susceptibility of Australian mammals, birds and reptiles to cat predation is assessed and presented in section 8. However, susceptibility of a species to cat predation may be nuanced. For example, it is likely to be influenced by the co-occurrence of other threatening factors, by variation among individual cats in their prey selectivity, and by habitat characteristics (e.g., native species may persist better in habitats that provide more cover).

4.1.2 Which native species are preyed upon by cats?

A series of recent reviews collated and analysed large data sets from Australian cat dietary studies, to indicate the characteristics of species that may render them particularly likely to be preyed upon by cats. For birds, species that nest or forage on or near the ground, occur on islands, and are in the weight range 60 to 300 g are most likely to be consumed by cats, and those that occur mostly in rainforests and wetlands are less likely to be cat-consumed (Woinarski *et al.* 2017b). Mammal species that are most likely to be consumed by cats are of intermediate weight (peaking at 400 g) and occur in more arid areas, and mammal species occurring mainly in rocky areas are less likely to be consumed (Woolley *et al.* 2019). Reptile (squamate) species are most likely to be consumed by cats if they are of medium body size (peaking at ca. 220 g.) and are less likely to be consumed if they occur in rainforests (Woinarski *et al.* 2018; Stobo-Wilson *et al.* 2021a). Although there have also been recent collations of records of cat predation on frogs (Woinarski *et al.* 2020) and invertebrates (Woolley *et al.* 2020), the evidence base for these groups remains limited, and insufficient to indicate traits that render species more or less likely to be preyed upon by cats.

Those analyses of cat dietary studies also tallied the numbers of Australian animal species known to be consumed by cats. Table 2 provides a summary of the number of native terrestrial vertebrate species known to be killed or consumed by cats (including pet cats) in Australia. Note that this tally is undoubtedly incomplete and has some biases (towards more common species, species that are more likely to be identifiable in cat dietary samples, and species occurring in areas where most cat dietary studies have been conducted). Notwithstanding such incompleteness, it is evident that cats consume a high proportion of Australian vertebrate species.

Table 2 The numbers of Australian vertebrate species known to be killed or consumed by cats, based on recent compilations of large datasets of cat dietary studies and other research

Taxonomic group	No. of native species known to be consumed by cats (% of Australian terrestrial total)	Source
Fish	Not compiled	Not applicable
Frogs	30 (13%)	Woinarski *et al.* (2020)
Reptiles	250 (23%)	Woinarski *et al.* (2018)
Birds	338 (46%)	Woinarski *et al.* (2017a; 2017b)
Mammals	151 (52%)	Woolley *et al.* 2019

Many species listed as threatened under the EPBC Act are presumed or known to be killed by cats. Such species are priorities for management actions through this threat abatement plan. For some of these species, it is still challenging to evaluate the extent to which cats are causing imperilment or constraining recovery. For some species, the impact of cats has been well established; but for other species, the impact of cats is much more conjectural. In some cases, cats are known to consume individuals of a threatened species, but the impacts of cat predation may be far less significant than that of other threats. For other species, such as those now restricted to islands without cats, cats are not currently affecting the population, but may have been the major cause of their historic range collapse and may now constrain options for translocations. In terms of prioritising management for the recovery of many threatened species, there is a need for more robust evidence of the actual consequences of predation by feral cats (e.g., the extent to which cat predation affects population viability), and the magnitude of these impacts relative to other putative threats.

Appendix 7 lists all EPBC Act listed threatened frog, reptile, bird and mammal species that are known to be consumed by cats and/or for which cats have been recognised as a confirmed or possible threat in their conservation advice or recovery plan, or in recent action plans. No threatened invertebrates or threatened fish are known or suspected to be affected by cat predation; cats are suspected to be, or are a potential, threat to (or are known to consume):

- 17 threatened frogs (40% of the 42 threatened frogs)
- 40 threatened reptiles (57% of the 70 threatened reptiles)
- 80 threatened birds (52% of the 153 threatened birds)
- 94 threatened mammals (85% of the 110 threatened mammals)

The number of threatened species known or suspected to be affected by feral cats has increased across the iterations of the cat threat abatement plans, with 81 threatened species considered suspected or known to be affected by cats in the 2008 threat abatement plan (Department of the Environment Water Heritage and the Arts 2008b), 122 in the 2015 plan (Department of the Environment 2015b), and 231 in this plan (Appendix 7). This trend may reflect increased knowledge of impacts (especially recent syntheses of data from cat dietary studies), increased size of threatened species lists, and it may also be influenced by inconsistent definitions of suspected and known impacts.

Some threatened species for which cat predation is not listed as a threat may – with more research – be found to be affected, or preyed upon, by cats, and some species added to the EPBC Act after 2023 may also be affected by cat predation: therefore, this list (Appendix 7) should not be seen as definitive or exclusive.

Any declines of these species because of predation by cats may also affect associated species, including other threatened species. For example, there are records of cat consumption of the Endangered golden-shouldered parrot *Psephotus chrysopterygius*, but not of the Endangered antbed parrot moth *Trisyntopa scatophaga*, which is dependent upon the parrot, and likely to decline should the parrot decline. Likewise, many native parasites closely associated with threatened animals (Kwak 2018) are also likely to decline should cats cause further decline in their threatened hosts. Furthermore, broad-scale reductions in the abundance of some animal species due to cat predation may also affect the status of some native predators (e.g., the threatened masked owls *Tyto novaehollandiae melvillensis, T. n. kimberli* and *T. n. castanops* (Tasmanian population)), even if these native predators are not directly affected by cats.

The EPBC Act stipulates that, 'in making a threat abatement plan, regard must be had to ... meeting Australia's obligations under international agreements ... relevant to the species or ecological community threatened by the key threatening process that is the subject of the plan' (s271 (3) (d)). Feral cats also prey on migratory and marine species that are protected under international agreements between Australia and other countries. These include the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA), and the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals). Of the 155 Australian species of fish, reptiles, birds and mammals that are listed under these agreements, 36 species are known to be consumed by cats, including nine species that are also listed as threatened (Appendix 7) (Stobo-Wilson *et al.,* 2022a, b; Woinarski *et al.* 2022). The 36 species comprise one reptile (Loggerhead Turtle *Caretta caretta*), with hatchlings taken at nesting sites on Dirk Hartog Island (Hilmer *et al.* 2010). Cats have recently been eradicated from this island (Algar *et al.* 2020b). The remaining 35 species are migratory birds, and the instances of greatest impact are likely to be at seabird breeding sites, affecting species such as short-tailed shearwaters *Ardenna tenuirostris*, red-tailed tropicbirds *Phaethon rubricauda* and common noddies *Anous stolidus* (e.g., Kirkwood *et al.* 2005). Cat eradication has occurred at some Australian islands used as breeding sites for listed seabirds (Springer 2018; Algar *et al.* 2020), and ongoing cat control (including in some cases, seeking to achieve eradication) is occurring at many others.

4.1.3 Predation tolls on native species

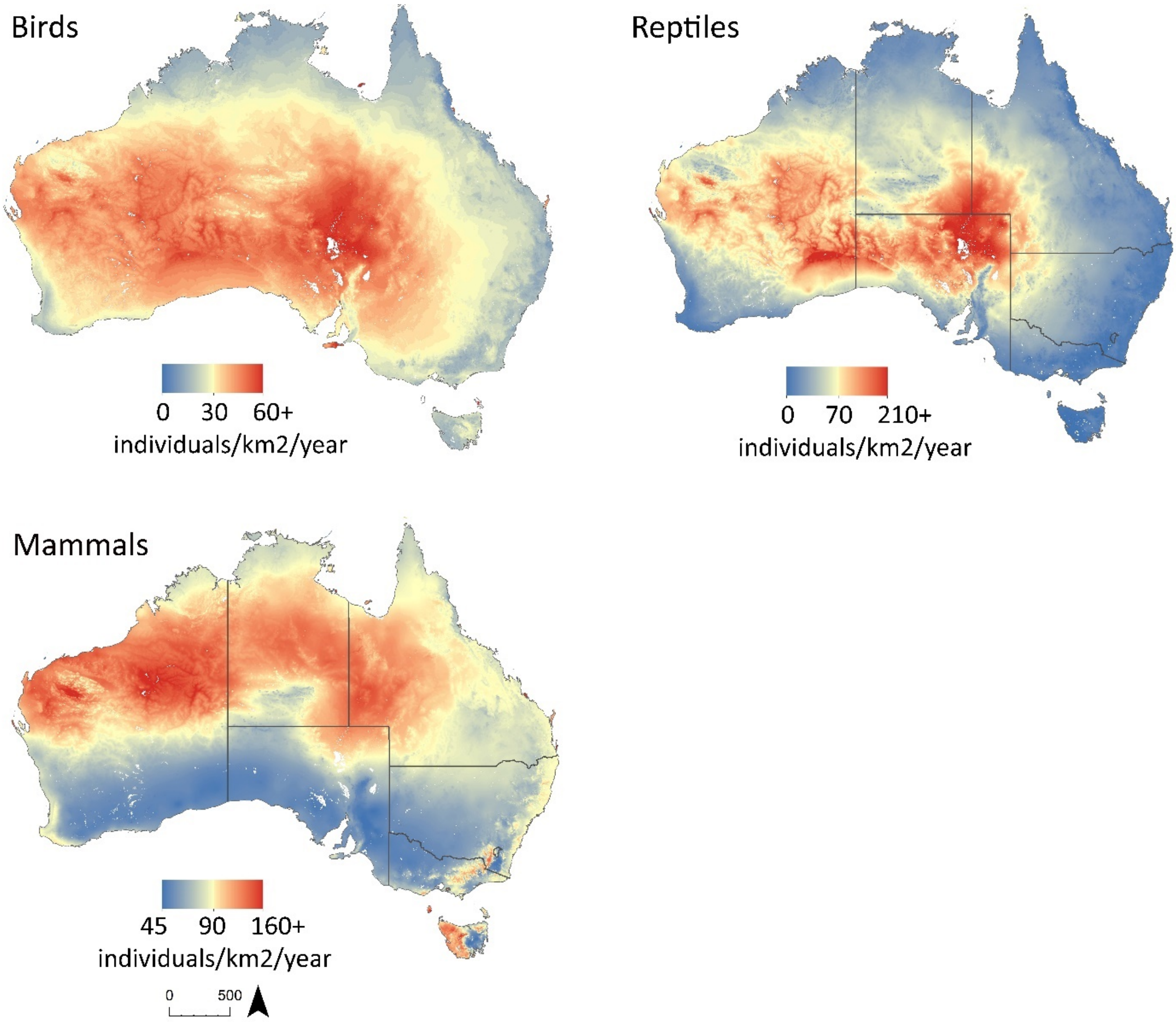
Based on data from the frequency of occurrence of prey items in cat dietary samples and on cat density, the number of individual animals killed annually by cats in Australia has been estimated in a series of recent studies, along with spatial variation in such tallies. These tallies (Table 3) demonstrate that cat predation represents a large and continuous pressure on the population of Australia's native animal species. For mammals, these tallies were also calculated for various taxonomic subsets, with feral cats in largely natural landscapes consuming an estimated 275 million native rodents, 84 million dasyurids, 21 million possums, 19 million macropods and 5 million bandicoots per year (Murphy *et al.* 2019; Stobo-Wilson *et al.* 2022).

On average, a single feral cat kills 393 mammals (of which 221 are native), 225 reptiles, 129 birds, 44 frogs and 371 invertebrates per year (Woinarski *et al.* 2017a; Woinarski *et al.* 2018; Murphy *et al.* 2019; Woinarski *et al.* 2020; Woolley *et al.* 2020). The average area-related number of kills by feral cats are 107 mammals, 61 reptiles, 36 birds, 12 frogs and 101 invertebrates per km^2 per year. These tallies show substantial spatial variation (Figure 5), related in part to spatial variation in the abundance of prey items: for example, the highest rates of predation by cats on reptiles is in arid and semi-arid areas (where reptiles are most abundant), and on possums is in the higher rainfall forested areas of south-eastern Australia.

Table 3 Estimates of the number of individual animals, by taxonomic group, killed by feral cats in Australia each year

Taxonomic group	No. of individual animals consumed per year by feral cats in natural environments	No. of individual animals consumed per year by feral cats living in/near towns	No. of individual animals consumed per year by all feral cats	Source
Invertebrates	1100 million	unknown	>1100 million	(Woolley *et al.* 2020)
Frogs	92 million	unknown	>92 million	(Woinarski *et al.* 2020)
Reptiles	466 million	130 million	596 million	(Woinarski *et al.* 2018)
Birds	272 million	44 million	316 million	(Woinarski *et al.* 2017a)
Mammals	815 million	149 million	964 million	(Murphy *et al.* 2019)

Figure 5 Geographic variation in cat predation on birds, reptiles and native mammals



Source: (Woinarski *et al.* 2017a; Woinarski *et al.* 2018; Murphy *et al.* 2019).

Human-associated feral cats eat refuse and more introduced species than feral cats in natural environments, but their densities are so high that the predation toll on native species per area within the limited area of modified environments still exceeds that of feral cats in natural environments: 2614 mammals, 2281 reptiles and 777 birds per km^2 per year (Woinarski *et al.* 2017a; Woinarski *et al.* 2018; Murphy *et al.* 2019).

A recent assessment reported that Australia's pet cats kill a total of over 545 million mammals, reptiles, birds and frogs per year (Legge *et al.* 2020c; updated to refelect the increase in the pet cat population since that study). Because pet cats typically are present at much higher densities than for feral cats, the predation pressure per unit area exerted by them in residential areas can be over 30 times greater than the average predation rates per square kilometre for feral cats.

Predation from human-associated feral cats, and pet cats, is likely to extend out from built-up areas in a halo, but the 'width' of this halo is unknown (Denny *et al.* 2002; Denny 2005).

4.1.4 Interactive and compounding impacts with other threats and factors

Predation by cats on Australian native species can interact with, compound, or be compounded by, other factors and threats, producing cumulative impacts. These other factors include fire, clearing and habitat fragmentation, infrastructure development, habitat degradation due to livestock grazing, periods of drought or high rainfall, other predators (notably foxes *Vulpes vulpes*), and dynamic variation in the abundance of some food resources such as rabbits *Oryctolagus cuniculus* and house mice *Mus musculus*. The spatial extent and severity of some of these threats are themselves varying with climate change.

Fire, in its many manifestations, has diverse impacts on Australian biodiversity. Changed fire regimes are recognised as a major threat to many Australian plant and animal species, including many threatened species (DAWE 2022). Several studies, particularly in northern Australia, have demonstrated that cats are attracted to recently burnt areas, where the reduction in ground cover vegetation post-fire renders native animals that may have survived the fire more susceptible to predators (McGregor *et al.* 2014; McGregor *et al.* 2015a; Leahy *et al.* 2016; McGregor *et al.* 2016b), thereby compounding the impacts of fire alone. The direct biodiversity loss due to fire may be more substantial in the typically more severe wildfires of the forests and woodlands of southern Australia than is the case in northern Australia, and such fires will also kill some cats and reduce their abundance (Catling *et al.* 2001; Hohnen *et al.* 2023). However, given that the population size of many native animal species may also have been depleted by fire and the habitat quality for surviving native animals may have been reduced, the surviving cats may have even more substantial impacts on the viability of native animal populations than was the case prior to fire (Hradsky 2020). Furthermore, recovery of native species after wildfire will be increasingly challenging as climate change leads to decreases in the interval between fires, and predation by cats on populations of native species struggling to recover after fire will further compromise that recovery.

Habitat loss and fragmentation is a major driver of biodiversity decline globally, and in Australia (Ward *et al.* 2019). Cat predation can exacerbate this impact, given that the abundance of cats can be especially high at the interface between cleared areas and bushland fragments (Graham *et al.* 2013), such that predation pressure may be magnified around the margins of remnant habitat, with this impact likely to be increasingly pronounced as remnant patch size decreases. Cats also use track networks (Wysong *et al.* 2020), so their predation impacts may be concentrated especially in the vicinity of roads; consequently, establishing new roads into areas of native vegetation may result in more predation pressure for wildlife. Feral cats also may be favoured by the development of infrastructure (such as mining camps), because such development may provide additional food and shelter resources.

Grazing by livestock or feral stock can also reduce ground cover vegetation, with direct reduction in habitat quality for some native animals (James 2003; Legge *et al.* 2011). This reduction in ground cover can reduce the number and quality of shelters for ground-dwelling native animals, and hence increase the predation risk from cats and other predators (McGregor *et al*. 2014).

Climate change is having, and will continue to have, many impacts on Australian biota, and on the impacts of feral cats. Cats occupy all Australian habitats and are highly flexible in their diet and ecology, so they are likely to adapt to changing climates and environments far more readily than will most native species. Climate change is driving an increased incidence of severe environmental disturbances such as drought, wildfire, floods and cyclones and other storm events (Abatzoglou *et al.* 2019). Such changes may affect management options for feral cats – for example, a higher frequency of floods and wildfires will increase the risks to, and costs of maintenance for, fenced mainland havens.

Cats are a component of complex food webs (Robley *et al.* 2004; Lurgi *et al.* 2018). In most of Australia (but notably not northern Australia, Tasmania and some islands including Kangaroo Island) and most habitats, these food webs also include another introduced predator, the red fox. Foxes have major impacts on many threatened Australian species (Kinnear *et al.* 2002). Foxes and cats have both overlapping and complementary diets (with foxes tending to eat larger prey, more carrion and more eggs) (Stobo-Wilson *et al.* 2021b; Woinarski *et al.* 2022), so the combined impacts of these two species tend to be greater than either alone. But there are also interactions between cats and foxes. Although results are inconsistent across studies and locations, in some cases, foxes may suppress cat numbers, or change their hunting behaviours and use of space (Glen and Dickman 2005; Molsher *et al.* 2017). In such cases, management actions that reduce the abundance of foxes may result in subsequent increases in the abundance of cats, sometimes leading to reversal of the conservation gains temporarily achieved through fox control (Wayne *et al.* 2017a).

Dingoes and wild dogs also have impacts on some threatened Australian animals (Allen and Fleming 2012), and have some interactions with cats. In general, the dietary overlap between cats and dingoes is less than between cats and foxes (Fleming *et al.* 2022) and dingoes may suppress cat abundance in some situations, including through direct predation on cats by dingoes (Moseby *et al.* 2012), although the evidence is far less compelling than for the impacts of foxes on cats (Allen *et al.* 2015).

Introduced rabbits have detrimental impacts on many Australian species and ecological communities (Department of the Environment and Energy 2016). In much of Australia, rabbits are a main component of the diet of feral cats (Murphy *et al.* 2019), although cats typically do not suppress rabbit abundance (Pech *et al.* 1992; Cruz *et al.* 2013). High densities of rabbits support high densities of cats, and such high densities of cats may then cause heightened impacts on native species, including threatened animals. These impacts may be especially pronounced in the arid zone during rapid transitions from wet periods to dry periods (the onset of drought) when rabbit numbers may decline rapidly, the decline of cats is delayed or more gradual, and cats switch their diet to take more native prey (Catling 1988; Letnic and Dickman 2010). More sustained control of rabbits, such as occurred following the spread of the rabbit haemorrhagic disease virus, has been shown to lead to long-lasting reductions in cat densities and consequent increases in the abundance of native species, including threatened animals such as the plains mouse *Pseudomys australis* and dusky hopping-mouse *Notomys fuscus* (Pedler *et al.* 2016).

Finally, recent studies suggest that the presence of invasive cane toads *Rhinella marina* could also lead to elevated cat abundance, because the toxic toads cause population collapse in large goanna species *Varanus* spp., leading to reduced competition with cats, and reduced predation on cats (Radford *et al*. 2020; Doody *et al*. 2023).

4.2 Indirect interactions and impacts, including on ecological communities

The depletion, through cat predation, of much of the Australian mammal fauna, including many species that were formerly very abundant, is likely to have had substantial repercussions on many other species that were dependent upon those native animal species (such as parasites), and on the functioning of ecological communities (or, ecosystems)

Many of the cat-depleted Australian mammals were also keystone species that provided important ecological services. The most notable of these include the burrowing bettong, which constructed large burrow systems (used for shelter by many other species) (Noble *et al.* 2007), and many bandicoots whose digging activity had major benefits for soil fertility, seed dispersal and germination, and may have moderated fire intensity (Fleming *et al.* 2014; Eldridge *et al.* 2015; Coggan *et al.* 2016; Hayward *et al.* 2016; Verdon *et al.* 2016; Valentine *et al.* 2017; Gibb *et al.* 2018; Valentine *et al.* 2018; Ryan *et al.* 2020). Where cats can be controlled effectively enough to allow for the recovery of such mammal species, ecological function is likely to be improved.

Exclosure of cats (and foxes) and the reintroduction of cat-susceptible mammals within such exclosures can lead to diffuse changes in food webs and the relative abundances of many other species across trophic levels (Moseby *et al.* 2009; Roshier *et al.* 2020; Gibb *et al.* 2021). This complex web of impacts has been most well established in studies that have compared the biodiversity inside and outside of predator exclosures. Such reintroductions of native fauna that have been extirpated because of predation by cats and foxes, and the environmental repercussions that are a consequence of such reintroductions, represent a localised from of ‘re-wilding’, a return from a highly disturbed state towards an environment and ecology more similar to that which existed before the introduction of cats and other threats (Sweeney *et al.* 2019).

In some exclosures, native animal species – released from the predation pressure imposed by cats (and foxes) – may increase to such an extent that they have detrimental impacts on vegetation condition and the abundance of some native plant species (Moseby *et al.* 2018). Such local-scale habitat degradation, due mainly to the ‘over-abundance’ of some cat-susceptible herbivorous native mammals within confined areas, may be particularly pronounced in some seasonal conditions, notably droughts.

4.3 Competition

Cats consume a very wide range of Australian animals, and such predation can reduce the populations of at least some prey species, thereby reducing resource availability for many native predator species, particularly snakes, varanids (monitors, goannas), raptors, owls and quolls (Glen 2014). Potentially, this competition for food resources could affect the EPBC Act listed threatened olive python (Pilbara subspecies) *Liasis olivaceus barroni*, Christmas Island goshawk *Accipiter Hiogaster natalis*, red goshawk *Erythrotriorchis radiatus*, grey falcon *Falco hypoleucos*, Christmas Island hawk-owl *Ninox natalis*, Norfolk Island boobook *Ninox novaeseelandiae undulata*, masked owl (Tasmanian) *Tyto novaehollandiae castanops*, masked owl (northern Australia) *T. n. kimberli*, masked owl (Tiwi Islands) *T. n. melvillensis*, kowari *Dasyuroides byrnei*, western quoll *Dasyurus geoffroii*, northern quoll *D. hallucatus*, spotted-tail quoll (north Queensland) *D. maculatus gracilis*, spotted-tailed quoll (Tasmania) *D. m. maculatus*, spotted-tailed quoll (south-eastern mainland) *D. m. maculatus* and eastern quoll *D. viverrinus*, northern brush-tailed phascogale *Phascogale pirata* and brush-tailed phascogale (Kimberley) *P. tapoatafa kimberleyensis*.

4.4 Disease

Cats have impacts on biodiversity, including threatened species, through their critical role in transmitting a range of diseases. Cats are the definitive or sole primary host for some of the pathogens that cause these diseases: that is, the diseases would not occur in Australia were it not for cats and could be expected to disappear from areas in which cats are extirpated. The most notable of these pathogens is the protozoan parasite *Toxoplasma gondii* that cycles between cats and other warm-blooded animals, with transmission occurring when other animals ingest oocysts in infected cat faeces (or where these have contaminated soil or vegetation), or when consuming the tissues of infected prey.

Toxoplasmosis (the disease caused by *Toxoplasma gondii*) is reported to be a significant cause of mortality or morbidity (especially central nervous system abnormalities) in many bird and mammal species across the globe, and is recognised as one of the major risk factors for many threatened species (Work *et al.* 2000; Work *et al.* 2002; Howe *et al.* 2013; Work *et al.* 2015). Toxoplasmosis now occurs in many Australian bird and mammal species (Parameswaran *et al.* 2010; Wendte *et al.* 2011), with very high incidence of *Toxoplasma gondii* for some species at some sites: for example studies have reported >90% prevalence in water rat (rakali) *Hydromys chrysogaster*, 40% in pademelons *Thylogale* species and long-nosed bandicoot *Perameles nasuta*, and 36% in quokka *Setonix brachyurus* (Pope *et al.* 1957; Cook and Pope 1959; Hartley and Munday 1974). It has been recorded in many Australian threatened species (Groenewegen *et al.* 2017). Mortality due to toxoplasmosis has been reported for some Australian wildlife species (Hartley and Dubey 1991; Mason *et al.* 1991). Infection can involve complex pathways: for example, a recent study reporting major decline for a breeding populations of little penguins *Eudyptula minor* at an island (without cats) off Western Australia implicated toxoplasmosis, with infection presumed to come from waterways contaminated by cat faeces (Campbell *et al.* 2022). *Toxoplasma gondii* infections have also been reported in Australian sea lions *Neophoca cinerea* breeding on South Australian islands, including two cat-free islands, revealing that infections are probably being contracted from the water when the animals are foraging off the mainland (Lindsay *et al.* 2022). The incidence of *Toxoplasma gondii* infection is typically higher in cold and wet parts of Australia, but it has been reported in arid areas.

Notwithstanding many studies demonstrating the occurrence of *Toxoplasma gondii* in Australian native animals, and of cases of mortality, the evidence implicating toxoplasmosis as a cause of population decline in Australian wildlife remains poorly resolved (Fancourt and Jackson 2014; Hillman *et al.* 2016).

Some cat-borne diseases also have significant detrimental impacts on people, and on livestock. A recent assessment concluded that two cat-dependent diseases in people (toxoplasmosis and cat scratch disease) imposed a $6 billion cost per year in Australia (Legge *et al.* 2020b). Toxoplasmosis, in particular, can have many severe consequences for human health, including birth deformities and mental health concerns. That recent review also estimated that cat-dependent diseases (sarcocystosis and toxoplasmosis) imposed a ca. $12 million cost per year on livestock production in Australia (Legge *et al.* 2020b). Rates of infection are likely higher around farms and other heavily modified areas that support high densities of feral cats and introduced rodents (Okada *et al.* 2022).

4.5 Public amenity

In built-up areas, feral cats and free-roaming pet cats can cause nuisance to residents, instigate conflict between neighbours, and impose a substantial burden on local governments that are usually responsible for implementing the companion animal legislation of their jurisdiction, and also for controlling feral cats living in towns and cities. A recent survey of cat management by local governments on mainland Australia and Tasmania (Nou *et al*. 2021) found that they collectively spend over $76 million annually on pet and feral cat management. This survey also found that most local governments (87%) consider that feral cats were a problem, and that managing pet and feral cats was an interlinked issue that needs to be approached holistically to reduce the predation burden on urban peri-urban wildlife, and improve public amenity. A contemporaneous survey by the Australian Institute of Animal Management produced similar findings (Australian Institute of Animal Management 2020).

4.6 Cultural values

People have a wide range of perspectives on the value and impacts of cats (Riley 2019). However, most Australians recognise that cats have a detrimental impact on Australian wildlife, including on many animals that most Australians cherish (Hall *et al.* 2016). This recognition of the impacts of cats on valued native animal species may be most profound for Indigenous Australians. Many of the native animal species that have become extinct or severely depleted were important totemic or food items and distinctive components of Country, and the loss of these species represents a challenge to the ongoing responsibility for the care of Country. The return to Country of animal species that have become regionally extinct due to cat predation, such as through reintroductions to large exclosures, can help restore cultural values and the perceived health and integrity of Country (Legge *et al.* 2020a). In some parts of Australia, there is now a long-standing practice of hunting of feral cats by Indigenous Australians for food and bush medicine (Paltridge *et al.* 2020).

A pre-consultation process informing the development of the threat abatement plan, with over 100 Indigenous ranger groups and other Indigenous land management organisations, showed that most groups consider that feral cats damage cultural values, by preying on threatened and culturally significant species, and upsetting ecosystem balance (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022).

Cats are also kept in many Indigenous communities and outstations, for companionship and because they are believed to reduce the numbers of snakes and other problem animals. These pet cats may have significant impacts on local populations of native species. The pre-consultation process with Indigenous groups revealed that the numbers of community cats is believed to be increasing, but that community members often distinguish between community cats and feral cats, recognising that the impacts from feral cats are a problem, but considering that the impacts from community cats less of a problem (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022).

4.7 Critical Habitat

The Environment Protection and Biodiversity Conservation Regulations 2000 (Part 7) stipulate that a threat abatement plan must state, *inter alia*, areas of habitat listed in the register of critical habitat kept under section 207A of the Act that may be affected by the key threatening process concerned.

Critical habitat is registered for five species: wandering albatross *Diomedea exulans* (Macquarie Island), grey-headed albatross *Thalassarche chrysostoma* (Macquarie Island), shy albatross *T. cauta* (Albatross Island, The Mewstone, Pedra Branca), black-eared miner *Manorina melanotis* (Gluepot Station, Taylorville Station and (part of) Calperum Station), and Ginninderra peppercress *Lepidium ginninderrense* (part of Belconnen Naval Transmission Station).

Of these areas of critical habitat, feral cats were a major predator of nesting seabirds on Macquarie Island (Jones 1977; Brothers 1984; Brothers *et al.* 1985) and largely for that reason were eradicated in 2000, resulting in substantial recovery of several seabird species (Springer 2018; Garnett and Baker 2021). There are no feral cats on Albatross Island, the Mewstone or Pedra Branca. Feral cats are not a major threat to black-eared miners, so control measures for feral cats are not a priority for the listed critical habitat for black-eared miners at Gluepot, Taylorville and Calperum. Feral cats are not a threat for Ginninderra peppercress, so control measures for feral cats are not a priority for the listed critical habitat for Ginninderra peppercress at Belconnen.

4.8 World Heritage Areas

Of the 15 Australian sites listed as World Heritage for present-day natural values, cats have been eradicated from the Lord Howe Island group and Macquarie Island; have never occupied the Heard and McDonald Islands site; and have been eradicated from (or not colonised) some parts of Shark Bay (e.g., Dirk Hartog Island, Faure Island, Bernier and Dorre Islands). Cats are present and subject to some management at most other natural sites (including Budj Bim Cultural Landscapes, Gondwana Rainforests of Australia, Great Barrier Reef, Greater Blue Mountains Area, Kakadu National Park, K'gari (Fraser Island), Purnululu National Park, Tasmanian Wilderness, The Ningaloo Coast, Uluṟu-Kata Tjuṯa National Park, and Wet Tropics of Queensland). At some of these sites, cats are having some impact on the natural values for which the sites were recognised. For example, the most recent (2020) assessment of the conservation outlook for the Kakadu National Park site is 'of significant concern' due mostly to ongoing decline in biodiversity, for which predation by cats is a likely causal factor. Feral cats are subject to some ongoing management at some of these World Heritage sites.

5 Monitoring

5.1 Monitoring the abundance of feral cats

There are many reasons for surveying and monitoring the abundance of feral cats. These include:

- Surveillance monitoring to provide early warning of any cat incursions to sites managed to be cat-free (such as predator exclosures and some islands).
- Evaluating risks to sites that have significant biodiversity values (e.g., seabird breeding colonies, populations of highly restricted threatened species).
- Assessing the responses of cats to control efforts, or evaluating the need to implement, target or refine such management.
- Evaluating the responses of cats to major disturbance events, such as wildfire or drought.

Protocols for survey and monitoring for cats have been described in detail in a recent review (Hradsky *et al.* 2021). Approaches used will vary depending upon the research or management focus, on the duration over which the program operates, on resources, and on the need for precision or metrics of cat abundance required (e.g., density, number of captures per trap-night).

There are many challenges in attempting to monitor the abundance of feral cats, but recent advances in equipment and analytical approaches have allowed for major improvements in the precision and reliability of estimates of cat density, and the recent application of these approaches has now provided many robust estimates of cat density across Australia. The approach used is a form of capture-resight population estimation, based on images taken from an array of unbaited camera traps operating over an adequate time period to allow for sufficient detections of captures and recaptures of cats (typically 6-12 weeks). Each image is examined to attempt to identify individual cats by their distinctive markings (McGregor *et al.* 2015b). Based on the incidence of individually recognisable cats across a history of nights and cameras, density is then estimated using a spatially explicit mark-resight approach. The sampling area requires estimating a buffer distance around the array, with this distance based on estimates of the home range of a cat in the sampled environment. Examples of such analysis can be found in (McGregor *et al.* 2015b; Rees *et al.* 2019; Hohnen *et al.* 2020).

There are some caveats in the approach. Some images may not show the distinguishing features of individual cats; some cats (particularly ones with immaculate black pelage) cannot be individually distinguished; if cats are at low density, it may be impossible to obtain sufficient images to derive a robust density estimate; some cats may not be resident in the sampled area; buffer distances need to be inferred; a reasonable level of analytical capability is required; and there can be considerable time required to sort through images.

There are other options for monitoring the incidence or abundance of cats. Cat tracks can be readily detected in sandy substrates across much of Australia. There is now a large network of collaborative monitoring of such plots (established to monitor a wide range of native and introduced species) across arid Australia; and this approach to monitoring is now used by many Indigenous ranger groups. More information on the methodology and results is presented in Indigo *et al*. (2021).

Broad-scale distributional records of feral cats are being compiled in the program Feral CatScan.

5.2 Monitoring the impacts of feral cats

Management of feral cats should be evidence-based, and capable of ongoing refinement (i.e., be adaptive) in response to increases in that evidence base. Monitoring is a critical process for deriving such evidence. The preceding section provides information on approaches to monitoring the abundance of feral cats. Monitoring is also critical for documenting the inputs to cat management (e.g., the numbers of baits deployed, number of cats trapped, the resources spent on a cat control program) and the responses of cats to that management (e.g., reduction in the abundance of feral cats in a managed area). However, at least as important is monitoring of the *impacts* of cats and of the outcomes of cat management actions: for, indeed, this is the purpose of cat management. However, this can be a complex challenge, because: cats may have a wide range of direct and indirect impacts on a wide range of biodiversity; biodiversity may respond to a broad range of factors in addition to, and possibly compounding, the impacts of cats; impacts may be influenced by seasonal factors; and some impacts may be evident in the short term, but others may not be manifest for many years.

Broadly, components that should be considered in monitoring (i.e., sampling over time) to assess the impacts of cats include:

- The abundance (or density, population size, detection) of species (especially threatened species) that may be impacted by cats.
- The predation rate by cats on particular species (e.g., the proportion of known individuals found to be killed by cats, or the proportion of cat dietary samples (faeces, stomachs) that contain a particular native animal species).
- The breeding success of species where this may be influenced by cat predation (e.g., for breeding seabirds).
- The incidence and impacts of cat-borne diseases on native species.
- The abundance of native species that may compete with cats for food resources.
- The abundance of other introduced species that may respond to cat control efforts (e.g., rabbits and introduced rodents).
- Indirect impacts (e.g., soil fertility, plant germination rates, 'health' of cultural values) in environments in which native animal species that play critical ecological roles may be affected by cat predation.

Interpretation of monitoring results will be most straightforward where cat management can be designed systematically, ideally as a Before-After-Control-Impact study – i.e., where monitoring encompasses some sites that are subject to a particular form of cat control and matched sites are not (or where matched sites represent different intensities or types of cat management), and where monitoring is undertaken at sites before and after the imposition of cat management. Examples of this approach that have demonstrated marked responses of native animal species at contrasting monitored sites with and without the management of introduced predators include (Dexter and Murray 2009; Robley *et al.* 2014). However, in many cases such structured design may not be possible.

Interpretation of monitoring may also be most capable of assessing meaningful impacts if monitoring results (e.g., cat predation rates) can be incorporated into demographic models that can then interpret the influence of those cat impacts on the population viability of the native species, and/or to indicate what levels of cat control may be required to maintain population viability. As an example, one recent study demonstrated that cat predation was the factor that most affected the viability of a population of northern bettongs *Bettongia tropica* (Whitehead *et al.* 2018), although in this case, the cat predation rates were simulated rather than being derived from data from a monitoring program. In another example, observed rates of cat predation before and after cat control were used in population viability analyses to show that a breeding population of red-tailed tropicbirds *Phaethon rubricauda* on Christmas Island was declining towards extinction before cats were reduced (Willacy *et al.* 2023).

Monitoring can also usefully be scaled across sites and species to indicate broad-scale cross-species impacts of cats, and of their management. For example, the recently developed Threatened Mammal Index collated and analysed monitoring data across 71 Australian threatened and near threatened mammal species, over a ca. 20-year period. It concluded that the average abundance of mammal species declined markedly at sites without management of cats and foxes, was more or less stable in areas subject to intensive control of cats and foxes, but increased at sites where cats and foxes were absent or had been eradicated (Tulloch *et al.* in press). For such analyses to be possible, monitoring needs to be maintained consistently over long periods, and monitoring results need to be publicly available, or at least capable of being included within national collations.

There are well-established protocols for monitoring for some Australian animal species, and in some cases, these protocols have been implemented consistently in monitoring spanning many years. However, a notable constraint on monitoring of the impacts of cats, and of cat management, is that there are no established protocols for monitoring for many native species; and for many threatened species there are no existing monitoring programs or existing programs have a range of deficiencies (Scheele *et al.* 2019). The Threatened Species Action Plan 2022-2032 seeks to redress this deficiency, with an explicit target to establish such protocols and programs, at least for priority threatened species:

> **Target 20:** *Monitoring standards for all priority species are published and monitoring tools and protocols are created for at least 50 per cent of priority species.*

6 Managing feral cats and their impacts

Wildlife management is complex, and may involve difficult trade-offs between costs, likelihood of success, timescales, collateral benefits and detriments, and social acceptability; and these trade-offs may change over time with development of new techniques, enhancements of existing techniques, new evidence, and changing social mores. Broad principles for ethical wildlife control are increasingly recognised (Dubois *et al.* 2017): most relevant to management of cats, these principles include that control should: contextualising and modifying any underlying human practices that cause the conflict; be evidence-based; have measurable outcome-based objectives; minimise animal welfare harms; be informed by community values; be integrated into longer-term planning; and avoid negative labels applied to the target species. Social licence for control of cats and application of poisons should not be taken for granted; however, recent research has demonstrated that a clear majority of Australians recognise and accept the need to kill invasive animals if this will prevent extinctions and allow for the recovery of native species (Zander *et al.* 2022).

There are many successful site-based cat management efforts. Nevertheless, overall, cat management in Australia tends to be sporadic, uncoordinated across management areas and jurisdictions, and of variable effect. This is because cats are cryptic, wary, and therefore challenging to control. The available control options all have some constraints, either in terms of the scale at which they can be deployed (mostly small scales), where they can be used (some are restricted to particular regions), the extent of the cat knock-down they produce (mostly only partly effective), the effort required to use them (usually high effort and difficult to sustain), their welfare outcomes (for cats, or for non-target native species), or the regulatory approvals process and training required beforehand. However, research effort by many stakeholders over the past 10-20 years has increased the range of options available, and improved knowledge of when and where each option works best (Doherty *et al.* 2017; Legge *et al.* 2020). The current cat control effort is preventing extinctions, helping the recovery of some threatened species, and reducing the likelihood of some currently unthreatened species from becoming threatened. Nevertheless, outcomes can be further improved by refining the use of existing control options and continuing to innovate and develop alternative approaches to reducing cat impacts.

The sections below summarise the current status (including limitations) and priority action areas over the next 5-10 years for each existing and emerging cat control option. The existing options (6.1 to 6.7) are ordered approximately according to how effectively they suppress cats or their impacts at a site, from highly effective (i.e. cat exclusion) to least effective. Awareness of the relative effectiveness is critical for matching control options to suit the native species that the cat control aims to protect: native species that are most susceptible to cat predation may need complete cat exclusion, whilst for other native species that are only mildly susceptible to cats, habitat management may suffice. The scale at which the options can be delivered is roughly inverse to the strength of cat knockdown: ecological management (via manipulating prey, habitat or predators) can occur over larger areas than shooting and trapping programs, for example.

Emerging options for cat control (6.8) aim to increase target specificity and efficacy, improve humaneness, or offer longer-term solutions, when compared to existing cat control options. None are likely to be operative within the lifetime of this plan, but progress towards their development and evaluation should be maintained.

6.1 Eradication and exclusion from small areas

Current status

There is currently no prospect of eradicating feral cats from the Australian or Tasmanian mainlands. However, cats can be completely removed from contained areas such as islands and mainland fenced areas (so-called ‘havens’, Legge *et al.* 2018), usually by using a combination of poison-baiting, trapping and shooting (see relevant sections below).

Cat eradications from islands have a long history in Australia – the first intentional eradication may have occurred on Betsey Island (Tas) in the late 1860s, when the gamekeeper killed cats that had earlier been released there (S. Robinson, pers. comm.). Several islands were cleared of cats in the 1970s, with a steady trickle since then; as of December 2022, cats have been eradicated from 30 islands, ranging in size from 0.05 to 628 km^2 (Appendix 5). At 628 km^2, Dirk Hartog is the largest island in the world from which cats have been eradicated (Algar *et al.* 2020a). In addition to intentional eradications, cats died out from natural causes on an additional 17 islands (Appendix 5). Adding the tally of islands from which cats have been eradicated or died out naturally, to the tally of islands where cats never reached or established, cats are confirmed as absent from at least 701 islands over 1 ha in size, covering 5754 km^2 (Figs. 3, 4), and may be absent from an additional 4649 islands covering 2173 km^2. Active eradication projects are currently underway on ten islands: Bruny (356 km^2; Tas), Christmas (137 km^2; Ext. Terr), Flinders (1359 km^2; Tas), French (174 km^2; Vic), Lungtalanana (Clarke) (82 km^2; Tas), Kangaroo (4416 km^2; SA), Little Dog (0.8 km^2; Tas), Phillip (101 km^2; Vic), Three Hummock (70 km^2; Tas), West (Pellew) (130 km^2; NT).

Cat eradications from islands have sometimes occurred to create host sites for translocations of threatened mammals, but often also to benefit seabirds. Although seabirds spend most of their life at sea, they can potentially encounter cats during breeding. Many seabird species breed on islands, and their nestlings (as well as the brooding adults of smaller species) may be highly susceptible to predation from invasive species, including cats. The contribution of cats to species extinctions and population losses on islands is well-documented (Medina *et al.* 2011), and breeding populations of seabird species are particularly at risk (Spatz *et al.* 2017). Cat eradications from islands has resulted in increased breeding success and colony size – and in some cases the return of seabird colonies that had been extirpated – across many species of seabirds in Australia (Dunlop *et al.* 2015; Springer 2018).

Fenced areas (predator exclosures) for conservation were first constructed in Australia in the late 1980s and early 1990s, with the number of new fencing projects, and their size, increasing in the past decade. As of December 2022, 33 fenced areas in Australia exclude cats from 719 km^2 (Figs. 3, 4; Appendix 6); five fenced areas each exceed 70 km^2, with the largest being Arid Recovery in South Australia, at 123 km^2 (Legge *et al.* 2018). Australia has become a world leader, along with New Zealand, in the use of fencing to exclude feral animals (Burns *et al.* 2012).

Most fenced areas have been undertaken to create sites to receive translocations of threatened mammal species that are highly or extremely susceptible to cat predation, but *in situ* species can also benefit markedly. For example, populations of small mammals and reptiles inside fenced areas may increase following cat (and fox, and rabbit) exclusion (Moseby *et al.* 2009; Roshier *et al.* 2020). The return of small to medium sized mammals is increasingly framed as 'rewilding', as these species restore ecological processes to the local area, such as accelerated rates of decomposition, improved soil health, increased fungal and plant vigour (section 4.4) (Fleming *et al.* 2014; Foster *et al.* 2020).

Thirteen taxa from ten mammal species now exist only within cat-free islands and fenced areas; elsewhere, they have disappeared wherever they are exposed to cats (and potentially foxes). Five taxa were restricted to islands that cats never invaded, but based on the impacts of cats on closely related species, they would probably have been extirpated had cats invaded their islands. Cat exclusion has therefore prevented extinction of these 13 taxa. Many more mammal taxa that are highly imperilled by cat predation are also protected in these cat-free havens.

Protections within havens is unevenly spread across the native mammal species that need cat exclusion: an assessment in 2018 (Legge *et al.* 2018) found that although all havens were making a substantial contribution to the conservation of many mammal species, there was a notable 'protection gap', where almost half the taxa that needed cat (and fox) exclusion were not protected in any, or very few, havens. The protection gap has emerged even though the number of island and fenced havens has increased over time (Ringma *et al.* 2018; Ringma *et al.* 2019). Despite several new haven projects since the 2018 assessment, the gap persists (Fig. 6). The protection gap arises for several reasons: some cat-susceptible species are easier to source for translocations than others, and priority species for translocations (i.e., those considered at highest risk of extinction) may change over time. Another contributing reason is that havens are established by many independent organisations and agencies that have differing objectives and operate at different scales (local to national).

Havens can be expensive to establish – eradicating feral cats from remote islands, and constructing feral-proof fencing, can be multi-million dollar projects (Hayward *et al.* 2014; Springer 2018; Algar *et al.* 2020a). The ongoing maintenance and capital replacement costs for fencing are also costly: fences need to be monitored closely for their integrity; incursions of cats (or other feral animals) need to be dealt with rapidly; and the fencing infrastructure needs to be replaced at intervals. Mainland fences also have some ecological detriment: they disrupt animal movements, and the fences can cause mortality in reptiles that try to move through them, and in birds that fly into them (Hayward and Kerley 2008). Given the size constraints to haven projects, many populations within havens are small, and may lose genetic diversity through drift, and because they are interacting with a narrow set of environmental conditions. Small populations are also at risk from inbreeding effects. Complete exclusion from feral cats could also cause the erosion of any predator awareness and avoidance behaviours they have (Jolly *et al.* 2018). Finally, the cumulative area of havens in Australia covers a tiny proportion of the total land area (c. 0.1%), and tiny proportions of the previous distributions of most native species.

Priority action areas over the next 5-10 years

Havens could be used to remove or reduce the impacts of cats for a greater range of cat-susceptible mammal species, and potentially some reptile and bird species (see section 8). The protection gap noted above for mammals could be reduced by adopting systematic planning approaches to identify priority areas for new haven creation at regional and national scales, to ensure all cat-susceptible species are represented in a specified number of havens, with a minimum population size, most efficiently (Ringma *et al.* 2018; Ringma *et al.* 2019). Eradicating cats from islands is likely to benefit *in situ* species, including breeding seabirds, even if the eradication is not followed by a translocation.

Most risks or detriment associated with havens can be mitigated and are outweighed by the benefits. For example, genetic management plans, potentially including translocations between sites, can minimise the risk of genetic bottlenecks and inbreeding. Similarly, controlled exposure to cats could be used in some circumstances to minimise the risk of losing predator recognition and response behaviours in the cat-free populations. Although haven projects are costly, there is considerable potential to leverage non-government funding to support their development and management, and the cost should be contextualised by the likelihood that havens will deliver significant, diverse and long-lasting conservation benefits. Fence-related mortality can be reduced (but not eliminated) with site positioning and fence designs, but the disruptions to animal movements are harder to solve. Once the initial cat eradication is complete, ongoing killing of cats is not required, making havens more humane than some other control options.

6.2 Toxic baits

Current status

Since cats are live prey specialists that rarely eat carrion, traditional meat baits laced with toxin were rarely effective for controlling cats. To solve this problem, Eradicat baits were developed in the early 2000s. These baits present 1080 (sodium fluoroacetate) poison in a moist sausage matrix and are robust enough to be deployed from the air, which increases the scale at which they can be used. Toxic baiting is the only method for direct control of cats that can be used at large scale.

Eradicat is presented on the ground surface because cats are not inclined to dig. This means that the bait is accessible to other, non-target species. In the southwest of WA, where native species have high tolerance to 1080 (because it is naturally present there in the foliage of many abundant native plant species), non-target impacts are of less concern than in other parts of Australia. Therefore, Eradicat is registered for use in southwestern WA, and is now distributed there over about 15,000 km^2 annually (Garrard *et al.* 2017). Elsewhere, Eradicat can only be used under minor use research permits issued by the Australian Pesticides and Veterinary Medicines Authority, after a thorough risk assessment, and when the benefits are likely to far exceed the risks (McDonald *et al.* 2017).

To reduce the risk to non-target species and potentially expand the area in which 1080 can be safely used, Hisstory™ bait encapsulates the 1080 within the sausage. Hisstory is currently being trialled (Marks *et al.* 2006; Hetherington *et al.* 2007).

An alternative toxin (para-aminopropiophenone, PAPP) has also been developed and pelletised into a sausage-style presentation (Curiosity™) and is registered for use across Australia (Algar *et al.* 2011; Johnston *et al.* 2011). PAPP is considered relatively more humane than 1080, and unlike 1080, PAPP has an antidote (Eason *et al.* 2014).

Priority action areas over the next 5-10 years

The use of toxins throws up challenges: bait uptake can be variable, there are non-target risks and concerns about humaneness, the effectiveness of knockdowns is variable and perverse outcomes are possible. However, toxic baiting has been critical for maintaining populations of cat-susceptible species in parts of the southwest of WA, as well as in site-based applications elsewhere, such as central Australia (central rock-rats), western Queensland (bridled nailtail wallabies), and in cat eradications from islands (e.g. West Island, Pellews). The threat abatement plan includes actions to address these limitations and help ensure that baiting is undertaken in a manner that maintains public support and confidence that its use is justified. To that end, toxic baiting programs should be justified based on the expected conservation benefit and a thorough assessment of risks, and be accompanied by monitoring to quantify the potential non-target impacts, to confirm that reductions in cat density are occurring, and that these are translating to measurable benefits for native species (Fancourt *et al.* 2022a). The key limitations associated with toxic baiting, and potential solutions, are listed below.

Non-target impacts: 1080 poses risks to native species in areas where levels of 1080 in vegetation are low: this includes much of eastern, northern and central Australia (McIlroy 1992; Fancourt *et al.* 2022b). Reptiles are sensitive to PAPP, so scavenging goannas are especially vulnerable (Jessop *et al.* 2013), although the risks can be reduced by using the baits only during the colder months in southern latitudes, when goannas are less active. All three current bait formulations will kill dingoes, unless the baits can be modified to discourage dingoes from ingesting them. For example, the pellets used in Curiosity and Hisstory could be coated with an emetic that specifically causes dingoes to vomit up the bait and pellet (Algar *et al.* 2017). Non-target impacts are of strong concern for most Indigenous ranger groups (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022).

Humaneness: Poisoning is considered inhumane by some people, including many Indigenous communities (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022),and there is some public concern about the use of poisons generally. Public engagement is needed to highlight the conservation importance of using poison to control cats and other feral pests, and the use of poison must always be justified in terms of the conservation benefit, relative to the risks involved.

Uptake of bait by cats: Baiting trials have revealed variable rates of bait uptake: bait encounter rate, declines in bait palatability over time, uptake by non-target species, cat hunger and ambient weather conditions all play their parts, but more research will improve understanding of why toxic baits do/do not work in different situations, and thus sharpen protocols (Fancourt *et al.* 2021). In addition, adjusting the sausage formulation so the bait remains palatable for longer would help increase encounter rates.

Declines in effectiveness of cat knockdown over time: there is strong selection for animals to avoid taking baits, or develop physiological tolerance of the toxin (Twigg 2014; Allsop *et al.* 2017). This pattern is likely to be evident for cat baiting programs, especially given sub-lethal exposure to toxins is so likely, given the high rates of bait caching by non-target species (Moseby *et al.* 2011a). Monitoring should be attached to baiting programs to track its effectiveness over time.

Perverse outcomes: Modest reductions in cat numbers in an area subject to cat control could have no or limited benefit for native species, or even negative effects, if the sudden reduction results in immigration pulses and short-term increases in cat activity (Lazenby *et al.* 2015; Minnie *et al.* 2016). In some circumstances, removing cats could lead to increases in introduced prey species (such as rodents and rabbits) that themselves have adverse effects on native fauna; this may be especially pertinent on islands (Courchamp *et al.* 1999). Cat baiting programs are also likely to cause reductions in dingo and fox numbers, which could cause detrimental ecological cascades (Marlow *et al.* 2015; Wayne *et al.* 2017a; Wayne *et al.* 2017b). Monitoring is required to check for perverse outcomes and shape responses accordingly. Note that this is a risk relevant to all control options other than haven creation.

6.3 Alternative toxin delivery

Current status

Given the concerns about non-target impacts from broadscale toxic baiting, and the risk of increasing bait avoidance, researchers and managers have worked to develop alternative ways of delivering toxin to cats with increased target specificity and reduced opportunity for learned avoidance or inherited bait shyness. Felixer grooming traps use laser sensors or cameras with artificial intelligence to recognise a passing cat (as distinct from any other animal), after which a dose of toxin-infused gel is squirted onto the cat's body. The cat later licks the gel off, ingesting the poison (Moseby *et al.* 2020).

Another approach involves implanting pellets of toxin into potential prey of cats. If a cat kills and eats the implanted animal, the pellet casing dissolves in the cat stomach, releasing the toxin (Read *et al.* 2016). Toxic implants may be especially useful for targeting specific cats that are specialising on hunting individuals in a small population of native animals living in a small area (Moseby *et al.* 2015; Hardman *et al.* 2016). Toxin can also be presented on a collar fitted to a prey animal, or potentially via a collar fitted to a female cat, that would attract males whilst in oestrus (Burns *et al.* 1996).

Priority action areas over the next 5-10 years

These alternative toxin presentations are at various stages of development, with further trials required to refine their use, and to inform their regulatory controls.

6.4 Trapping, shooting, tracking

Current status

Cat trapping can be used in small areas; it is labour-intensive, and trap success tends to be low. Cage trap success rates are typically higher when live prey is scarce, or in situations where cats are more accustomed to human infrastructure (e.g. around farm dwellings or near rubbish dumps). Cage trapping is one of the most common cat control techniques used by Indigenous rangers, because of its target specificity, and more navigable training and regulatory framework (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022). Soft-jaw traps often outperform cage traps, but injury, including to non-target captures, can be an issue (McGregor *et al.* 2016a; Surtees 2017), they require more training to use, and they are not legal for use in all jurisdictions. Given the small scale at which trapping can be used, and the effort involved, trapping approach works best when targeting a specific cat, or targeting an area that cats congregate in or through (such as drainage channels in an arid landscape, or rubbish dumps), or as part of an integrated strategy to eradicate cats from islands and fenced areas (Parkes *et al.* 2014).

Shooting is also labour-intensive, but can potentially cover larger areas than trapping, and has been an important component of cat control programs using multiple approaches (Read *et al.* 2018). Like cage trapping, it is one of the more common techniques used by Indigenous rangers (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022). Success improves if shooting is carried out at night using spotlights or thermal imaging to detect cats or using trained dogs to bail cats. Shooting can occur in some areas where other methods like toxic baiting cannot, and it is a control option available to some members of the public, for example many farmers and recreational shooters have gun licences (Garrard *et al.* 2020). Like trapping, shooting has been an important component of cat control using multiple approaches (Algar *et al.* 2013). However, the effectiveness of shooting carried out by recreational shooters, farmers and landholders for reducing cat density and impacts is mostly poor or unclear, because the shooting is often not intensive nor sustained, and because there is rarely any monitoring of outcomes attached to the activity.

In parts of the Tanami, Gibson and Great Sandy Deserts, Indigenous people hunt cats in areas with sandy substrates by following cat tracks by car and on foot to where cats are hiding under vegetation or in burrows. The cats are hunted for bush tucker and medicine, as cat meat is considered to give strength and health. Such cat hunting activity has been encouraged in areas supporting cat-susceptible threatened species (Ninu, Tjalapa; bilby, great desert skink), by formalising the action in IPA management plans, and by offering bounties that are structured to encourage cat hunting near threatened species even as cat density there falls (Paltridge *et al.* 2020). The approach works best when there are multiple motivations for hunting (conservation, food, medicine, bounty).

Priority action areas over the next 5-10 years

Reforming regulations so that leg-hold traps can be used, with appropriate safeguards, in all jurisdictions, would be very useful. The interest and skills of recreational shooters and landholders could be better harnessed by designing programs to focus effort where cat density reduction could benefit cat-susceptible species, and to integrate monitoring of outcomes attached to the activity. Indigenous ranger groups can be better supported (with training, resourcing, and access to expertise) to control cats, using tracking techniques or any other method suitable for their area. Developing more effective attractants (scent, visual, auditory, behavioural) would enhance trapping success in trapping programs.

6.5 Prey management

Current status

Introduced rabbits and rodents have major impacts on many threatened species and ecological communities, so are priorities for management in many parts of Australia. Rabbits are also favoured prey items for cats (Murphy *et al.* 2019). Their presence elevates cat density, which can cause hyper-predation of native species (Taylor 1979; Smith and Quin 1996; Courchamp *et al.* 2000). Rabbits also contribute to reduced habitat complexity which can worsen cat impacts (McGregor *et al.* 2014). Reducing rabbit densities is an effective and efficient way to reduce cat densities, enough to benefit many cat-susceptible species, including some that are highly susceptible to cat predation (Pedler *et al.* 2016), but probably not enough to benefit those species that are extremely cat-susceptible.

Introduced rodents can support high cat densities on some islands, and in urban and peri-urban areas where they contribute to high densities of feral cats (Legge *et al.* 2017). Native rodent irruptions in the arid zone can also support 'cat plagues' (Letnic and Dickman 2010). Control of introduced rodents may lead to some decreases in cat numbers and hence impacts on native species, but many widely used poisons for controlling introduced rodents can have substantial non-target impacts. Broad-scale control programs for introduced rodents, especially during 'plague' periods, are also typically driven by agricultural and other reasons, rather than to ameliorate the impacts of cats on native species.

Managing introduced rodents around human infrastructure and restricting the access of cats to 'free food' in rubbish bins, skips, rubbish tips, and intensive farm sites, is one of the key actions available for reducing the feral cat population living in these places.

Reducing rabbit and rodent populations must be done with care, as rapid reductions cause cats to switch prey (Catling 1988; Rich *et al.* 2014; Bode *et al.* 2015; McGregor *et al.* 2020). The sudden and marked increase in predation pressure on native prey can cause rapid population declines in those native species, even if the effect is temporary, lasting only as long as it takes for the cat population to re-stabilise at a lower level.

Priority action areas over the next 5-10 years

Management that controls rabbits and introduced rodents benefits agricultural productivity as well as biodiversity, and this production benefit has been the main driver for innovation in rabbit control. Reframing this effort to more explicitly acknowledge the importance of rabbit and rodent control for biodiversity would be useful. Rabbit control could potentially be intensified around prioritised sites supporting cat-susceptible species, and approaches to prevent prey-switching after sudden decreases in rabbit or rodent densities could be trialled, such as intensive cat management at prioritised sites before populations peak. The densities of introduced rodents around human infrastructure could be minimised with improved waste management, and there may be ways to reduce rodent access to farm produce, and to reduce rodent populations using rodenticides with low risks of non-target impacts more strategically.

6.6 Habitat management

Current status

Cat impacts have been greatest in more open habitats (deserts, open woodlands), suggesting that ground layer complexity moderates cat impacts (Burbidge and McKenzie 1989; Smith and Quin 1996). In the tropical savannas of northern Australia, reductions to vegetation structural complexity from high severity fire or intense livestock grazing have been shown to increase the hunting efficiency of cats (McGregor *et al.* 2015a). Several studies across northern Australia have also shown that large, severely burnt areas attract cats, suggesting increased impacts to *in situ* native species (Leahy *et al.* 2016) arise from a combination of higher cat density and higher hunting efficiency (McGregor *et al.* 2014; McGregor *et al.* 2016b; Davies *et al.* 2020; Stobo-Wilson *et al.* 2020). Similarly, in temperate forests of southeastern Australia, native species avoid cats and foxes by staying in thicker ground cover. When this cover is removed by fire, introduced predators move in and predation rates on native animals increases (Hradsky *et al.* 2017). The effect probably exists in any fire-prone habitat, including deserts: rufous hare-wallabies in the Tanami Desert (where cats are present) relied on patches of long-unburnt spinifex for shelter (Lundie-Jenkins 1993), whereas those on Dorre and Bernier islands (both cat-free) did not (Short and Turner 1992). The difference may have been due to the presence of cats in the Tanami; nevertheless, rufous hare-wallabies were extirpated from the Tanami soon after these studies (Langford and Burbidge 2001).

The relationship between fire and cat impacts may be context dependent. For example, fire could reduce cat density more substantially than prey density (Arthur *et al.* 2012; Hohnen *et al.* 2022). The spatial scale and characteristics of the fire or grazing disturbance, the vegetation complexity and post-disturbance recovery rate, and the prey density, are all likely to affect the marginal benefit for a cat or fox that travels to the burnt or grazed area to hunt within, or along its edge (Parkins *et al.* 2018). Nevertheless, managing fire and grazing to maximise vegetation cover and complexity near the ground may benefit many native species, in habitats where fire or grazing is common, and where alternative structural refuges (e.g. rugged rocky areas) do not exist (Legge *et al.* 2011; Legge *et al.* 2019).

Fire management is considered by many Indigenous ranger groups to be their best option for reducing cat impacts over large areas, consistent with an integrated, holistic approach to managing Country (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022).

Priority action areas over the next 5-10 years

Although the benefits of managing the interactions between fire, grazing and cat predation may only help species with low to moderate cat susceptibility, such management is a tool that can be applied at very large scales, achieving a very large overall benefit.

In fire-prone habitats, managing fire and grazing to maintain the complexity of the ground layer is likely to have multiple benefits, including reducing the impacts of cat predation on cat-susceptible species. Given the interaction between fire and predation by cats, fire management practices could be refined to include consideration of the need for post-fire predator control. Research to improve our understanding of the contextual factors that amplify or dampen interactions between fire, grazing and cat predation would also help to sharpen management.

6.7 Apex predator management

6.7.1 Maintain/restore dingo populations where possible

Current status

Apex predators may structure communities, and their removal can cause cascades of ecosystem changes (Crooks and Soulé 1999; Ritchie and Johnson 2009). Consistent with this theory, the loss of dingoes from Australian ecosystems is associated with a cascade of changes, including higher kangaroo density, changes to vegetation, and lower abundances of small mammals (i.e. the prey of cats) (Gordon *et al.* 2017; Morris and Letnic 2017). Some of these changes (such as the change in small mammal populations) relate to the abundance and effects of mesopredators like feral cats. Dingoes could reduce cat density by killing them directly, or at least alter cat behaviour in ways that shift which native species are bearing the cat's predation pressure (Paltridge 2002; Brook *et al.* 2012; Kennedy *et al.* 2012). Dingoes favour larger prey than cats, will eat carrion, and often occur at lower densities than cats, so their own predation profile on native communities differs from that of the cat.

The role of dingoes in controlling mesopredators and moderating their impacts is still unsettled (summarised in, Woinarski *et al.* 2019b); dingoes may exert mesopredator control in some biomes more than others, and their interactions may be affected by prey densities, and their own densities (Letnic *et al.* 2012; Newsome *et al.* 2017). Dingoes were present when cats spread across the continent and caused population declines in many species, so clearly dingoes are insufficient to protect the most cat-susceptible species from cats. Nevertheless, relaxing dingo control in areas where they are currently persecuted could bring conservation benefit to many other native species, and restore a species considered culturally important by many Indigenous groups (Newsome *et al.* 2015a). Conversely, small populations of threatened species could now be at risk from predation from the dingoes themselves (Cremona *et al.* 2017). Relaxing dingo control may also be economically favourable in some cattle producing areas, if the benefits of dingoes (reducing the density of macropods, rabbits and goats that compete with cattle for grazing) outweigh the costs of dingo control and some loss of livestock (Prowse *et al.* 2015). The presence of dingoes is less likely to be compatible with sheep production, as stock losses to dingo predation are higher for this smaller animal.

Priority action areas over the next 5-10 years

To evaluate whether and how dingo management could bring conservation benefit, dingos could be reintroduced into areas with a robust experimental framework (Dickman *et al*. 2009; Ritchie and Johnson 2009; Newsome *et al*. 2015a). Cattle-rearing areas would be more suitable than sheep-rearing areas. The effects on cats (and foxes if they are present), native species, and cattle production should be tightly monitored, as well as other parts of the ecosystem. Social research to understand the barriers to restoring dingos in areas where they have been persecuted will be critical for making dingo restoration possible (Fleming *et al*. 2012; Smith and Appleby 2018).

6.7.2 Recovery and reintroduction of Tasmanian devils

Current status

The devil is Tasmania's apex predator, and was present on the Australian mainland until <4000 years ago (Westaway *et al.* 2019). There is evidence that the recent rapid decline of Tasmanian devils in Tasmania has produced cascading ecological impacts for feral cats and some native animal species (Fancourt 2014; Cunningham *et al.* 2018; Cunningham *et al.* 2020), and conversely increase or introduction of devils may lead to reduction in cat abundance. For example, the release of devils onto Maria Island was quickly followed by a twofold reduction in the cat population on the island (Scoleri 2019). Given the possibility that devils exert some control on cat abundance or behaviour (Hollings *et al.* 2014; Fancourt *et al.* 2015), there have been proposals to reintroduce devils to selected sites on the Australian mainland (Hunter *et al.* 2015). Such proposals are contentious, as the interactions among devils, cats, foxes and other animals are contested (Fancourt and Mooney 2016), and because devils themselves may exert predation pressure on some native wildlife species that exceeds that of the original cats (Scoleri *et al.* 2020).

Priority action areas over the next 5-10 years

Further research on devil-cat interactions, and the consequences for native species and ecosystems, will help resolve the uncertainties. This research could include introductions of devils to fenced mainland areas on the Australian mainland.

6.7.3 Guardian dogs

Current status

Guardian dogs, bred originally to protect livestock from large predators (Van Bommel and Johnson 2012; Van Bommel and Johnson 2015), have more recently been repurposed for use in conservation (van Bommel and Johnson 2016). In Australia, they have been/are being used successfully to protect some native species living in small areas (e.g. fairy penguins, gannets, eastern barred bandicoots) from foxes (van Bommel 2010; Wallis *et al.* 2017; Johnson *et al.* 2021). It is unclear whether guardian dogs can also successfully repel feral cats.

Priority action areas over the next 5-10 years

More research is needed to establish the efficacy of guardian dogs for repelling cats and any potential adverse effects from introducing a large canid into the ecosystem, as they could potentially add a humane and sustainable approach for reducing cat impacts, especially in localised areas, and where other options are constrained.

6.8 Emerging options

6.8.1 Synthetic biology: Disease and immunocontraception

Releasing pathogens that cause disease in cats is unlikely to be effective against cats on the Australian mainland, and may be considered unacceptably inhumane with high non-target risks (Moodie 1995; RSPCA 2017). Feline panleukopenia has been used in the past to help eradicate cats from islands in other countries, and it is possible that diseases could be a useful part of an integrated control program for future island eradications.

Immunocontraception – where an animal's immune system works against its own gametes or reproductive hormones – prevents mature gametes from being produced or fertilised. Vectors (viruses or bacteria) can be engineered to carry the protein that causes the immune response. The approach has been trialled in cats (Eade *et al.* 2009; Levy *et al.* 2011), but the effects have been transient, or variable, and host resistance is likely to develop quickly. Once released, the spread of the engineered vector cannot be controlled. Given these issues, immunocontraception may be most useful as one part of a program for eradicating cats from islands, because the virus vector is eliminated along with the cat population in a relatively short period (Courchamp and Cornell 2000; McLeod *et al.* 2007). Alternatively, it may be as viable tool for controlling feral cats living around human infrastructure, where cats could more easily be caught and dosed without relying on a viral or bacterial vector (Johnston and Rhodes 2015).

There may be other pathways for harnessing disease vectors and/or the cat's immunological system, or its endocrinological system, to reduce reproductive output. More research into alternative concepts is needed.

6.8.2 Synthetic biology: Gene drives

Genetic engineering, which involves manipulating the genome of individual animals, includes the use of gene drives. A gene drive spreads a genotype through a population at a faster rate than theoretically possible from Mendelian inheritance. Gene drives are common in nature, and arise from many different mechanisms (Esvelt *et al.* 2014). In one mechanism, called a homing drive, genes copy onto the opposite chromosome during meiosis, causing all germline cells to carry the drive and associated gene sequence. With the recent development of the CRISPR/cas9 gene editing tool, which enables precise gene editing (Jinek *et al.* 2012), engineered genes could be designed and then released to propagate through populations. The engineered genes could make the carrier more susceptible to a toxin or could force all offspring to be of one sex. Gene drives have been successfully developed in lab populations of small organisms with short-generation times such as yeast, fruit flies and mosquitoes (e.g. DiCarlo *et al.* 2015; Gantz *et al.* 2015). Developing gene drives for vertebrates entails additional technical challenges, as well as ethical, legislative and policy challenges and risks that could affect public support for using this technology (Campbell *et al.* 2019). A current program to develop gene drives for eradicating house mice from islands may address some of these issues. However, a detailed, national plan that outlines the pathways for addressing the technical, ethical, risk, legal and policy issues and requirements for using such technology is needed to support responsible research and development, with an informed and engaged public.

6.8.3 Enhance predator awareness in cat-susceptible species

A key reason for the susceptibility of many native species to cats is predator naivety, caused by the lack of co-evolutionary history (Carthey and Blumstein 2018). The naivety was (and remains) so profound that populations of native species succumbed to cats well before improved predator recognition and avoidance behaviours could develop through natural selection. However, if populations of cat-susceptible native species could be exposed to closely managed numbers of feral cats, enough to result in some predation without causing overall population decline, then predator recognition and avoidance could be enhanced over time (Moseby *et al.* 2016; Evans *et al.* 2022). Research at Arid Recovery (SA) (West *et al.* 2018; Moseby *et al.* 2019), Wild Deserts (NSW) (Kingsford *et al.* 2021), and in the Cotter (ACT) (with a focus on foxes rather than cats, Evans *et al.* 2021) has sought to impose such directional selection. These trials have revealed shifts in morphology and behaviour of some wildlife species, consistent with improvement in predator avoidance capability. Whether predator recognition and avoidance can be enhanced sufficiently to allow these species to coexist with cats is unknown. In addition, most highly cat-susceptible species now have much-reduced genetic diversity as a result of their recent population contractions.

Epigenetics may be leveraged to improve predator awareness and responses in native species. Epigenetics explores how changes in the expression of genes alters individuals, rather than changes to the genetic code itself. Any individual has many genes that are present but not ‘switched on’. It may be possible to identify genes relevant to an effective predator response, such as smell receptor genes, or genes involved in the fight or flight responses, then switch them on, so that the activated animals have higher chances of surviving the threat from cats.

6.9 Managing feral cats around human habitation and infrastructure

Reducing the impacts of cats living with and around humans requires a different approach than managing feral cats in natural environments. Some control options are usually out of scope (e.g. toxic baits, shooting). The most important action for reducing feral cat populations living near people is to remove access to superabundant food, including unsecured bins and skips, rubbish dumps (Crawford *et al.* 2020), and the super-abundant populations of introduced rodents that may occur in heavily modified areas including farms (Denny 2005; Newsome *et al.* 2015b; Nou *et al.* 2021). Intensive trapping of cats can be used at small sites (Short *et al.* 2013; Nou *et al.* 2021), but removing access to the resources at these sites is essential for preventing cat numbers from building up again.

The legislation framing feral cat management living in heavily modified areas is a complex interplay between up to three levels of government (Commonwealth, state/territory, local), and there are opportunities to improve management outcomes with better alignment of the legislative and regulatory environments across jurisdictions (Nou *et al.* 2021).

Options for managing feral cats living with or around people are strongly influenced by human attitudes and behaviours, which may vary from place to place. Meeting the objective therefore requires that actions are informed by social science research to understand how the public (which contains diverse interest groups) responds to, and is involved in, the issues of cat impacts and management in and around human habitation and infrastructure (RSPCA 2018). Feral cat management programs that focus on multiple objectives, such as improving the welfare of cats; reducing the transmission of diseases that affect pet cats, livestock and people; reducing nuisance issues; as well as enhancing biodiversity values, are likely to enjoy wider support (McLeod *et al.* 2017; McLeod *et al.* 2019).

Trap Neuter Release is an approach advocated by some cat welfare groups, that aims to catch feral cats, desex them, then release them at the point of original capture. The procedure may (or may not) be followed with some level of veterinary care and feeding. Advocates suggest that trap-neuter-release is an alternative cat population control mechanism. In reality, there are only very limited circumstances where trap-neuter-release can be viable: when the cat population is 'closed' (i.e. no immigration); when the desexing rates are high enough to cause population decline, and those rates can be maintained as kittens mature to breeding age; when there is sufficient funding to provide veterinary care and food to the released cats and maintain the program until the last cats have died; and when there are no cat-susceptible native species at risk from the released cats (Crawford *et al.* 2019).

7 Managing pet cats

In most years, there are more pet cats than feral cats in Australia (section 3.2.1). Freely roaming pet cats can inflict substantial predation tolls on native species in urban and suburban areas (Legge *et al.* 2020c), they act as a reservoir for zoonotic disease, and are a potential source for augmenting the feral cat population living around human infrastructure. Freely roaming cats also experience higher rates of illness, injury and death than contained cats (RSPCA 2018).

Local governments are responsible for pet cat management. Overarching legislation on domestic/companion animal management is set by their state or territory, and local governments can enact local bylaws (with varying degrees of difficulty) to augment that state/territory legislation. Local governments rely on up to five key measures for managing pet cats: registration, identification (i.e., microchipping), desexing, limits on the number of cats per household, and restrictions on cat presence/movements (varying from partial curfews, 24-hour containment to the owner's property, and cat prohibition in designated suburbs). These measures are used to different degrees and in different combinations across local governments, creating a patchwork of approaches that is often ineffective, confusing to the public, and hampers efforts to ensure and monitor compliance. Some of the measures, such as desexing, are difficult to achieve in rural and remote areas without access to veterinary services (Nou *et al*. 2021)

A recent survey of local governments canvassed their views on cat management practices, barriers, and needs, and made a number of recommendations for improving pet cat management in ways that would reduce the predation burden of pets on native animals, improve welfare outcomes for cats, and reduce the risk of pathogen transmission (Nou *et al.* 2021). They included:

1) Strong, enabling legislation to mandate responsible pet cat management set at the state/territory level, that is harmonised across jurisdictions. The legislative frameworks should include household limits to the number of pet cats; mandatory registration, identification, desexing and containment to the owner's property (or equivalent control); and provisions to enable local governments to designate some residential areas as mandatory cat prohibition zones.
2) The legislative reform and its local implementation to be accompanied by community awareness and education programs.
3) Coordinated incentive programs to encourage uptake of responsible pet cat ownership.
4) Enhanced monitoring, collating and reporting of activity information, including key data on registrations, desexing statistics, identification details, impoundments, and numbers of feral cats killed.
5) Enhanced monitoring of outcomes, especially the number of free-roaming cats and the consequences for local wildlife.

The number of remote Indigenous communities with very high densities of resident cats may be growing, increasing the frequency of nuclei of high-density cats in natural environments that prey on native species directly, and provide a source of dispersers into the feral population (Kennedy *et al.* 2018). Local governments of remote and very remote areas face some unique challenges; organisations such as Animal Management in Rural and Remote Indigenous Communities (AMRRIC) already have an important role in companion animal management. Support mechanisms for this organisation could be enhanced. The pre-consultation process for this plan highlighted the need to improve the content and accessibility of relevant information about cat impacts (including from pets) and management to Indigenous communities (Conservation Management Pty Ltd 2022; Territory Natural Resource Management 2022).

8 Current status of protection for cat-susceptible native species

Cats prey upon many native animal species, however such predation has population-level impacts only on some of these native species: these species are a primary conservation focus of this plan. This section summarises an assessment of which native animal species are most cat-susceptible at population level, and an overview of the current level of protection for such species in cat-free islands and fenced havens. Based on this, the plan suggests performance criteria (targets) for the creation of new havens that align with the relevant target in the Threatened Species Action Plan 2022-2032.

8.1 Categorising species with cat susceptibility

Given the importance of understanding the level of cat-susceptibility for selecting the most appropriate cat control options, this threat abatement plan updates a previous assessment of cat-susceptibility undertaken by Radford *et al*. (2018) by:

1) Revising the categorisations to consider only susceptibility to cats (Radford et al. considered susceptibility to cats and/or foxes).
2) Enhancing the definitional crispness of the categories.
3) Adding an additional category, 'moderately cat-susceptible' to cater for species that fail to clearly fit the low or high cat susceptibility categories.
4) Incorporating new information that has emerged since the earlier assessment.
5) Extending the assessment to include all terrestrial mammals (i.e. including bats), terrestrial birds and reptiles, and threatened seabirds.

Note that susceptibility is also context dependent. For example, the buff-banded rail *Hypotaenidia philippensis* survives with cats across its large continental range and on many islands. However, on the small islands of the Cocos (Keeling) island group, which can support only small populations of rails, the endemic subspecies *Hypotaenidia philippensis andrewsi* has been extirpated from almost all islands by cats and black rats, other than on one cat-free island (Woinarski *et al.* 2016), so that subspecies is rated as of extreme susceptibility to cats.

New information was gleaned from recent species recovery plans and conservation advices, action plans, expert assessment of threats to vertebrates (Woinarski *et al.* 2014; Chapple *et al.* 2019; Garnett and Baker 2021; Ward *et al.* 2021), and a series of papers that quantified dietary information and the likelihood of being consumed by a cat (see section 4.1). Ideally, these categorisations should be regularly updated so that cat management can be appropriately prioritised for the conservation of cat-susceptible species.

The updated assessment shows that for terrestrial species, mammals contain the greatest number of extremely, highly and moderately cat-susceptible species, with birds and reptiles having lower numbers (summarised in Table 4; full list in Appendix 8). Overall, the updated assessment indicates that nine species of mammals, one species of terrestrial bird (or land-bird), and six species of threatened seabirds are extremely susceptible to cat predation; 38 mammal species, three terrestrial bird species, four reptile species, and one threatened seabird species are highly susceptible to cat predation (Table 4). Reducing cat impacts is (or, in some cases, has been) crucial for preventing declines and extinctions in these species. In particular, **cat exclusion is essential** for preventing extinction in the extremely susceptible species, and **highly desirable** to prevent further declines in highly cat-susceptible species.

Note that the assessment considered susceptibility to cat predation under ‘usual’ conditions. Susceptibility is likely to change, potentially markedly, after extreme events. For example, a ground-dwelling bird that lives in thick cover and is usually little-affected by feral cats could temporarily become highly cat-susceptible after an extensive high severity fire. Furthermore, for some taxa, the categorisation of cat-susceptibility is based on limited evidence; further targeted research and interpretation with population viability analysis will clarify the degree of population level susceptibility for some species for which the current assessment is not yet well resolved.

Table 4 Categories of susceptibility to cat predation that determine the level of cat control required to ensure population viability, and the numbers of extant mammal, reptile, land-bird and threatened seabird species that fall into each category.

Susceptibility of native animal species to cat predation		No. of taxa: Mammals	No. of taxa: Land-birds	No. of taxa: Reptiles	No. of taxa: Threatened seabirds
Extreme	Population likely to be extirpated where cats occur, and cats were, or are, or plausibly could occur in at least 50% of the native species' range.	9 (12 including subspecies)	1	0	6
High	Population likely to be extirpated where cats occur, and cats were, or are, or plausibly could occur in 20-50% of the native species' range. OR Population likely to persist with cats, but with severe reduction (>50%) in its population size and viability, and cats were, or are, or plausibly could occur in at least 50% of the native species' range.	38 (48 including subspecies)	3	4	1
Moderate	Population likely to persist with cats, but with moderate reduction (<50%) in its population size and viability.	24 (26 including subspecies)	11 (13 including subspecies)	9	8 (9 including subspecies)
Low	Likely to persist with cats but with some reduction in population size or viability (i.e. 0-9%); will have higher viability where cats are more effectively controlled.	227 (232 including subspecies)	611 (665 including subspecies)	977	0
Not	Viability is unaffected by introduced predators.				

Where subspecies exist, they are tallied with the new total shown in brackets. Vagrants and introduced species have been excluded from the tallies. For seabirds, only threatened species with Australian breeding populations are considered here.

Twelve of the extremely or highly cat-susceptible mammal taxa are Priority species in the Threatened Species Action Plan: western quoll *Dasyurus geoffroii*, eastern quoll *D. viverrinus*, northern quoll *D. hallucatus*, numbat *Myrmecobius fasciatus*, greater bilby *Macrotis lagotis*, mountain pygmy-possum *Burramys parvus*, western ring-tailed possum *Pseudocheirus occidentalis*, Gilbert's potoroo *Potorous gilberti*, quokka *Setonix brachyurus*, New Holland mouse *Pseudomys novaehollandiae*, northern hopping-mouse *Notomys aquilo*, and central rock-rat *Zyzomys pedunculatus.*

In addition, two of the 22 priority bird species are highly susceptible to cat predation; these are night parrot *Pezoporus occidentalis*, and western ground parrot *Pezoporus flaviventris*; and so is one reptile, the great desert skink *Liopholis kintorei*.

8.2 Current protection in cat-free havens

To inform the threat abatement plan actions relating to new havens, and ensure they are aligned with the Threatened Species Action Plan 2022-2032, the Legge *et al* (2018) assessment of haven protection for cat-susceptible mammals has been updated here by

1) Using the revised cat-susceptible categorisations described in section 8.1.
2) Including translocations into havens that have occurred since 2018.
3) Including cat-susceptible reptiles, land birds, and threatened seabirds.

A matrix of the current havens, and the cat-susceptible species they protect, is available in Appendix 10. In summary:

8.2.1 Mammals

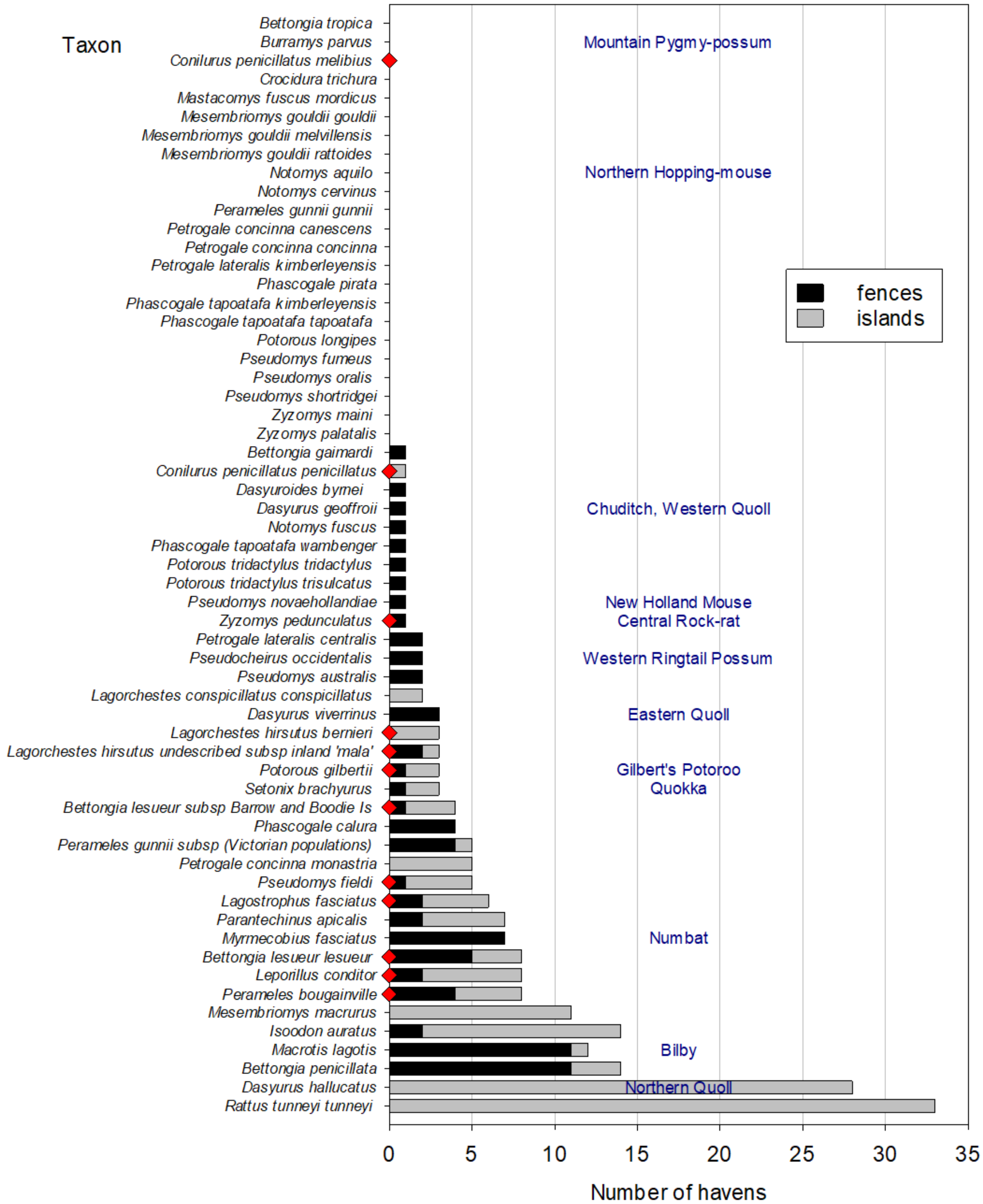
As of December 2022, 25 fenced areas and 119 islands protect

- All 9 **extremely** susceptible mammal species (and 11 of 12 subspecies) (Fig. 6), although two species, the brush-tailed rabbit-rat *Conilurus penicillatus* and the central rock-rat *Zyzomys pedunculatus* are only in one haven each; the ongoing presence of the rabbit-rat on a second cat-free island (Bentinck Island: last recorded in 1963) needs to be confirmed, and the translocation of central rock-rats to Newhaven Sanctuary is so recent that its success has yet to be established.
- 20 of the 38 **highly** cat-susceptible species (25 out of 48 subspecies) are in havens, but 6 species (7 subspecies) of these are only in one haven, and some of these are very recent translocations (e.g. Kowari *Dasyuroides byrnei* at the Arid Recovery Reserve). Only 13 highly cat-susceptible mammal taxa are in three or more havens (Fig. 6).

Protection gap:

- Of the extremely cat-susceptible species, the brush-tailed rabbit-rat and the central rock-rat have the lowest, and inadequate levels of protection.
- Of the 38 highly cat-susceptible mammal species, 18 species (or 24 taxa) of highly cat-susceptible mammal taxa are not represented in any havens (Fig. 6), but some of these occur at sites with intensive predator control (e.g. mountain pygmy possum), or are targets for fenced area projects that are underway (e.g. an exclosure is currently being established primarily to protect the northern bettong *Bettongia tropica*).

Figure 6 A histogram showing the number of populations of extremely (shown with red diamonds) and highly cat-susceptible subspecies protected in cat-free island and fenced havens



The common names listed (blue text) show the priority species in the Australian Government's Threatened Species Action Plan 2022-2032. (Note two subspecies of golden bandicoot combined to species level here).

8.2.2 Reptiles

- Of the four threatened reptile species with high cat-susceptibility, one, the great desert skink *Liopholis kintorei*, is represented within the fenced area of Newhaven Wildlife Sanctuary. The other three occur in eastern mainland Australia and do not occur in any haven (Table 5).

8.2.3 Terrestrial birds

- One threatened subspecies of buff-banded rail is considered extremely cat-susceptible. The Cocos Keeling subspecies *Hypotaenidia philippensis andrewsi* was extirpated from all ca. 26 islands of the southern atoll after the introduction of cats (and black rats) and persisted only on one island (Pulu Keeling) on which cats and rats were not introduced. It has since been translocated to cat-free Horsburg Island and emigrated from there to nearby Direction Island (Woinarski *et al.* 2016; Znidersic *et al.* 2019). It therefore currently exists on three cat-free islands.
- Of the three highly susceptible threatened terrestrial bird species, the Houtman Abrolhos painted buttonquail *Turnix varius scintillans* is endemic to two islands in the Houtman Abrolhos, and was extirpated from a third partly because of cats (which are now gone). The remaining two species, both parrots, exist in mainland Australia (Table 5). Neither are represented in havens, but cats are intensively managed where the western ground parrot *Pezoporus flaviventris* still occurs, and there is a fenced haven within a national park (Waychinicup) that is being considered as a translocation site.

8.2.4 Threatened seabirds

Seabirds are assessed separately because many species rarely, if ever, encounter cats. However, many seabirds breed exclusively, or largely, on islands, and nestlings or adults can be extremely susceptible to cats during breeding. Of 100 Australian seabird species (i.e. excluding vagrants), 20 threatened species breed exclusively on 31 islands (Appendix 9). Of these islands, 30 are now cat-free. The island with both cats and breeding colonies of threatened seabird is Christmas, where a cat eradication program is underway. The reduction in cat density already achieved there has increased breeding success for the red-tailed tropicbird *Phaethon rubricauda westralis* (Listed as Vulnerable by the Bird Action Plan) (Willacy *et al*. in review). Cat eradication is also planned or underway on another four islands (Flinders (Tas), French (Vic), Kangaroo (SA), Three Hummocks (Tas)), which may open up opportunities for seabirds to recolonise. One more threatened seabird, the fairy tern *Sternula nereis*, breeds on >65 islands, as well as the mainland.

Of the 20 threatened seabirds, six species are considered as extremely cat-susceptible (in relation to their breeding colonies), and one as highly cat-susceptible (Table 5). All have breeding colonies on cat-free islands, but at least some may increase their population size or number of locations with eradications of cats from other islands.

Over the course of the threat abatement plan, this tabulation of islands with seabird breeding colonies (Appendix 9) should be extended to cover non-threatened seabirds, to inform prioritisations for cat eradications from islands.

Table 5 The bird and reptile species considered extremely or highly susceptible to cat predation, and their representation within havens (as of December 2022)

Scientific name	Common name	EPBCA status	Cat susceptibility	Representation within havens
Birds				
Fregetta grallaria grallaria	White-bellied storm-Petrel	Vulnerable	Extreme	5 small islands in the Lord Howe group (extirpated from Lord Howe)
Halobaena caerulea	Blue petrel	Vulnerable	Extreme	Macquarie and surrounding stacks
Pachyptila turtur subantarctica	Fairy prion	Vulnerable	Extreme	Macquarie and surrounding stacks; Bishop and Clerk Islands
Pterodroma leucoptera leucoptera	Gould's petrel	Endangered	Extreme	Boondelbah, Cabbage Tree, Broughton, Little Broughton, Tollgates and Montague
Pterodroma mollis	Soft-plumaged petrel	Vulnerable	Extreme	Maatsuyker, Macquarie
Pterodroma neglecta neglecta	Kermadec petrel	Vulnerable	Extreme	Ball's Pyramid, Phillip (Norfolk group) (extirpated from Lord Howe, and possibly from main Norfolk Is)
Phaethon rubricauda westralis	Indian Ocean red-tailed tropicbird	Endangered; *Threatened status in Bird Action Plan*	High	Majority breed on Christmas Island (cats present, being eradicated); some pairs on 3 Ashmore Reef islands, Pulu Keeling, Bedwell (Rowley Shoal)
Hypotaenidia philippensis andrewsi	Cocos Keeling buff-banded Rail	Endangered	Extreme	Relictual population only on cat-free Pulu Keeling, with recent translocation to cat-free Horsburg Island, and emigration from there to Direction Island
Turnix varius scintillans	Houtman Abrolhos painted buttonquail	Vulnerable	High	East Wallabi, West Wallabi and sometimes recorded on 4 nearby islets (Oystercatcher, Turnstone, Seagull, Pigeon) but not resident. Extirpated from North Island, cats a potential contributor to this loss.
Pezoporus flaviventris	Western ground parrot	Critical	High	Nil
Pezoporus occidentalis	Night parrot	Endangered	High	Nil
Reptiles				
Liopholis guthega	Guthega skink	Endangered	High	Nil
Liopholis kitorei	Great desert skink	Vulnerable	High	Occurs within one fenced exclosure (Newhaven Wildlife Sanctuary)
Liopholis montana	Montane rock-skink	Endangered	High	Nil
Nangura spinosa	Nangur spiny skink	Critical	High	Nil

Note: the Western ground parrot, Night parrot and Great desert skink are Priority Species in the Threatened Species Action Plan 2022-2032.

8.3 Targets for the creation of new havens

Over the course of the implementation of this plan, five and ten-year targets for protection for extremely and highly cat-susceptible species should be set by the Safe Haven Network Working Group, but interim targets used in the threat abatement plan are:

- Extremely cat-susceptible species should be represented in at least three havens, with an overall population size across havens of at least 2000, with that population stable or increasing.
- Highly cat-susceptible species should be represented in at least 1 cat-free haven, or an area with sustained, very intensive cat control, and with an overall population size of at least 2000 that is stable or increasing.

Current extent of protection gap:

As of December 2022, there are 25 cat-free fenced areas and 119 cat-free islands protecting extremely and highly cat-susceptible native species. However, there remains a large protection gap (Fig. 6). Specifically:

Mammals:

- Of nine extremely cat-susceptible species, **two species (brush-tailed rabbit-rat** *Conilurus penicillatus*; **central rock-rat** *Zyzomys pedunculatus*) **are only in one haven each**; although it is possible that the rabbit-rat persists still on another island that is cat-free (Bentinck Island). The translocation of central rock-rats to Newhaven Sanctuary is so recent that its success has yet to be established. The seven other extremely cat-susceptible species are each in three or more havens, but **two species (Mala** *Lagorchestes hirsutus 'mala'* **and Gilbert's Potoroo** *Potorous gilberti*) **have overall population sizes < 2000.**
- Of 38 highly cat-susceptible species, **18 species are not in any havens.** However, some of these species occur at sites currently managed with intensive predator control (e.g. mountain pygmy possum).

Havens or increased cat control are needed for many taxa; a prioritisation for haven-dependent species based on current population status and trends is needed, but the most urgent needs for haven expansion are likely:

Extremely cat-susceptible mammal species:

- 2 new havens for the central rock-rat (a priority species in the Threatened Species Action Plan, it is currently only in one, recently created haven)
- 2 new havens for the brush-tailed rabbit-rat (it exists on one and may exist on another cat-free island, but this needs confirmation)
- 1 new haven for the Gilbert's potoroo (a priority species in the Threatened Species Action Plan, it has a total population of << 2000)
- 1 new haven for the Mala (in three havens, it has a total population of < 2000, although recently established population at Newhaven is expected to increase).

Highly cat-susceptible mammal species, with small populations and/or signs of rapid decline; at least one haven for each of:

- northern hopping-mouse (a priority species in the Threatened Species Action Plan)
- northern bettong (an exclosure is currently being established for one population)
- broad-toothed rat
- Carpentarian rock-rat.

Reptiles:

- Of the four highly cat-susceptible species:
  - Three are species of colonial skink with declining populations (Guthega skink *Liopholis guthega*, montane rock-skink *Liopholis montana*, Nangur spiny skink *Nangura spinosa*). Although havens could provide benefit, intensive management of cats and other threats may provide benefits over a larger area.
  - In the fourth species (great desert skink *Liopholis kintorei*), the priority is to monitor how the population responds to cat exclusion within the recently established fenced area of Newhaven Wildlife Sanctuary.

Birds:

- One subspecies of terrestrial bird is considered extremely cat-susceptible: the Cocos Keeling subspecies of the buff-banded rail *Hypotaenidia philippensis andrewsi* was extirpated from all ca. 26 islands of the southern atoll after the introduction of cats (and black rats) and persisted only on one island on which cats and rats were not introduced. It has recently been translocated to cat-free Horsburgh Island and emigrated from there to nearby Direction Island. Therefore, it currently exists on three cat-free islands, although the total area of these occupied islands is very small (collectively ca. 2 km^2).
- Of the three highly cat-susceptible terrestrial bird species, the Houtman Abrolhos painted buttonquail occurs on two cat-free islands, and the other two are not represented in any haven. The night parrot *Pezoporus occidentalis* persists across a very large range and may make long-range movements; fenced areas are unlikely to be a priority action in their conservation. The second species, western ground parrot, now persists in a small range, but is known to make large-range movements, so the benefits of a fenced area are unknown, but are currently being trialled at Waychinicup National Park.
- Note that fenced havens may have limited value for cat-susceptible land-birds, given their ability to fly over fences, and given the risk of bird strike on the fencing.
- Of six extremely cat-susceptible threatened seabird species, all rely (to varying extents) on islands from which cats have been eradicated (especially Macquarie, Lord Howe). One species is highly cat-susceptible and still breeding on an island with cats: the Indian Ocean red-tailed tropicbird *Phaethon rubricauda westralis* breeds mainly on Christmas Island where cat eradication is underway.

- The cat eradication underway at Christmas Island is critical for the conservation of the Indian Ocean red-tailed tropicbird.
- Eradicating feral cats from other islands *could* allow breeding colonies to re-establish. For example, eradicating cats from Norfolk Island could benefit the Kermadec petrel *Pterodroma neglecta neglecta*, which currently breeds on nearby Phillip Island.

In summary, the priorities for new haven creation are:

- **Complete the cat eradication underway on Christmas Island.**
- **Establish ten haven populations for eight mammal species. There are no additional fenced areas suitable for these species (apart from already established populations, in some cases), but existing cat-free islands may be suitable for four species (northern hopping mouse, brush-tailed rabbit-rat, central rock-rat, mala).**

The targets relating to haven creation in this threat abatement plan align with Target 12 of the Threatened Species Action Plan (2022-2032):

> **Target 12:** *Five new populations of appropriate species are added across the national safe haven network to improve representation of invasive predator-susceptible threatened species.*

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10 Glossary

Term	Definition
Cat susceptibility	A categorisation of the population level susceptibility of a native species to predation by cats, with levels including extreme, high, moderate, low or not: modified from (Radford *et al.* 2018).
Critically Endangered	Under the EPBC Act, a native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered	Under the EPBC Act, a native species is eligible to be included in the endangered category at a particular time if, at that time, (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Endemic	A species that is restricted to a particular place.
Eradicate	To remove all animals from a population.
Exclosure/exclusion (fencing)	An area that is fenced to protect the native species within and to prevent the entry of introduced predators.
Feral	An introduced animal, formerly in domestication, with an established, self-supporting population in the wild.
Feral cat	As defined in section 2, feral cats are individuals of the species *Felis catus* that are not formally owned, or cared for, by people. They survive by hunting or scavenging for themselves and live in diverse habitats. Most feral cats live in natural environments and have no or few interactions with people. A subset of feral cats is found in and around cities, towns and rural properties; these cats may rely on resources that are inadvertently created by people.
Haven	A location at which a major threat to a species that is highly or extremely susceptible to that threat is absent or has been eradicated; in this case cat-free islands or mainland exclosures, as defined by Legge et al. (2018).
Key threatening process	Under the EPBC Act, a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.
Performance indicator	A criterion or measure that provides information on the extent to which a policy, program or initiative is achieving its outcomes.
Threat abatement plan	Under the EPBC Act, a plan providing for the research, management and any other actions necessary to reduce the impact of a listed key threatening process on affected species and ecological communities.
Threatened species	A species under the EPBC Act listed as critically endangered, endangered, vulnerable or conservation dependent.
Vulnerable	Under the EPBC Act, a native species is eligible to be included in the vulnerable category at a particular time if, at that time, (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.

11 List of appendices

Note that some of these appendices are not included in this document, but are databases accessible through the links given.

1) Relevant sections of the EPBC Act relating to threat abatement plans.
2) Relevant legislation relating to feral (and pet) cats in Australian states and territories.
3) Other management plans and protocols that focus on, or partly on, feral cats.
4) List of Australian islands >1 ha with information on the presence or absence of feral cats.
5) Islands from which feral cats have been eradicated (or have had populations that died out).
6) Fenced areas on mainland from which cats have been excluded.
7) Nationally threatened or migratory animal species known to be preyed upon by cats, or for which predation by cats is considered a possible or confirmed threat.
8) Cat-susceptibility of terrestrial mammals, reptiles and birds; and threatened seabirds.
9) Breeding sites for threatened seabirds that breed on islands.
10) Matrix of cat-free islands and fenced areas with the highly and extremely cat-susceptible native animals occurring within them.

Appendix 1. Relevant sections of the EPBC Act relating to threat abatement plans

Objects of Act

1) The objects of this Act are:
   - a) to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance; and
   - b) to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources; and
   - c) to promote the conservation of biodiversity; and
   - ca) to provide for the protection and conservation of heritage; and
   - d) to promote a cooperative approach to the protection and management of the environment involving governments, the community, landholders and Indigenous peoples; and
   - e) to assist in the cooperative implementation of Australia's international environmental responsibilities; and
   - f) to recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and
   - g) to promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

Section 271 Content of threat abatement plans

1) A threat abatement plan must provide for the research, management and other actions necessary to reduce the key threatening process concerned to an acceptable level in order to maximise the chances of the long-term survival in nature of native species and ecological communities affected by the process.
2) In particular, a threat abatement plan must:
   - a) state the objectives to be achieved; and
   - b) state criteria against which achievement of the objectives is to be measured; and
   - c) specify the actions needed to achieve the objectives; and
   - g) meet prescribed criteria (if any) and contain provisions of a prescribed kind (if any).
3) In making a threat abatement plan, regard must be had to:
   - a) the objects of this Act; and
   - b) the most efficient and effective use of the resources that are allocated for the conservation of species and ecological communities; and
   - c) minimising any significant adverse social and economic impacts consistently with the principles of ecologically sustainable development; and

d) meeting Australia's obligations under international agreements between Australia and one or more countries relevant to the species or ecological community threatened by the key threatening process that is the subject of the plan; and

e) the role and interests of Indigenous people in the conservation of Australia's biodiversity.

4) A threat abatement plan may:

a) state the estimated duration and cost of the threat abatement process; and

b) identify organisations or persons who will be involved in evaluating the performance of the threat abatement plan; and

c) specify any major ecological matters (other than the species or communities threatened by the key threatening process that is the subject of the plan) that will be affected by the plan's implementation.

5) Subsection (4) does not limit the matters that a threat abatement plan may include.

Section 274 Scientific Committee to advise on plans

1) The Minister must obtain and consider the advice of the Scientific Committee on:

a) the content of recovery and threat abatement plans; and

b) the times within which, and the order in which, such plans should be made.

2) In giving advice about a recovery plan, the Scientific Committee must take into account the following matters:

a) the degree of threat to the survival in nature of the species or ecological community in question;

b) the potential for the species or community to recover;

c) the genetic distinctiveness of the species or community;

d) the importance of the species or community to the ecosystem;

e) the value to humanity of the species or community;

f) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

3) In giving advice about a threat abatement plan, the Scientific Committee must take into account the following matters:

a) the degree of threat that the key threatening process in question poses to the survival in nature of species and ecological communities;

b) the potential of species and ecological communities so threatened to recover;

c) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

Section 279 Variation of plans by the Minister

1) The Minister may, at any time, review a recovery plan or threat abatement plan that has been made or adopted under this Subdivision and consider whether a variation of it is necessary.

2) Each plan must be reviewed by the Minister at intervals of not longer than 5 years.

3) If the Minister considers that a variation of a plan is necessary, the Minister may, subject to subsections (4), (5), (6) and (7), vary the plan.

4) The Minister must not vary a plan, unless the plan, as so varied, continues to meet the requirements of section 270 or 271, as the case requires.

5) Before varying a plan, the Minister must obtain and consider advice from the Scientific Committee on the content of the variation.

6) If the Minister has made a plan jointly with, or adopted a plan that has been made by, a State or self-governing Territory, or an agency of a State or self-governing Territory, the Minister must seek the cooperation of that State or Territory, or that agency, with a view to varying the plan.

7) Sections 275, 276 and 278 apply to the variation of a plan in the same way that those sections apply to the making of a recovery plan or threat abatement plan.

Content of threat abatement plans — Environment Protection and Biodiversity Conservation Regulations 2000

Part 7 Species and communities

Regulation 7.12 Content of threat abatement plans

For paragraph 271 (2) (g) of the Act, a threat abatement plan must state:

a) any of the following that may be adversely affected by the key threatening process concerned:

   i) listed threatened species or listed threatened ecological communities;

   ii) areas of habitat listed in the register of critical habitat kept under section 207A of the Act;

   iii) any other native species or ecological community that is likely to become threatened if the process continues; and

b) in what areas the actions specified in the plan most need to be taken for threat abatement.

Appendix 2. Relevant legislation relating to cats in Australian states and territories

Table 6 Relevant legislation relating to cats in Australian states and territories

Jurisdiction	Legislation relating to feral cats	Legislation relating to pet cats	Feral cats defined as a pest?
Australian Capital Territory	*Pest and Animals Act 2005*	*Domestic Animals Act 2000*	No
New South Wales	*Local Land Services Act 2013; Biosecurity Act 2015; Biodiversity Conservation Act 2016; Game & Feral Animal Control Act 2002*	*Companion Animals Act 1998*	No
Northern Territory	*Territory Parks and Wildlife Conservation Act 2006*	None	Yes
Queensland	*Land Protection (Pest and Stock Route Management) Act 2002; Biosecurity Act 2014; Animal Care and Protection Act 2001*	*Animal Management (Cats and Dogs) Act 2008*	Yes
South Australia	*Natural Resource Management Act 2004*	*Dog and Cat Management Act 1995*	Yes (threat to natural resources)
Tasmania	*Biosecurity Act 2019*	*Cat Management Act 2009*	No
Victoria	*Catchment and Land Protection Act 1994; Flora and Fauna Guarantee Act 1988; Wildlife Act 1975; Prevention of Cruelty to Animals Act 1986*	*Domestic Animals Act 1994; Domestic (Feral and Nuisance Animals) Act*	Yes (on some public lands)
Western Australia	*Biosecurity and Agriculture Management Act 2007; Biodiversity Conservation Act 2016*	*Dog and Cat Management Act 1995; Cat Act 2011*	Yes

Appendix 3. Other management plans and protocols that focus on, or partly on, feral cats

Australian Capital Territory

ACT Cat Plan 2021-2031: A plan developed under the 2017 ACT Animal Welfare and Management Strategy

New South Wales:

NSW Code of Practice and Standard Operating Procedures for the Effective and Humane Management of Feral Cats (2022). (Sharp *et al.* 2022)

Includes:

NSWCAT SOP1 **Ground shooting of feral cats**
NSWCAT SOP2 **Trapping of feral cats using cage traps**
NSWCAT SOP3 **Trapping of feral cats using padded foot-hold traps**

Tasmania

Tasmanian Cat Management Plan, 2017-2022. (Department of Primary Industries Parks Water and Environment 2017)

pestSMART (Centre for Invasive Species Solutions)

Model code of practice for the humane control of feral cats (Sharp and Saunders 2012)

Includes:

CAT001: Ground shooting of feral cats – PestSmart
CAT002: Trapping of feral cats using cage traps – PestSmart
CAT003: Trapping of feral cats-using soft net traps – PestSmart

Baiting of feral cats with paraaminopropiophenone (PAPP). Standard Operating Procedure CAT004

Appendix 4. List of Australian islands > 1 ha with information on feral cat presence and absence

[linked excel file]

Appendix 5. Islands from which feral cats have been eradicated (or have had populations that died out)

[linked excel file]

Appendix 6. Fenced areas on mainland from which cats have been excluded

[linked excel file]

Appendix 7. Nationally threatened and migratory animal species known to be preyed upon by cats, or for which predation by cats is considered a possible or confirmed threat

[linked excel file]

Appendix 8. Cat-susceptibility of terrestrial mammals, reptiles and birds; and threatened seabirds

[linked excel file]

Appendix 9. Breeding sites for threatened seabirds that breed on islands

[linked excel file]

Appendix 10. Matrix of cat-free islands and fenced areas with the extremely and highly susceptible native animals occurring within them

[linked excel file]