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IDENTIFICATION OF SITES OF HIGH CONSERVATION PRIORITY IMPACTED BY FERAL CATS

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EXECUTIVE SUMMARY

Feral cats (*Felis catus*) have been recorded throughout the Australian mainland and on many offshore islands. Predation by feral cats has been implicated, together with other factors, in the population declines of many species of native vertebrates. Some of these declines have resulted in the shifting of species' conservation status to a more endangered level, with several native species having become extinct. Predation by feral cats is classified as a key threatening process by the Australian Government under the *Environment Protection and Biodiversity Conservation Act* 1999.

The cryptic nature of the cat, its exploitation of both modified and unmodified habitats, its status as both a pest and a pet species, and the abundance of introduced prey species and supplemental food sources throughout its range, all contribute to the many acknowledged problems associated with the control or eradication of feral cats in Australia.

In the absence of a single, robust way to measure cat densities and the known difficulties associated with assessing cat impacts at the species level, indirect methods are required to prioritise sites for the implementation of cat control programs.

This report uses an interactive decision-making tree based on characteristics of prey species to provide a relative measure of probable cat impacts between sites on the Australian mainland and offshore islands. The decision-making tree provides a single score for geographical (IBRA) regions, specific mainland sites and offshore islands that may be used comparatively for the allocation of resources for cat control programs. Although the scores in this report are based only on those species listed in the Australian Government's *Threat Abatement Plan for Predation by Feral Cats* (2008), comparative scores can be calculated and allocated for sites that support any species at risk of predation by feral cats and classified as threatened, endangered, or vulnerable at the national, state or local level. Indeed, the decision-making tree also allows non-threatened species to be assessed for their risk of predation from cats, should the need arise to do so.

The interactive decision-making tree provided comparative scores for the potential impact of cats in each IBRA region of Australia. These scores varied from a high of 328 for the South Eastern Highlands IBRA region of eastern Australia, to a low of 24 for the Gawler IBRA region of South Australia and for three other IBRA regions located wholly or largely in Western Australia. However, there were also 9 IBRA regions with no extant TAP-listed species; these consequently received no scores. The decision-making tree also provided comparative scores for the impact of feral cats in specific sites throughout the mainland and on offshore islands. These scores, based on data provided by land managers or available in the literature, varied from highs of 117 for the Diamantina National Park in Queensland and 108 for the East Gippsland area in Victoria, to a low of 10 for Dirk Hartog Island off the Western Australian coast. Further scores were calculated for sites at which cat control is uncertain ('data deficient') and from which cats have been eradicated or never recorded to identify sites that could be potentially impacted by feral cats in future. These scores varied from a high of 201 for sub-Antarctic Macquarie Island to a low of 9 for Boondelbah Island off the coast of New South Wales.

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

INTRODUCTION

Scope of report

The Department of Environment, Water, Heritage and the Arts (DEWHA) commissioned research by members of the Institute of Wildlife Research, University of Sydney, to identify sites of high conservation priority impacted on by feral cats in Australia. The key aims of the project were to:

1. Identify sites around Australia where the impact of feral cats is recognised as a significant threat to native species or ecological communities.
2. Prioritise the sites identified in (1) by the level of impact by the feral cats.
3. Identify sites where the impact of feral cats is recognised as a potential significant threat to native species or ecological communities but where the population of feral cats is currently zero or very low, and estimate the degree of potential threat for each site.
4. Prioritise the sites identified in (2).
5. Determine for the sites identified in (1) and (2) options for:
    a. Eradication if possible;
    b. Reduction in cat numbers, including methods for determining optimal density of cats and the methods for obtaining long-term reduction in numbers.
6. Identify specific feral cat control programs for the sites identified in (1) and (2) and document, where possible:
    a. Resources required;
    b. How feral cat numbers and impacts are monitored; and
    c. Control techniques used.

7. Identify effective feral cat control programs in locations outside the sites identified in (1) and (2) that may be applicable in these sites and provide details of control techniques, resources and monitoring.
8. Advise where possible on regional feral cat control programs around the sites identified in (1) and (2) and prioritise areas for regional control.

This report identifies sites of high conservation priority based on broad areas comprising bioregions as defined in the Interim Bioregionalisation of Australia (IBRA), particular sites within these regions, and offshore islands where threatened species have been recorded. Sites discussed in this report are confined largely to areas where those threatened species listed in the *Threat Abatement Plan for Predation by Feral Cats* (2008) have been recorded. A decision-making tree, based on characteristics of both predator and prey species, is constructed and used to compare and prioritise sites throughout the Australian mainland and offshore islands. This is a flexible tool that can be used to identify sites based on threatened species listed by the Australian Government and/or at the state/territory and regional levels, depending on management objectives.

Background

The domestic cat (*Felis catus*) is believed to have been introduced into Australia at multiple points along the coastline during the period 1824-1886 (Abbott 2002). The descendants of some of these cats, now feral and largely independent of people for their resource requirements, are now widespread across the Australian mainland, Tasmania and many offshore islands (Burbidge *et al.* 1997; Abbott 2002) and have been implicated in the status shifting and decline of native mammal species (Dickman *et al*. 1993; Burbidge *et al.* 1997).

The primary impact of the feral cat in Australia is via predation on mammals, birds, reptiles, amphibians and some invertebrates. There is also evidence of a potential threat from cats to native species through the dissemination of diseases and parasites (Moodie 1995; Henderson 2009), and competition with feral cats for available resources may negatively impact larger dasyurids, varanids and large raptors (Dickman 1996). The impacts of feral cats on native fauna may be exacerbated when prey species are already negatively impacted by habitat modification; climatic events such as droughts, fires and floods; disease; and changes in food distribution and abundance (Dickman 1996). The impacts also may vary between sites due to differences in climate, landform, habitat, and species richness and diversity - factors that affect the relative abundance of both prey and predator.

The evidently high level and deleterious nature of impacts of feral cats has resulted in the formulation of threat abatement plans at both the national and state/territory levels (Greenaway 2009). Effective implementation of these plans over the Australian mainland and on offshore islands requires the prioritisation of sites of high conservation value for control efforts to preserve threatened native species and ecological communities. Prioritisation of sites of high conservation value provides a basis for targeting those areas of highest feral cat impact or potential impact, and for the distribution of the resources available for cat control programs on the Australian mainland and offshore islands.

The identification of sites of high conservation priority impacted by feral cats is multi-faceted, comprising:

- assessment of the number of threatened species and the status of threatened species at particular sites,
- the relative vulnerability of each threatened species to cat predation based on characteristics of these prey species including size (e.g., critical weight range (Dickman 1996)), habitat use, cycle (diurnal or nocturnal), locomotion and defenses, and
- assessment of whether any cat control programs are in place or are planned for bioregions on the Australian mainland, or specific sites including national parks, nature reserves and offshore islands.

In 2006, Reddiex *et al.* provided an overview of the patterns of control and monitoring of vertebrate pests on the Australian mainland and offshore islands based on a survey of the actions of conservation-focused organisations between 1998 and 2003. The authors reported that feral cat control operations in Australia increased fivefold in 2002 and that 57.5% of feral cat control operations were ongoing, whilst

27.5% had ceased because the goal was attained. This relatively high success rate (compared to 0.5% foxes and 0% for wild dogs) reflected the concentration of cat control programs on islands and within predator-proof sites on the mainland (Reddiex *et al.* 2006).

However, between 1998 and 2003, the mean area of control operations for feral cats (>3,355 ha) fell well below that of foxes (>93,643 ha) or wild dogs (>22,534 ha), despite a much wider distribution of cats in Australia than either foxes or wild dogs. Most cat control operations occurred in the south-west and south-east of the mainland, or on offshore islands.

The relative abundances of cats among habitats in Australia are difficult to assess because of habitat-specific variation in the detectability of cats, and because of variations in the methodology used in different studies. Reddiex *et al.* (2006) reported that most feral cat control programs were conducted on offshore islands or on mainland sites enclosed by predator-proof fences, and were aimed at ongoing control rather than eradication. Direct and indirect sampling techniques for the assessment of presence/absence and relative abundance of free-living cats in Australia vary in effectiveness between different environments. Factors that may lead to bias in density estimates or estimates of relative abundance include:

- vegetative cover, including tree species – feral cats are more visible in open, sparsely vegetated habitats and use vegetation for concealment when hunting or moving between sites;
- substrate – tracks of feral cats are more easily discernible on soft, sandy substrate than on harder, more stony or vegetated substrates (Denny 2005);
- proximity of sampling sites to runways (e.g., tracks, roads, dune crests) – feral cats have been recorded preferentially using runways (Mahon *et al*. 1998, Denny 2005), so estimates of cat activity may under- or over-estimate the abundance of cats if runways are excluded from or included in detection studies;
- flowing or dry creek lines and water courses – at sites where creeks and water courses are most usually dry (e.g., arid areas) signs of feral cat presence such as tracks and scats are more easily discovered than in habitats with frequently flowing creek lines or water courses;
- domestic stocking rates – tracks and scats of larger, hard-footed domestic stock may obscure tracks of the smaller, soft-footed feral cats;
- human and vehicular traffic movements – feral cat tracks and scats may be obscured along roadways and tracks by human and vehicular movements; and
- densities of medium to large ground-dwelling mammals – signs of other mammalian pest species (foxes and wild dogs) may be confused with those of feral cats (Denny 2005), and signs of the presence of feral cats may be obscured at sites of abundant larger marsupials such as kangaroos, wallabies and wombats.

Published densities of feral cats in the Australian literature range from 0.03 cats km^{-2} (Ridpath 1990, Burrows and Christensen 1994) to 4.7 cats km^{-2} (Newsome 1991), although higher densities have been reported on both offshore islands (Domm and Messersmith 1990) and at resource-rich sites such as rubbish dumps (Denny *et al*. 2002). Variations in feral cat densities in Australia have been related to time of year, with cat densities higher in summer when juvenile cats are dispersing, than in winter (Jones and Coman 1982); and prevailing climatic conditions, with cat densities higher during non-drought than during drought periods when the relative abundance of prey species is higher (Newsome 1991, Burrows and Christensen 1994). Densities of cats have also been related to proximity to highly modified and resource-rich habitats such as rural townships or rural refuse sites (Read and Bowen 2001; Denny 2005). Throughout the world, the highest cat densities have been recorded in urban/peri-urban habitat, next highest on islands, and lowest at mainland sites remote from human activity (Liberg *et al.* 2000). These geographical variations in cat densities are related to the relative abundance and distribution of food resources, with the greatest cat densities recorded where food abundance is relatively high and clumped and lowest where the food abundance is low and dispersed (Liberg *et al.* 2000).

Limitations

Several limitations are inherent in developing prioritised listings of sites throughout the Australian mainland and on offshore islands where feral cats have been reported, or are likely to, have negative impacts on biodiversity. Such limitations include:

- Lack of reliable data on feral cat densities or relative abundance throughout the continent – this precludes the use of basic measures to formulate a methodology for prioritising sites impacted by feral cats. Consequently, alternative data (discussed later in this document) were used for this project.
- Lack of reliable data on causal relationships between cat predation/disease dissemination/competition and extinction/status shifting of native prey at the species level.
- Lack of data on cat control programs - apart from relatively large, well-documented cat control/eradication programs on islands, in predator-proof exclosures, and sites where above-ground baiting is feasible, there are few data available on cat control programs at specific sites.
- Variations in land tenure and state/territory legislation relating to sites where cats are known to, or may possibly have an impact – land management and relevant legislation are both central to feral cat control programs and the limited time frame for this project precluded investigations into the feasibility of instigating control at a number of sites.

The methodology that we adopt here – a rank-scoring system – acknowledges these limitations and attempts to provide an objective and repeatable means by which managers can assess the likely impact of feral cats on native fauna on land under their jurisdiction. By using the rank-scoring approach first at the bioregional scale and then at a smaller site-specific scale, we also show how the methodology can be used to develop a prioritised list of places where cat impacts on threatened species can be expected to be greatest, and hence where control efforts may best be directed.

METHODOLOGY

Threatened species potentially impacted by feral cats

The native species considered here to be at risk of predation by feral cats are those listed in Appendix A of the *Threat abatement plan for predation by feral cats* (TAP) (2008). This list, specifying species and subspecies considered to be vulnerable, endangered or critically endangered under the TAP, formed the basis for identifying and prioritising sites on mainland Australia and offshore islands impacted by feral cats. The threatened species listed in the TAP (2008) for predation by feral cats are shown in Table 1. Note that, following Appendix A in TAP (2008), listed critical habitats and some unlisted taxa that could be affected by feral cats are also given.

Table 1: Threatened species and critical habitats that may be adversely affected by feral cats

Type/category	Scientific name	Common name	Current status
Listed threatened species that may be adversely affected by feral cats			
Birds	*Cereopsis novaehollandiae grisea*	Cape Barren goose (southwestern), Recherche Cape Barren goose	Vulnerable
	Chalcophaps indica natalis	Emerald dove (Christmas Island)	Endangered
	Cinclosoma punctatum anachoreta	Spotted quail-thrush (Mt Lofty Ranges)	Critically endangered
	Cyanoramphus cookii (listed as *Cyanoramphus novaezelandiae cookii*)	Norfolk Island green parrot	Endangered
	Dasyornis brachypterus	Eastern bristlebird	Endangered
	Diomedea exulans	Wandering albatross	Vulnerable
	Fregetta grallaria grallaria	White-bellied storm-petrel (Tasman Sea), white-bellied storm-petrel (Australasian)	Vulnerable
	Gallirallus philippensis andrewsi	Buff-banded rail (Cocos [Keeling] Islands)	Endangered
Birds (continued)	*Halobaena caerulea*	Blue petrel	Vulnerable
	Lathamus discolor	Swift parrot	Endangered
	Leipoa ocellata	Malleefowl	Vulnerable
	Leucocarbo atriceps purpurascens (listed as *Phalacrocorax purpurascens*)	Imperial shag (Macquarie Island)	Vulnerable
	Lichenostomus melanops cassidix	Helmeted honeyeater	Endangered

Type/category	Scientific name	Common name	Current status
Listed threatened species that may be adversely affected by feral cats			
	Macronectes giganteus	Southern giant-petrel	Endangered
	Malurus coronatus coronatus	Purple-crowned fairy-wren (western)	Vulnerable
	Malurus leucopterus leucopterus	White-winged fairy-wren (Dirk Hartog Island), Dirk Hartog black-and-white fairy-wren	Vulnerable
	Melanodryas cucullata melvillensis	Hooded robin (Tiwi Islands)	Endangered
	Neophema chrysogaster	Orange-bellied parrot	Critically endangered
	Pachycephala pectoralis xanthoprocta	Golden whistler (Norfolk Island)	Vulnerable
	Pachyptila turtur subantarctica	Fairy prion (southern)	Vulnerable
	Pardalotus quadragintus	Forty-spotted pardalote	Endangered
	Pedionomus torquatus	Plains-wanderer	Vulnerable
	Petroica multicolor multicolor	Scarlet robin (Norfolk Island)	Vulnerable
	Pezoporus occidentalis	Night parrot	Endangered
	Pezoporus wallicus flaviventris	Western ground parrot	Endangered
	Pterodroma heraldica	Herald petrel	Critically endangered
	Pterodroma leucoptera leucoptera	Gould's petrel	Endangered
	Pterodroma mollis	Soft-plumaged petrel	Vulnerable
	Pterodroma neglecta neglecta	Kermadec petrel (western)	Vulnerable
Birds (continued)	*Sterna vittata bethunei*	Antarctic tern (New Zealand)	Endangered
	Sterna vittata vittata	Antarctic tern (Indian Ocean)	Vulnerable
	Stipiturus malachurus intermedius	Southern emu-wren (Fleurieu Peninsula), Mount Lofty southern emu-wren	Endangered
	Thalassarche chrysostoma	Grey-headed albatross	Vulnerable
	Thalassarche melanophris	Black-browed albatross	Vulnerable

Type/category	Scientific name	Common name	Current status
Listed threatened species that may be adversely affected by feral cats			
	Turnix melanogaster	Black-breasted button-quail	Vulnerable
Mammals	*Bettongia lesueur lesueur*	Boodie, burrowing bettong (Shark Bay)	Vulnerable
	Bettongia lesueur unnamed subsp.	Boodie, burrowing bettong (Barrow and Boodie Islands)	Vulnerable
	Burramys parvus	Mountain pygmy-possum	Endangered
	Dasycercus byrnei	Kowari	Vulnerable
	Dasycercus cristicauda	Mulgara	Vulnerable
	Dasycercus hillieri	Ampurta	Endangered
	Hipposideros semoni	Semon's leaf-nosed bat, greater wart-nosed horseshoe-bat	Endangered
	Isoodon auratus auratus	Golden bandicoot (mainland)	Vulnerable
	Isoodon obesulus obesulus	Southern brown bandicoot	Endangered
	Lagorchestes hirsutus bernieri	Rufous hare-wallaby (Bernier Island)	Vulnerable
	Lagorchestes hirsutus dorreae	Rufous hare-wallaby (Dorre Island)	Vulnerable
	Lagorchestes hirsutus unnamed subsp.	Mala, rufous hare-wallaby (central mainland form)	Endangered
	Lagostrophus fasciatus fasciatus	Banded hare-wallaby, marnine, munning	Vulnerable
	Leporillus conditor	Wopilkara, greater stick-nest rat	Vulnerable
	Macrotis lagotis	Greater bilby	Vulnerable
	Myrmecobius fasciatus	Numbat	Vulnerable
Mammals (continued)	*Notoryctes caurinus*	Karkarratul, northern marsupial mole	Endangered
	Notoryctes typhlops	Yitjarritjarri, southern marsupial mole	Endangered
	Onychogalea fraenata	Bridled nail-tail wallaby	Endangered
	Parantechinus apicalis	Dibbler	Endangered
	Perameles bougainville bougainville	Western barred bandicoot (Shark Bay)	Endangered

Type/category	Scientific name	Common name	Current status
Listed threatened species that may be adversely affected by feral cats			
	Perameles gunnii gunnii	Eastern barred bandicoot (Tasmania)	Vulnerable
	Perameles gunnii unnamed subsp.	Eastern barred bandicoot (mainland)	Endangered
	Petaurus gracilis	Mahogany glider	Endangered
	Petrogale lateralis MacDonnell Ranges race	Warru, black-footed rock-wallaby	Vulnerable
	Petrogale penicillata	Brush-tailed rock-wallaby	Vulnerable
	Petrogale persephone	Proserpine rock-wallaby	Endangered
	Phascogale calura	Red-tailed phascogale	Endangered
	Potorous gilbertii	Gilbert's potoroo	Critically endangered
	Potorous longipes	Long-footed potoroo	Endangered
	Pseudomys fieldi	Djoongari, Alice Springs mouse, Shark Bay mouse	Vulnerable
	Pseudomys fumeus	Konoom, smoky mouse	Endangered
	Pseudomys oralis	Hastings River mouse	Endangered
	Sminthopsis aitkeni	Kangaroo Island dunnart	Endangered
	Sminthopsis douglasi	Julia Creek dunnart	Endangered
	Zyzomys pedunculatus	Central rock-rat	Endangered
Reptiles	*Delma impar*	Striped legless lizard	Vulnerable
	Egernia kintorei	Great desert skink, tjakura, warrarna, mulyamiji	Vulnerable
Reptiles (continued)	*Egernia obiri*	Arnhem Land egernia	Endangered
	Eulamprus leuraensis	Blue Mountains water skink	Endangered
	Eulamprus tympanum marnieae	Corangamite water skink	Endangered
	Hoplocephalus bungaroides	Broad-headed snake	Vulnerable
	Lepidodactylus listeri	Lister's gecko, Christmas Island gecko	Vulnerable

Type/category	Scientific name	Common name	Current status
Listed threatened species that may be adversely affected by feral cats			
Amphibians	*Heleioporus australiacus*	Giant burrowing frog	Vulnerable
	Litoria aurea	Green and golden bell frog	Vulnerable
	Philoria frosti	Baw Baw frog	Endangered
Type/category	**Scientific name**	**Common name**	**Current status**
Unlisted species or taxa that could be adversely affected by feral cats			
Birds	*Amytornis textilis textilis*	Thick-billed grasswren (western)	
	Phaethon rubricauda westralis	Red-tailed tropicbird	
	Puffinus assimilis	Little shearwater	
	Zosterops tenuirostris	Norfolk Island white-eye, slender-billed white-eye	
Reptiles	*Cryptoblepharus egeriae*	Blue-tailed skink	
	Emoia nativitatis	Forest skink	
Listed critical habitat			
Diomedea exulans (Wandering albatross) — Macquarie Island			
Thalassarche chrysostoma (Grey-headed albatross) — Macquarie Island			

Data acquisition

For each of the TAP (2008) -listed species and subspecies shown in Table 1, we sought information on particular sites and bioregions where these taxa had been documented. To obtain reliable records, several sources of information were explored.

Questionnaire

A questionnaire (Appendix A) was prepared and sent to 48 researchers and land managers associated with feral cat research/control programs throughout Australia. The questionnaire sought data on sites and species known/likely to be impacted by feral cats (including sites that were considered by researchers or managers to be data deficient); whether any local or regional cat control programs were being conducted or were planned for these sites; data on the specific locations of sites (e.g., latitude and longitude or other geographical descriptors); and links to other researchers/land managers who may be able to provide further information on feral cat impacts.

Personal contacts

Based on the responses to the questionnaire, an additional 14 researchers and land managers were contacted by telephone and asked for their responses to the questionnaire.

Literature search

A comprehensive literature search was conducted to identify those sites and bioregions on the Australian mainland and offshore islands where both feral cats and TAP-threatened species occur together, as well as to find any available data on cat eradication/control programs. Literature searches included all issues from 1996 of the *Australian Journal of Zoology*, *Australian Zoologist*, *Pacific Conservation Biology*, and *Wildlife Research*; the taxon-specific journals *Australian Mammalogy*, *Corella* and *Herpetofauna* were consulted over the same period of time. References prior to 1996 were compiled and collated by Dickman (1996). Many other specific references were used, and these are noted below.

Mainland bioregions and sites

The Australian Natural Resources Atlas (www.anra.gov.au accessed April 2009) was consulted to determine whether feral cats were present in those bioregions where the native species listed in Appendix A of the TAP were recorded. This information was checked or refined further by reference to regional and national field guides (e.g., Horner 1992; Storr *et al*. 1999; Cogger 2000; Barrett *et al*. 2003; Wilson and Swan 2008; Swan *et al*. 2004; Wilson 2005; Woinarski *et al*. 2007), other books (e.g., Pyke and Osborne 1996; Sattler and Williams 1999; Lunney 2004; Robin *et al*. 2009; Russell-Smith *et al*. 2009; Robin and Dickman 2010), and reliable online databases (e.g., FaunaBase http://www.museum.wa.gov.au/faunabase/prod/index.htm accessed April and December 2009) and a database listing the mammals of Australia and the IBRA regions in which they have been recorded (Burbidge *et al.* 2008). We also consulted the survey, collection and fauna summary reports cited in Burbidge *et al*. (2008). Finally, responses to the questionnaire by researchers and land managers throughout Australia were superimposed on the bioregions to provide a list of sites of high conservation priority known/likely to be impacted by feral cats.

Island bioregions and sites

Databases listing all the islands of Australia were consulted to identify those islands where cats have been recorded. The databases accessed in April 2009 were:

www.environment.gov.au/biodiversity/invasive/publications/pubs/nsw-feral-final-report.pdf

www.environment.gov.au/biodiversity/invasive/publications/pubs/nt-islands-report.pdf www.environment.gov.au/biodiversity/invasive/publications/pubs/tasmanian-islands-lists1-4.pdf

www.environment.gov.au/biodiversity/invasive/publications/pubs/database1.pdf

www.dse.vic.gov.au/Introduced+animals+Vic+islands+2008.pdf

Field guides and data on individual islands were also used to identify those islands where both cats and TAP-listed species occur. Assessments of the accessibility of islands, and thus possibility of cat invasion or re-invasion, were gathered from both the island databases and searches of the characteristics of individual islands. Additional material consulted included Burbidge (1989); Dickman (1992); Burbidge and Manly (2002); New South Wales National Parks and Wildlife Service (2004); Western Australian Department of Conservation and Land Management (2004); New South Wales Department of Environment and Climate Change (2006, 2007, 2008); Woinarski *et al*. (2007), Johnston (2008), and South Australian Department of Environment and Heritage (2009).

Prioritisation of sites

To provide a basis for the prioritisation of sites identified as impacted, or potentially impacted, by feral cats, a decision-making tree was developed to standardise assessment of the available data.

Criteria for interactive decision-making tree

Characteristics of both cats and prey species were considered for the construction of a decision-making tree to be used to formulate scores to allow prioritisation of sites of high conservation value impacted by cats. The decision-making levels considered for the construction of the tree comprised:

Cat presence/absence – data on feral predators in bioregions, at specific sites on the mainland and on islands, were collated to determine the presence/absence of cats to provide a measure of the probability of cat impacts. Data on abundance (e.g., Wilson *et al*. 1992; West 2008) were considered to be too unreliable to use in the decision tree.

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

Threatened species – this report specifically addresses those species listed in Appendix A of the *Threat abatement plan for predation by feral cats* (2008); this comprises 35 species and subspecies of bird, 36 species and subspecies of mammal, seven species and subspecies of reptile and three amphibian species. Also included are four unlisted bird taxa and two species of reptiles that could be adversely affected by feral cats, as well as two listed critical habitats.

Although our focus was on taxa listed in TAP (2008), the decision-making tree can accommodate threatened species listed by both the Australian Government and all state/territory instrumentalities. However, expansion of the number of threatened species in each IBRA region and/or identified site to include other listings may change the order of priority of the identified sites. The threatened species identified in Appendix A of the TAP (2008) are considered particularly vulnerable to predation by feral cats because many occur only in small, fragmented or isolated populations, or fall within the critical weight (or size) range for species vulnerable to predation by feral cats (Dickman 1996).

Although specifically devised to provide a basis for the prioritisation of sites and potential sites of impacts of cat predation on TAP (2008) species, the decision-making tree can also be used by land managers to prioritise sites within specific management areas, even in the absence of threatened species listed in the TAP (2008), at the Australian Government or state/territory government levels. To allow this functionality, a multiplier (0.5) for non-listed species has been included in the decision-making tree (Table 2), although it has not been used in the assessments of listed species presented here.

Vulnerability of threatened species to cat predation – cats prey as individuals, in contrast to the co-operative hunting techniques of canids (Kleiman and Eisenberg (1973). Thus prey taken by cats is restricted to a size manageable by an individual. Studies of the diets of cats on the Australian mainland suggest that small mammals (< 220 g) or small birds and reptiles (< 25 cm long), are most vulnerable to cat predation (Dickman 1996). On offshore islands, species up to 3 kg (mammals) or 45 cm long (birds and reptiles) are also vulnerable to cat predation. Prey species are also more vulnerable to cat predation if they are nocturnal rather than diurnal. Those species that are terrestrial (ground-living) or scansorial (climbing) are more vulnerable than those that are fossorial (burrowing) or volant (flying) (Dickman 1996). The above measures are included in the decision-making tree to provide a score for the vulnerability of prey species. The ability of a prey species to defend itself against cat attack (aggression, sharp claws and teeth) was also factored into the decision-making tree (Dickman 1996).

Status of species identified at each site – The Australian Government *Environment Protection and Biodiversity Conservation Act* (1999) provided the status of each TAP-listed species, with status noted as critically endangered, endangered, vulnerable or conservation dependent. The levels of decision-making and the scores awarded at each level are shown in Table 2.

Table 2: Levels of decision-making used in the construction of a multiple-use decision-making tree

Level 1a **Level 1b**	Cat presence. Branches to either an assessment of cat control (Level 2a) or an assessment of the likelihood of feral cat invasion of the site (Level 2b). Threatened species either present or absent. Links to under options for threatened species multipliers at level 4.	Present Absent	1 0
Level 2a	Feral cat management at site where cats present.	Exclusion with active ongoing control	

	Branches to…		0
		Systematic ongoing control undertaken	1
		Systematic irregular control undertaken	2
		Incidental control undertaken	3
		No cat control undertaken	4
Level 2b	Likelihood of feral cat invasion of site: At this point sites are removed from the tree where feral cats are absent and the likelihood of invasion is nil. Remaining sites lead on to level 3.		
	Islands		
	Uninhabited, accessible only by air	Nil	0
	Uninhabited, infrequent access by boats	Low	1
	Uninhabited, frequent boat access; inhabited, pet/pest cat control	Medium	2
	Inhabited, no pet/pest cat control	High	3
	Mainland		
	Predator-proof fence, ongoing control	Nil	0
	Predator-proof fence, no ongoing control	Low	1
	No predator-proof fence, ongoing control	Medium	2
	No predator-proof fence, no ongoing control	High	3
Level 3 *******	Vulnerability of threatened species to cat predation based on a modified version of Dickman (1996). **Note**: where cat predation is on juvenile animals, use juvenile weight NOT adult weight		
	Mainland mammals (body weight)	>2000 g	0
		1001 – 2000 g	1
		220 – 1000 g	2
		< 220 g	3
	Mainland birds (body length)	> 45 cm	0
		35 – 45 cm	1
		25 – 35 cm	2
		<25 cm	3
	Island mammals (body weight)	>3000 g	0
		1001 – 3000 g	1
		220 – 1000 g	2
		< 220 g	3
	Island birds (body length)	>45 cm	0
		35 – 45 cm	1
		25 – 35 cm	2
		<25 cm	3
	Reptiles (snout-vent length)	>45 cm	0
		35 – 45 cm	1
		25 – 35 cm	2
		<25 cm	3
	Habitat use	Very dense ground cover/heath	0

		Closed forest, mangroves, swamps, caves	1
		Open forest, moderate ground cover	2
		Woodland, grassland, cultivated land, urban	3
	Behaviour	Diurnal	0
		Nocturnal or crepuscular	1
		Oceanic, aquatic, arboreal, fossorial, volant	0
		Terrestrial, scansorial	1
		Defences such as teeth, claws, aggression	0
		No defences	1
Level 4	Threatened species multiplier based on the Commonwealth *Environment Protection and Biodiversity Conservation Act* (1999) levels. **Note:** multiplier is applied only once per site and is based on the highest level present at the site.		
		Critically Endangered	4
		Endangered	3
		Vulnerable	2
		Conservation Dependant	1
		No TAP species present	0.5
*** Level 3 scores are cumulative for each threatened species present at the site			

Multiple-Use interactive decision-making tree

Using a fixed format, an interactive decision-making tree was devised using the scores in Table 2 to generate a score for each bioregion, several islands, and specific sites on the mainland based on the responses to the questionnaire and the results of personal contacts and literature searches. The interactive decision-making tree is appended to this report as a separate file.

RESULTS AND DISCUSSION

Data acquisition

Questionnaire responses

The response to the questionnaire was relatively high (60%) and the results were collated to provide data on sites where there is a known/perceived impact from feral cats on threatened species. In some regions, a combined response was received from multiple researchers (e.g., Tasmania). In combination with a literature search, the responses to the questionnaire revealed 62 specific and larger regional sites on the mainland and 26 islands where cats are, or potentially are, a significant threat. The sites varied in size from particular national parks or nature reserves (e.g., Wilson’s Promontory National Park) to entire bioregions (e.g., Channel Country). The questionnaire responses and results of the literature search are collated and shown in Appendices B1 and B2.

IBRA regions

Feral cats were recorded in all 85 IBRA bioregions (www.anra.gov.au accessed April 2009), and 76 of the 85 IBRA regions were found to support both feral cats and threatened species listed as being at risk of cat predation in TAP (2008) (McKenzie *et al.* 2007; Burbidge *et al.* 2008). No TAP-listed threatened species were recorded for nine bioregions (Table 3). The number of threatened species varied between regions, from one species (e.g., Desert Uplands Bioregion) to as many as 11 species (South Eastern Highlands). The IBRA regions and the TAP (2008) species recorded in each bioregion are shown in Appendix C. This assessment of the numbers of TAP (2008) species occurring in each bioregion and the scores for each bioregion exclude pockets of re-introduced species or captive-breeding populations. A map of the bioregions of Australia and the scores for each bioregion is shown in Figure 1.

Prioritisation of regions and sites at risk of impact from feral cats

IBRA regions

Each IBRA region where both TAP (2008) -listed threatened species and feral cats were known to occur were entered into the decision-tree analysis and scores summed for all species present. The scores for each IBRA region are shown in Table 3.

Table 3: Prioritised scores for IBRA regions and number of TAP (2008) -listed species in each region (* no TAP (2008) species)

IBRA REGION	No. of TAP species	Score
South Eastern Highlands	**11**	**328**
South East Coastal Plain	**8**	**248**
Carnarvon	**9**	**195**
Victorian Volcanic Plain	**6**	**192**

IBRA REGION	No. of TAP species	Score
Naracoorte Coastal Plain	**6**	**180**
South East Corner	**7**	**162**
Sydney Basin	**8**	**162**
Murray Darling Depression	**5**	**160**
Channel Country	**6**	**159**
Central Ranges	**7**	**150**
Victorian Midlands	**6**	**150**
Jarrah Forest	**5**	**148**
Gibson Desert	**6**	**147**
Great Sandy Desert	**6**	**141**
Esperance Plains	**6**	**135**
Flinders Lofty Block	**4**	**132**
Little Sandy Desert	**5**	**132**
Simpson Strzelecki Dunefields	**5**	**132**
Australian Alps	**5**	**126**
New England Tablelands	**5**	**126**
Brigalow Belt South	**5**	**123**
Tanami	**5**	**120**
Kanmantoo	**4**	**116**
Eyre Yorke Block	**5**	**114**
Mallee	**5**	**108**
South Eastern Queensland	**4**	**108**
Tasmanian Southern Ranges	**3**	**108**
New South Wales South Western Slopes	**4**	**105**
Flinders	**3**	**102**
Mitchell Grass Downs	**4**	**102**
Tasmanian Northern Slopes	**3**	**100**
Finke	**4**	**99**
King	**3**	**96**
MacDonnell Ranges	**4**	**96**
New South Wales North Coast	**3**	**90**
Dampierland	**3**	**84**
Great Victoria Desert	**3**	**84**
Nandewar	**3**	**84**
Tasmanian South East	**3**	**84**
Cobar Peneplain	**3**	**78**
Avon Wheatbelt	**3**	**75**
Stony Plains	**2**	**72**
Tasmanian West	**2**	**72**

IBRA REGION	No. of TAP species	Score
Swan Coastal Plain	2	63
Tasmanian Northern Midlands	2	57
Warren	2	57
Ben Lomond	2	54
Darling Riverine Plains	2	54
Wet Tropics	2	54
Cape York Peninsula	2	51
Central Mackay Coast	2	51
Burt Plain	3	46
Davenport Murchison Range	3	46
Riverina	2	46
Gascoyne	2	44
Northern Kimberley	2	44
Pilbara	2	42
Murchison	2	40
Ord Victoria Plain	2	40
Arnhem Plateau	1	39
Desert Uplands	1	39
Einasleigh Uplands	1	39
Gulf Plains	1	39
Pine Creek	1	39
Tiwi Coburg	1	39
Brigalow Belt North	2	38
Arnhem Coast	1	30
Broken Hill Complex	1	30
Central Kimberley	1	28
Tasmanian Central Highlands	1	28
Victoria Bonaparte	1	28
Yalgoo	1	26
Coolgardie	1	24
Gawler	1	24
Geraldton Sandplains	1	24
Hampton	1	24
Central Arnhem	NTS	
Daly Basin	NTS	
Darwin Coastal	NTS	
Gulf Coastal	NTS	
Gulf Falls and Uplands	NTS	
Mount Isa Inlier	NTS	

IBRA REGION	No. of TAP species	Score
Mulga Lands	**NTS**	
Nullarbor	**NTS**	
Sturt Plateau	**NTS**	

The distributions of mammal, bird, reptile and amphibian species listed in TAP (2008) as being at risk of predation from feral cats were correlated with the IBRA region databases and maps, resulting in 17 bioregions where no TAP (2008) -listed species were recorded as extant (NTS).

Specific sites

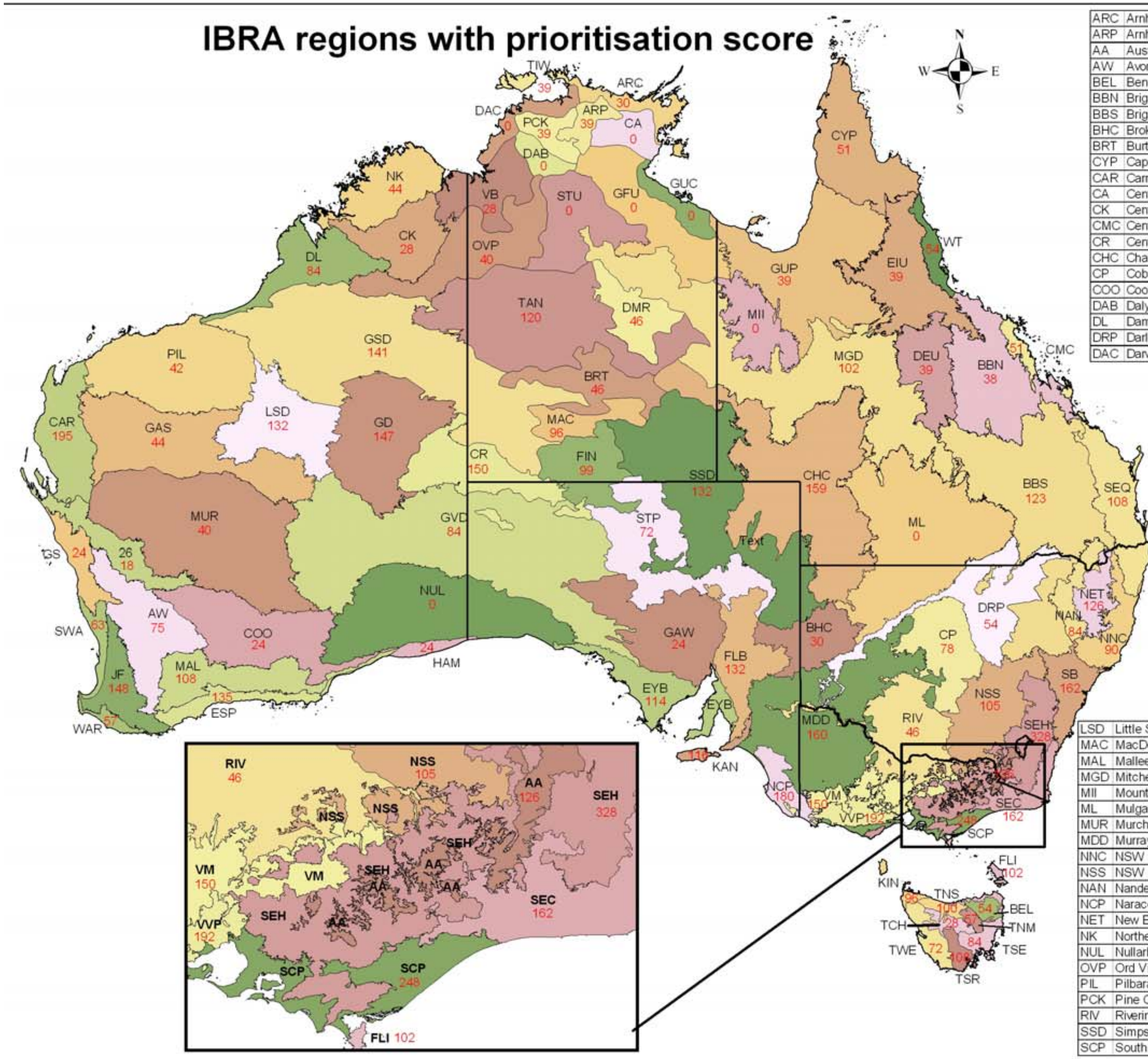
Based on the scores from the decision-making process, specific sites on both mainland Australia and offshore islands (identified by responses to the questionnaire and to literature searching) that are impacted by feral cats were identified. The results are shown in Figure 2.

The specific sites on the Australian mainland and on offshore islands impacted by feral cats were prioritised based on the scores calculated using the interactive decision-making tree. The prioritisation of these sites is shown in Table 4.

Table 4: Prioritised mainland and island sites, the states and the scores calculated from the decision-making tree

Site	State	Score
Diamantina National Park	QLD	117
East Gippsland	VIC	108
Uluru Kata Tjuta National Park	NT	105
Grampians National Park	VIC	78
Christmas Island	COM	75
Simpson Desert National Park	QLD	72
Blue Mountains National Park	NSW	66
Norfolk Island Group (Nepean Island, Phillip Is)	COM	66
Kosciuszko National Park	NSW	63
Astrebla National Park	QLD	62
Kangaroo Island	SA	57
Taunton National Park	QLD	57
Swan Island	WA	52
Maria Island	TAS	45
Bruny Island	TAS	39
Flinders Island	SA	39
Marchinbar Island	NT	39
Mount Buller Resort	VIC	39
Mount Hotham Resort	VIC	39
Mount Stirling Resort	VIC	39
South East Forests National Park	NSW	39
Tiwi Islands	NT	39

Recherche Archipelago	WA	33
Lord Howe Island (Ball's Pyramid)	NSW	32
Cocos (Keeling) Island	COM	30
Wilson's Promontory National Park	VIC	30
Jarrah Forests	WA	27
Area surrounding Arid Recovery exclosures	SA	24
Lorna Glen	WA	24
Dirk Hartog Island	WA	10



ARC	Arnhem Coast	DMR	Davenport Murchison Ranges
ARP	Arnhem Plateau	DEU	Desert Uplands
AA	Australian Alps	EIU	Einasleigh Uplands
AW	Avon Wheatbelt	ESP	Esperance Plains
BEL	Ben Lomond	EYB	Eyre Yorke Block
BBN	Brigalow Belt North	FIN	Finke
BBS	Brigalow Belt South	FLI	Flinders
BHC	Broken Hill Complex	FLB	Flinders Lofty Block
BRT	Burt Plain	GAS	Gascoyne
CYP	Cape York Peninsula	GAW	Gawler
CAR	Carnarvon	GS	Geraldton Sandplains
CA	Central Arnhem	GD	Gibson Desert
CK	Central Kimberley	GSD	Great Sandy Desert
CMC	Central Mackay Coast	GVD	Great Victoria Desert
CR	Central Ranges	GUC	Gulf Coastal
CHC	Channel Country	GFU	Gulf Fall and Uplands
CP	Cobar Peneplain	GUP	Gulf Plains
COO	Coolgardie	HAM	Hampton
DAB	Daly Basin	JF	Jarrah Forest
DL	Dampierland	KAN	Kanmantoo
DRP	Darling Riverine Plains	KIN	King
DAC	Darwin Coastal		

IBRA regions shown with prioritisation score

0 = No TAP Species present hence a score of 0

LSD	Little Sandy Desert	SEC	South East Corner
MAC	MacDonnell Ranges	SEH	South Eastern Highlands
MAL	Mallee	SEQ	South Eastern Queensland
MGD	Mitchell Grass Downs	STP	Stony Plains
MII	Mount Isa Inlier	STU	Sturt Plateau
ML	Mulga Lands	SWA	Swan Coastal Plain
MUR	Murchison	SB	Sydney Basin
MDD	Murray Darling Depression	TAN	Tanami
NNC	NSW North Coast	TCH	Tasmanian Central Highlands
NSS	NSW South Western Slopes	TNM	Tasmanian Northern Midlands
NAN	Nandewar	TNS	Tasmanian Northern Slopes
NCP	Naracoorte Coastal Plain	TSE	Tasmanian South East
NET	New England Tablelands	TSR	Tasmanian Southern Ranges
NK	Northern Kimberley	TWE	Tasmanian West
NUL	Nullarbor	TIW	Tiwi Cobourg
OVP	Ord Victoria Plain	VB	Victoria Bonaparte
PIL	Pilbara	VM	Victorian Midlands
PCK	Pine Creek	VVP	Victorian Volcanic Plain
RIV	Riverina	WAR	Warren
SSD	Simpson Strzelecki Dunefields	WT	Wet Tropics
SCP	South East Coastal Plain	YAL	Yalgoo

Data deficient sites

Several mainland sites where cats and TAP (2008) -listed species both occurred were data deficient as cat control programs were unknown. These sites were also prioritised with scores for level of cat control excluded. The prioritised list of these sites is shown in Table 5.

Table 5: Prioritised data deficient mainland and island sites, the states and the scores, calculated from the decision-making tree with the score for cat management omitted from the calculations

Data deficient site	State	Score
Tanami Desert	NT	99
Jourama Falls National Park	QLD	60
Watarrka National Park	NT	60
Nullica State Forest	NSW	39
North East State Forest	NSW	39
Fitzgerald River National Park	WA	39
Barrington Tops	NSW	39
Chaelundi National Park	NSW	39
Tinderbox Peninsula	TAS	33
Nadgee Nature Reserve	NSW	33
Mount Nelson	TAS	33
Mount Baw Baw	VIC	33
Moarinya National Park	QLD	33
Idalia National Park	QLD	33
Howden	TAS	33
Edmund Kennedy National Park	QLD	33
Coningham Peninsula	TAS	33
Booderee National Park	COM	33
Bladensburg National Park	QLD	33
Barren Grounds Nature Reserve	NSW	33
Warrambungle National Park	NSW	28
Morialta Conservation Park	SA	24
Budderoo National Park	NSW	24
Newhaven Reserve	NT	22
West McDonnell National Park	NT	16
Deep Creek Conservation Park	SA	16

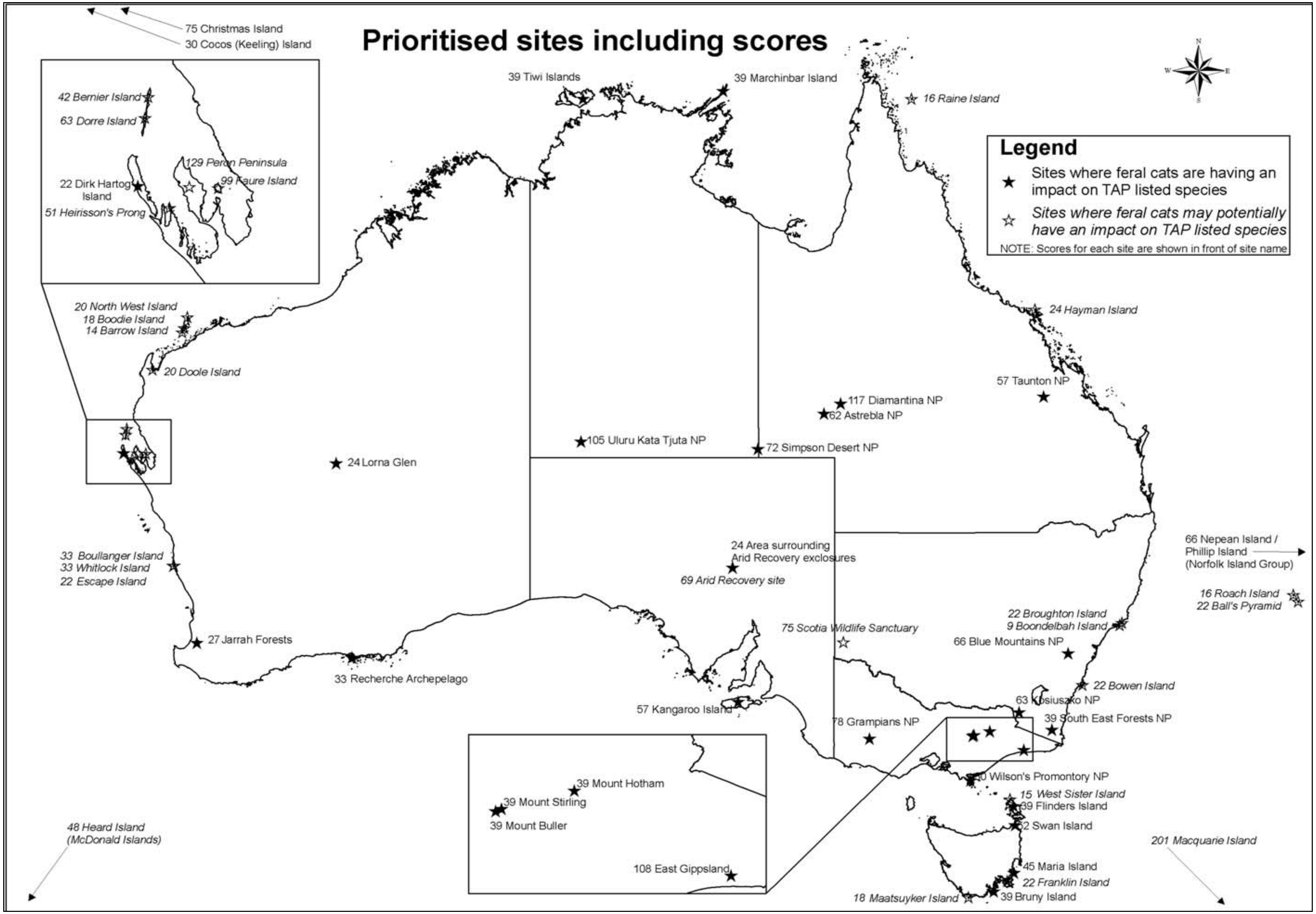
Specific sites where feral cats do not occur

Sites potentially impacted by feral cats are those sites where cats have been eradicated, or where TAP (2008) species occur and cats have not been recorded (Figure 2).

Using the decision-making tree, mainland sites and offshore islands where TAP (2008) species occur but where cats have not been recorded or have been eradicated were prioritised. The list of sites, ranked in descending order is shown in Table 6.

Table 6: Prioritised mainland and island sites that are free of cats but may potentially face invasion or re-invasion

Potential mainland and island sites	State	Score
Macquarie Island	TAS	201
Peron Peninsula	WA	129
Faure Island	WA	99
Scotia Wildlife Sanctuary	NSW	75
Arid Recovery Site	SA	69
Dorre Island	WA	63
Heirisson Prong	WA	51
Heard Island (McDonald Islands)	COM	48
Bernier Island	WA	42
Boullanger Island	WA	33
Whitlock Island	WA	33
Hayman Island	QLD	24
Ball's Pyramid	NSW	22
Bowen Island	NSW	22
Broughton Island	NSW	22
Escape Island	WA	22
Franklin Islands	SA	22
Barrow Island	WA	20
Doole Island	WA	20
North West Island	WA	20
Boodie Island	WA	18
Maatsuyker Island	TAS	18
Bishop Island	TAS	16
Raine Island	QLD	16
Roach Island	NSW	16
West Sister Island	TAS	15
Boondelbah Island	NSW	9


Prioritised sites including scores
75 Christmas Island
30 Cocos (Keeling) Island
42 Bernier Island
63 Dorre Island
129 Peron Peninsula
99 Faure Island
22 Dirk Hartog Island
51 Heirisson's Prong
39 Tiwi Islands
39 Marchinbar Island
16 Raine Island
Legend
Sites where feral cats are having an impact on TAP listed species
Sites where feral cats may potentially have an impact on TAP listed species
NOTE: Scores for each site are shown in front of site name
20 North West Island
18 Boodie Island
14 Barrow Island
20 Doole Island
24 Hayman Island
57 Taunton NP
117 Diamantina NP
62 Astrebla NP
105 Uluru Kata Tjuta NP
72 Simpson Desert NP
24 Lorna Glen
33 Boullanger Island
33 Whitlock Island
22 Escape Island
24 Area surrounding Arid Recovery exclosures
69 Arid Recovery site
66 Nepean Island / Phillip Island (Norfolk Island Group)
16 Roach Island
22 Ball's Pyramid
22 Broughton Island
9 Boondelbah Island
75 Scotia Wildlife Sanctuary
66 Blue Mountains NP
27 Jarrah Forests
33 Recherche Archepelago
22 Bowen Island
63 Kosiuszko NP
57 Kangaroo Island
39 South East Forests NP
78 Grampians NP
39 Mount Hotham
39 Mount Stirling
39 Mount Buller
108 East Gippsland
Wilson's Promontory NP
15 West Sister Island
39 Flinders Island
2 Swan Island
48 Heard Island (McDonald Islands)
201 Macquarie Island
45 Maria Island
22 Franklin Island
18 Maatsuyker Island
39 Bruny Island

Caveats and interpretations of the prioritisation analyses

Any process that reduces such complex biological phenomena as predator-prey and species-environment interactions to simple numerical scores may uncover broad patterns, but is likely also to be biased in a number of ways. Here, we attempt to identify the most important of these potential biases and consider how they may affect our results. We also review the advantages and disadvantages of using the bioregional and site-based approaches to prioritisation.

In the first instance, our list of at-risk species (TAP 2008) represents a best-guess list of native species that could be impacted by feral cats. Nonetheless, the list does not contain species such as the dusky and northern hopping-mice (*Notomys fuscus* and *N. aquilo*, respectively) or Gouldian finch (*Erythrura gouldiae*) that were identified as being at high risk of cat predation by Dickman (1996), and does not include all species from those listed under the *Environment Protection and Biodiversity Conservation* (EPBC) Act 1999 that could have been considered. For example, *Delma impar* is listed by TAP (2008), but three other vulnerable species (*Delma labialis*, *D. mitella* and *D. torquata*) are not. Of course, lists of the kind presented in TAP (2008) will always be open to debate, but inspection of the EPBC lists suggests nonetheless that species that could have been considered for potential inclusion in TAP (2008) are spread widely among bioregions. Thus, any omission of threatened species potentially at risk from cat predation should not introduce any systematic bias into our analyses, and therefore we use the TAP (2008) species lists as an agreed baseline.

Another potential bias of our approach is that it depends on a sound and commonly agreed taxonomy. If, for example, an apparently widespread species is subsequently found to be a species complex, some of the 'splinter' species may be threatened because they occupy very small ranges and could then increase the score of any site or bioregion in which they occur. In TAP (2008), and in the listings of the EPBC Act 1999, the most obvious need for taxonomic updating is with *Dasycercus* spp.; *D. hillieri* is no longer considered valid, and the genus is now believed to contain two species, *D. blythi* and *D. cristicauda* (Woolley 2005, 2006). (*Dasycercus byrnei* is usually considered to be *Dasyuroides byrnei*). However, as all members of the genus *Dasycercus*, as broadly understood, are likely to be threatened, this should have very little effect on our analyses. Our decision-making tree also can be used flexibly to accommodate any future taxonomic changes of TAP (2008) -listed species, and should thus provide an adaptable framework for managers to keep track of priority sites or regions.

A more obvious factor that can potentially bias our approach is survey effort. Limited survey effort at a site (or within a bioregion) may miss species that are there, and may require use of probability-detection techniques (e.g., MacKenzie *et al*. 2005, 2006) to estimate their likelihood of occurrence. By their nature, threatened species are particularly likely to be sparse and overlooked. It is possible, for example, that some of the bioregions listed as NTS (no TAP-listed species) in Table 3 actually do support such species, but survey effort to date has been insufficient to reveal them. We attempted to minimise this bias by using all site-based records, more general distribution maps, and other sources that were available, but acknowledge that scores for some sites or bioregions may be lower than they should be if complete species lists were available. Some of the desert and Gulf Country bioregions, in particular, may turn out to have more threatened species than we are currently aware of; if this is the case, the results will need to be run through the decision-tree to determine any new level of prioritisation that may be required.

A flip side of the under-survey bias is the effect of uncritically including old survey records when there is in fact no cause to think that a species is still extant. Inclusion of extinct species would lead to artificially high scores for sites or bioregions, elevating their apparent priority status. For example, several bioregions were noted in the mammal databases (McKenzie *et al.* 2007; Burbidge *et al.* 2008) to have once supported TAP (2008) -listed species which are now extinct in these bioregions. Thus, the dibbler (*Parantechinus apicalis*) is now extinct in the Avon Wheatbelt, Carnarvon, Eyre Yorke Block, Geraldton Sandplains, and Mallee bioregions. The numbat (*Myrmecobius fasciatus*) has likewise disappeared from most of the bioregions that it once occupied in southern Australia, persisting now only in the Jarrah Forest bioregion (Friend and Thomas 2003). Among other taxa, the night parrot (*Pezoporus occidentalis*) is the best example of a species for which there is no current evidence of persistence over most of its former range. Although listed in many bioregions on the Australian Natural Resources Atlas database, specimen records have been obtained only in the Channel Country and Mitchell Grass Downs bioregions since 1990, with perhaps two sets of credible sightings in the decades before this in Western Australia (Olsen 2009).

To avoid over-inflating scores, we omitted all species × bioregion records where species had been confirmed to be extinct. It is worth noting that, while this approach reduces prioritisation bias, and with it the possibility of improperly allocating management resources towards species that have gone, now-extinct species could be included in further analyses if there is an intention at some time in the future to reintroduce them (if still extant) from other parts of their ranges. Thus, sites or bioregions scoring highly could become targets for species reintroductions if cats were effectively controlled.

To further reduce over-inflation biases, we excluded records of species at the site or bioregional level if it appeared that the records represented incidental or vagrant individuals. Such records were most obvious for oceanic seabirds. Thus, with the exception of Gould’s petrel, which breeds on Cabbage Tree Island just off the coast of New South Wales, we could find no evidence that any of the albatross, tern or other petrel species listed in TAP (2008) have established breeding sites on the Australian mainland, and excluded them from the scoring process for bioregions and mainland sites (they were scored for island sites where they have established colonies). This approach was considered reasonable; while washed-up carcasses or occasional visits by seabirds contribute to the list of species that have been recorded at a site or in a bioregion, including them in the scoring process would help to give those areas unreasonably high priority for management. However, it is not clear that any amount of cat control would help to elevate populations of these species in these areas.

Perhaps most importantly, our decision-tree analyses do not account adequately for all the dynamics of predator-prey interactions in space and time. Building such complexity into our simple models would make them unwieldy and demand too much input information to make them viable as management tools. This aspect, instead, requires judgement calls to be made by managers at different times and places. To illustrate some of the complexities that might be expected, and also to provide guidelines to managers in what to look for, we provide several scenarios below:

- The intensity of cat predation increases after wildfire because country is opened up and hunting is made easier for marauding cats. This has been demonstrated in arid desert areas (Letnic and Dickman 2005, 2006; Letnic *et al*. 2005), and is suspected to be a causal factor in mammal declines in western Arnhem Land (Woinarski *et al*. 2009); wildfire should be seen as a factor that potentially intensifies cat predation in other habitats too.
- The intensity of cat predation increases in dry country environments after a rain-induced pulse of primary productivity has increased the prey base (often native rodents) for cats. As the pulse of productivity fades and prey species are in decline, the delayed numerical response of cats to the eruption event means that per capita predation on prey increases when prey populations are in decline (Dickman *et al*. 2010; Letnic and Dickman 2010). This can greatly exacerbate predation on species such as *Dasyuroides byrnei* (Pettigrew 1993) and *Dasycercus* spp. (Letnic and Dickman 2010). The period of most intense per capita predation will vary with rainfall, but will inevitably be in the decline phase of native rodents perhaps 1½-2 years after the initial rainfall event.
- Cats may achieve larger populations and / or greater levels of activity if released from constraints, and then will have increased impacts on prey. Constraints that are suspected include those arising from the presence of canids, primarily red foxes *Vulpes vulpes* and dingoes or wild dogs *Canis lupus* ssp. (Risbey *et al*. 2000; Letnic *et al*. 2009), but may include native carnivores such as the Tasmanian devil (*Sarcophilus harrisii*). If canid control programs are being undertaken, cat populations may benefit; in these situations, cat-impacts clearly should be monitored. In Tasmania, where *S. harrisii* populations have fallen over the last 15 years owing to facial tumour disease, anecdotal reports suggest that feral cat numbers are increasing (Saunders *et al*. 2006). Increased impacts on native species may be anticipated, and are being evaluated currently on Tasmania's east coast (B. Lazenby, personal communication).
- Feral cats may benefit from the subsidy effects of human activity and human settlement, exploiting rubbish dumps, rural enterprises and other sites where resources are freely available, as well as access tracks built into dense heath or forest habitats (May and Norton 1996; Denny *et al*. 2002; Hale 2003). Although feral cats may not always access these resources directly, resource-rich sites can act as sources to replenish their populations in less disturbed surrounding habitats, and hence act to maintain predatory pressure even when natural resource levels are low.
- Interactions may occur among any of the above scenarios (e.g., wildfire × canid control × resource enrichment), and could be expected to increase cat populations and impacts.

In these and other situations when biotic and environmental factors influence the relationship between populations of feral cats and their prey, scores for individual prey species should ideally vary, with priorities for sites and bioregions shifting accordingly. Of course, the dynamics of such complex systems are difficult to capture, especially with our current level of understanding. In lieu of constructing models that attempt to cover these dynamic aspects, we have instead opted to provide guidelines for managers about when and where to consider management interventions (see Recommendations, below).

Prioritising bioregions versus specific sites

In general terms, the results of the rank-scoring decision-tree process for the IBRA regions are most important for setting priorities for the broad-scale management of feral cats. This reflects the fact that the bioregions cover all parts of Australia and its near-shore islands, whereas the results of the site-based process are confined inevitably to smaller areas and fewer species. In addition, many of the sites that were available for inclusion in the rank-scoring process were not random inclusions, but had been selected for study or comment by individual researchers or managers because of their direct experience with them. It is highly likely that sites in less accessible areas or sites with different suites of TAP (2008) -listed species would have produced different results.

Despite the general importance of bioregions in the prioritisation process, however, the practical reality is that they are too large for cat control to be possible using current technologies. This means that specific sites assume greater importance – many are small enough that cat control can be effectively achieved and the goal of protecting TAP (2008) -listed species attained. Below, we consider the relative merits of prioritising areas at the bioregional versus site levels before making some suggestions about how the two scales of assessment should be used.

The bioregional approach

The IBRA regions used here vary greatly in area, from 4497 km^2 (Tasmanian Northern Midlands) to 385,724 km^2 (Great Victoria Desert). In consequence, they contain different numbers of native species that may be at risk of predation by feral cats (0 – 11) and have also been surveyed with very different levels of intensity. Many more TAP (2008) -listed species would be expected to occur in large bioregional areas than at specific sites, and it is no surprise that prioritisation scores for some bioregions are much greater than the highest scores achieved by any specific sites (cf. Tables 3, 4 and 6). However, it would be misleading to compare the raw total scores directly. In the first instance there would be few if any sites in any bioregion where all TAP (2008) -listed species occur together. In the Sydney Basin bioregion, for example, Gould's petrel (*Pterodroma leucoptera leucoptera*) is the only TAP (2008) -listed species that occurs on Cabbage Tree Island; broad-headed snakes (*Hoplocephalus bungaroides*) can be found primarily just in sandstone escarpment country; and green and golden bell frogs (*Litoria aurea*) occur alone at a scattering of primarily coastal localities. Secondly, many species are listed as present in bioregions when in fact their presence there is marginal. The kowari (*Dasyuroides byrnei*), for example, just creeps into the Mitchell Grass Downs bioregion, but its stronghold is further south in the Channel Country. It is not clear that the conservation status of the kowari would be greatly enhanced by controlling feral cats in Mitchell grass areas, although other species, with more extensive distributions in this bioregion, may well benefit.

Despite such problems, the use of broad bioregional areas to identify where feral cats potentially have strong impacts on threatened native fauna should be reasonably robust. Indeed, comparisons of our results with the conclusions of Dickman (1996) suggest that several broad areas have been identified in common, despite differences in the lists of threatened species and definitions of regional areas used in the two studies. Thus, Dickman (1996) identified coastal Victoria among his list of eight priority areas for feral cat research and control, coinciding with high scores for the South East Coastal Plain, South East Corner and Victorian Volcanic Plain bioregions here (Table 3). The Channel Country bioregion was rated highly in both analyses, with other arid regions generally achieving more moderate ranks. There are, nonetheless, some discrepancies. Some of these are likely to be more apparent than real. For example, Dickman (1996) considered Tasmania to be a priority area, but no individual Tasmanian bioregions in our present analyses scored very highly. However, if species are grouped across all bioregions in the Apple Isle, approximating the area considered by Dickman (1996), the score increases to 160 and leaps many places in the priority list. If the several bioregions in the south-western corner of Australia are combined in the same way to approximate the area covered by Dickman (1996), the nine species that occur there yield a high score of 244.

The greatest discrepancy is the high prioritisation given to the South Eastern Highlands in our current analyses and the lack of prominence given to it by Dickman (1996). This appears to arise for three main reasons. Firstly, survey work has recently reported species such as the southern brown bandicoot (*Isoodon obesulus*) to be present; secondly, species such as the smoky mouse (*Pseudomys fumeus*) have been added to the lists of the EPBC Act 1999 since 1996; and thirdly, frogs were assessed as part of the prioritisation process here (three TAP-listed species occur in the Australian Alps) but not by Dickman (1996). Taken together, we conclude that the bioregional approach produces generally repeatable and defensible results that allow reliable prioritisation of regions to target for cat management and control.

The site-level approach

The 30 sites identified in Table 4 as places where TAP (2008) -listed species are impacted by feral cats are widely scattered throughout mainland Australia and both its offshore and oceanic island territories. The list reflects the first hand experience of many individual managers and researchers, as well as their expert opinions about where cats are likely to be most problematic. Islands feature prominently, as do both remote areas (e.g., Diamantina and Simpson Desert National Parks) and more settled sites. For example, three ski resorts in the Victorian alpine region were nominated. Despite the close proximity of these latter sites, we have chosen to keep them separate here as they are subject to different cat control programs. It is likely that other specific sites could be identified after appropriate surveys.

The site-based scores are generally much lower than those in Table 3 and, as noted, reflect just the TAP (2008) -listed species that occur in the particular sites rather than all those in the surrounding bioregion. For this reason the two sets of scores are not directly comparable. However, the scores can be compared geographically, and here there is quite considerable congruence. For example, the high ranking East Gippsland site falls within the high ranking South East Corner bioregion, as does Diamantina National Park within the high ranking Channel Country bioregion. Other moderately high ranking sites in the Blue Mountains National Park and Kosciuszko National Park reflect the moderately high rankings of their respective bioregions, as do the ranks of the several arid sites with their bioregions. There are, inevitably, exceptions, such as the apparently low scores for the jarrah forest sites and areas surrounding the Arid Recovery exclosures in South Australia, but overall the level of congruence in rank scores for sites that can be matched with bioregions appears to be quite high.

The island sites identified in Table 4 generally score more poorly than mainland sites, and, for those islands that are close to Tasmania or mainland Australia, score lower than the mainland areas of their adjacent bioregions. To some extent this might be expected because island faunas are always more depauperate than neighbouring mainland areas, but in Table 4 some scores are likely to be lower than they should be because cats have already removed some species. Dirk Hartog Island is the best example. Located off the coast of Shark Bay in Western Australia, both the burrowing bettong (*Bettongia lesueur*) and possibly the banded hare-wallaby (*Lagostrophus fasciatus*) disappeared in the presence of cats, and another eight island relict species known only from sub-fossil material may also have succumbed (Burbidge and George 1978; Baynes 1990). Dickman (1996) listed a further 13 islands off the Australian coast and in Bass Strait where native vertebrates had declined or disappeared in the presence of cats; all would be potential sites for cat control or eradication, and sites for potential reintroductions of native species.

In addition to the 30 sites listed in Table 4, another 26 sites were identified by respondents and via the literature as having feral cats and TAP (2008) -listed species, but with uncertain levels of cat control being carried out. Given that no targeted programs of cat control could be identified at these sites, we suggest that the precautionary principle should prevail and that any cat control that is carried out be assumed to be sporadic or otherwise ineffective. This allows the sites in Table 5 to be viewed in exactly the same way as those in Table 4, with the score for each site indicating its rank in the prioritisation process. Comments made about the sites in Table 4 with respect to their geographical distributions and rank associations with their respective bioregions appear to apply more or less equally to the sites in Table 5.

In Table 6 we have listed sites where cats do not occur and the rank scores of TAP (2008) -listed species that are present. Most sites are islands to which cats have not been introduced, but Macquarie Island is exceptional in that cats have recently and successfully been exterminated (see Bergstrom *et al*. 2009 for review). Cats have also been removed from mainland sites at Peron Peninsula and Heirisson Prong in Western Australia, the Arid Recovery site in South Australia, and Scotia Sanctuary in New South Wales, and are kept out on a continuing basis by exclusion fencing. Some of the island sites are close to each other, such as Boullanger, Escape and Whitlock Islands, Barrow, Boodie and North West Islands and Bernier and Dorre Islands, and could be considered potentially as island groups for the purposes of management. Although some differences in faunal composition lead to differences in rank scores in some cases, the close island groups are characterised by strong nestedness (Patterson 1987) so that the highest score for any island within a group can be taken approximately as the score that all islands would receive if they were grouped together. We have left these adjacent island groups separate in Table 6 as they are still separated by sea channels that would slow or prevent the dispersal of feral cats from one island to another, but note the possibility that island clusters could be viewed as management units.

Synthesis and suggestions for prioritisation

The above discussion suggests that the ideal scale for prioritising areas for the control of feral cats is bioregional, but also that this ideal will not be achievable until effective, broad-scale techniques of cat control become available. Achieving bioregional control should serve as a beacon to guide future research; for now, we discuss below both the traditional and emerging control techniques that are available. In the absence of any ability to control feral cats over very large areas, our prioritised lists of specific sites – using the combined lists in Tables 4 and 5, should be used as the best guide to where control efforts should be allocated. The broad correspondence in rankings between these sites and the bioregions that contain them indicate that this should be an effective and efficient approach. At the same time, it must be acknowledged that other possible sites would likely benefit from cat control, so that surveys across the bioregions – in priority order – should be carried out to identify additional important sites that would benefit from cat control. There are several islands where native species disappeared following the arrival of cats. Although cat control on these islands could allow some native species to be reintroduced, we suggest that cat control on these islands be given lower priority than islands and other sites where native TAP (2008) -listed species still occur. The first priority should be that still-extant native species be conserved. Finally, for sites that are currently cat-free, our rank list indicates the priority that should be attached to appropriate monitoring. This issue is taken up further below, as is a review of the control efforts that are being made currently at sites with both TAP (2008) -listed species and feral cats.

Options for eradication of feral cats

The cat occupies the rare status of being both a pest species that can impact significantly on native species and a much-loved household pet (Dickman 1996). There is often no sharp delineation between domestic, stray and feral cats, with cats moving between categories depending on their individual circumstances (Moodie 1995). As a result, there is a large potential source population for feral cats within existing populations of domestic and stray cats. Dumping of unwanted kittens and adult cats by irresponsible pet owners is part of this larger problem (Environment Protection Authority 2003), and it is compounded by the dispersal of stray cats from highly modified, resource-rich sites into surrounding habitats (Denny 2005).

While the eradication of feral cats would remove the impact that they have on native species and give the benefit of not having to undertake additional or on-going control actions, eradication is an unrealistic expectation for mainland Australia. Feral cats are not only established across the Australian mainland, but as noted there may be continual recruitment of feral cats from the domestic / stray cat source population (Denny 2005).

Bomford and O’Brien (1995) list six criteria for eradication:
1. The rate of removal exceeds the rate of increase at all population densities;
2. There must be no immigration of new animals;
3. All reproductive animals must be at risk;

4. Animals can be detected at low densities;
5. Cost/benefit analysis favours eradication over control; and
6. Suitable socio-political environment.

The eradication of feral cats is possible on islands where self re-colonisation is not possible, or from areas on the mainland protected by exclosures with on-going monitoring and control to prevent re-invasion. Examples of this are Arid Recovery at Roxby Downs in South Australia (Moseby *et al.* 2009), Macquarie Island in Tasmania (Bergstrom *et al.* 2009) and Heirisson Prong in Western Australia (Risbey *et al.* 2000).

Eradication on islands or within predator-proof exclosures may be undertaken using a combination of techniques such as poison baiting, trapping, shooting and the use of tracking dogs (e.g., Macquarie Island). As feral cats are not normally social animals, the use of Judas animal techniques (McIlroy and Gifford 1997) is precluded.

Cat eradication also may release other species such as rats and rabbits that impact on threatened species as much as, or more than, the cats themselves (Courchamp *et al.* 1999; Scott and Kirkpatrick 2008). Feral cat control programs, particularly those where introduced prey species are present, should identify all introduced species and their possible impacts on the biodiversity following cat control. In order to minimise this mesopredator release effect, concurrent control programs for both feral cats and their introduced prey species should be considered (Denny and Dickman 2010).

A review of pest animal control programs by Reddiex *et al.* (2006) found that there were five common techniques employed for controlling feral cats. The most common technique was trapping, followed by ground shooting, then poison baiting. The most commonly used traps were either soft jaw traps (where not prohibited by legislation) or cage traps. Regardless of the technique employed for the control of feral cats, it must be undertaken in a humane manner to minimise stress and suffering by the feral cat (Sharp and Saunders 2004a).

Shooting - ground shooting is one of the most commonly employed techniques for the control of feral cats (Reddiex *et al.* 2006), and is usually undertaken at night with the aid of a spotlight. Shooting undertaken by competent, qualified and responsible shooters is a humane method for controlling feral cats (Sharp and Saunders 2004b), although it is also time- and labour-expensive. Shooting is a target-specific technique as only the target animal is fired at by the shooter.

Poisoning - at present, poisoning is restricted to the use of sodium monofluoroacetate (1080) in either meat or processed baits. Aerial baiting with Eradicat® injected with 1080 occurs in selected areas in Western Australia. As 1080 compounds are produced naturally in some Western Australian plant species, many of the native animals have some evolutionary tolerance to the poison (Twigg and King 1991). Many eutherians, including cats, do not have this tolerance and thus poisoned baits may be surface-laid without significantly affecting native animal populations (McIlroy 1981; Calver *et al.* 1989; Eason and Frampton 1991). This tolerance to 1080 does not exist to the same extent in the eastern states, and here 1080 baits must be buried to prevent impacts on non-target species (Department of the Environment Water Heritage and the Arts

2008). As cats will not exhume baits, buried baits are not effective in a feral cat control programs (Seebeck and Clunie 1997; Denny and Dickman 2010).

The Western Australian Department of Environment and Conservation has developed the Eradicat® bait substrate for use with cats (Burrows *et al.* 2003; Algar and Burrows 2004). It is a sausage-like soft meat bait containing kangaroo meat, chicken fat and flavour enhancers (Marks *et al.* 2006; Algar *et al.* 2007) and injected with 4.5 mg of 1080 per bait. The Eradicat® bait is used extensively in feral cat control through aerial baiting in Western Australia (Algar and Burrows 2004).

The Eradicat® bait is not target-specific, with native carnivores and omnivores such as foxes, large lizards and corvids taking the baits (Algar and Burrows 2004, Denny 2009a). In order to minimise the uptake of the toxicant by non-target species, research is underway to test the encapsulation of the toxicant in small hard capsules that dissolve in the cat's stomach, releasing the toxicant (Hetherington *et al.* 2007). As cat dentition is not suited to extensive chewing of food items, cats have a tendency to swallow large portions of food. Conversely, native dasyurids chew and comminute food items to a greater extent, increasing the likelihood of encountering and rejecting the hard capsule. Pellet rejection by many native species has increased the target specificity of the encapsulated toxicant in the Eradicat® bait (Hetherington *et al.* 2007).

Feral cats usually do not scavenge for food so will usually take baits only during periods of low prey abundance when they are food stressed (Molsher *et al*. 1999; Algar *et al.* 2007). These periods may be during winter when prey abundance is low, or during population declines following boom periods in low rainfall areas (Letnic and Dickman 2010). Targeting baiting campaigns towards periods when feral cats are food stressed may increase bait uptake and the effectiveness of the baiting program.

There is increasing public aversion to the use of 1080 for pest animal control as it is perceived to be inhumane due to the uncontrolled running, paddling and vomiting that can occur in the early stages of toxicosis (Marks *et al.* 2000). A synthetic toxicant, para-aminopropiophenone (PAPP, see Savarie *et al.* 1983), is now being trialled for use with feral cats Marks *et al.* (2004). PAPP is a methaemoglobin-forming compound that inhibits the ability of the blood to carry oxygen and, at sufficient concentrations, produces anoxia (Marks *et al.* 2004). Unlike 1080, an antidote is available to reverse the effects of PAPP toxicosis. Susceptibility to PAPP toxicosis varies widely between genera (Murphy *et al*. 2007), and field and pen trials are now underway to determine the susceptibility of non-target species to the toxicant. However, to date no data on the susceptibility of Australian native animals to PAPP have been published.

In order to overcome some of the difficulties of using 1080 as a surface-laid toxicant, the Curiosity® feral cat bait has been developed as a joint program between the Australian Government, Victorian and Western Australian conservation agencies for use in feral cat control programs (Johnston *et al.* 2008; Johnston *et al.* 2009). The bait consists of a pellet of encapsulated PAPP enclosed in an Eradicat® bait substrate. The encapsulation of the PAPP in a hard capsule reduces the likelihood of non-target species encountering the toxicant if they consume the bait substrate. In 2008 a successful field trial of the Curiosity® bait was undertaken on French Island (Johnston *et al.* 2008) and a limited trial was undertaken on Christmas Island (Johnston *et al.* 2009).

Investigations into the species most likely to take Curiosity® feral cat bait with a prototype capsule containing a ball bearing as a marker have been conducted in the semi-arid zone of New South Wales and on Kangaroo Island off the South Australian coast. In both these situations, most baits were taken by non-target species such as corvids, large lizards and possums (Denny 2009a and b). These uptake results agree with those reported for the uptake of Eradicat® baits reported by Algar and Burrows (2004). Taken together, these observations suggest that there may be merit in the use of targeted baits for feral cats, but also that more research is needed to identify and reduce the impacts of different baits on non-target species.

Trapping - trapping of feral cats is usually undertaken with either soft jaw (sometimes called padded-jaw or rubber-jaw) traps or cage-type traps (Sharp and Saunders 2004c; Sharp and Saunders 2004d). Using traps, particularly cage traps, allows non-target species to be released quickly. The use of steel jaw traps has been banned in all states/territories of Australia for feral cats as soft jaw traps are more humane, are just as effective at restraining animals, and have fewer impacts on non-target species. Some states, for example Victoria, do not allow the use of soft jaw traps for trapping cats on crown land.

The effectiveness of cage traps for feral cats is variable. Sharp and Saunders (2004d) stated that cage traps are a relatively ineffective tool for capturing feral cats away from urban or residential areas as cats are naturally wary animals and may not enter the confined area of a cage trap as it is too different from their natural surroundings. However, Molsher (2001) found no significant difference in capture efficiency between cage and leg-hold traps while trapping in woodland areas at Burrendong in New South Wales. Cage traps have been used most successfully in highly modified habitats such as farmland and rural rubbish tips (Denny *et al.* 2002). The recommended method for despatching captured cats quickly and humanely is by a single shot to the brain (Sharp and Saunders 2004a).

Exclusion fencing - this is employed where large areas are cleared of feral mammalian pests and predator-proof fences are constructed to prevent re-invasion. Exclusion fencing is expensive (Moseby and Read 2006; Department of the Environment Water Heritage and the Arts 2008) and must be regularly maintained and monitored to prevent breaches by feral cats. Even with continual maintenance and monitoring, however, breaches of exclusion fencing can occur (Saunders *et al.* 1995). On the Australian mainland, eradication of feral cats has been restricted to predator-proof exclosures.

Public Perceptions

Recently there has been an increase in awareness that factors other than simply the effectiveness of a given method of killing cats can influence the success or failure of a control program. One such factor, and probably the key one, is the human dimension. Public and cultural issues impact on any control program, and must be taken into account when designing and implementing feral cat control programs. Community surveys indicate that feral cats are perceived as a significant threat to native wildlife and most surveys show a high level of support for controlling feral cat populations (Johnston and Marks 1997; Finch and Baxter 2005). However, high levels of affection for cats and a lack of empirical knowledge by people of their actual impacts have restricted the ability of various statutory authorities to manage feral cats effectively (Dickman 2009). There may even be a small segment of the population that believes, erroneously, that feral and domestic cats are different species. This view was put by a small number of respondents to an earlier review of the impacts of feral cats in Australia (Dickman 1996), and perhaps flows from the common but again erroneous belief that feral cats are much larger than (and thus different from) their domestic counterparts. Despite the wealth of published and otherwise peer-reviewed information that dispels these myths (Dickman 1996, 2009; Abbott 2002; Denny 2005; Driscoll *et al*. 2007), their persistence in the public mind illustrates the need for care to be taken when devising programs to control feral cats.

As feral animals have been present in Australia for well over a century, some Aboriginal people now see these animals as belonging to the land rather than as interlopers. The feral cat is no exception to this. In many communities feral cats are seen as an important food source in the absence of traditionally-hunted native species, even to the point where the cat has been attributed medicinal qualities (e.g., Burbidge *et al*. 1988). In other communities, feral cats have a Dreaming and as a result have been incorporated into Aboriginal law and are now seen as part of the natural environment (Rose 1995). Not all Indigenous communities are likely to share the same benign view of cats and, especially in the period soon after the arrival of this predatory new invader, may sometimes have been inclined to view them with considerable suspicion (Duncan-Kemp 1933). Irrespective, it is clear that any feral cat control program occurring on Aboriginal land would need to take into account the perceptions and beliefs of the local Indigenous people during both design and implementation phases.

Strategic pest management for feral cats

In the past, most pest animal control programs were directed towards a single species and conducted on an *ad hoc* basis with little monitoring of the impacts. More recently, there has been a change in pest management towards a more strategic approach (Braysher 1993; Olsen 1998). Strategic pest management strategies have been adopted for nearly all major pests in Australia (e.g., Dobbie *et al.* 1993; Saunders *et al.* 1995; Williams *et al.* 1995; Choquenot *et al*. 1996; Caughley *et al*. 1998). Part of strategic pest management is the involvement of all key stakeholders in the planning of the control program, including animal welfare groups, surrounding land holders and other groups with a key interest in the land or pest. For example, Aboriginal peoples have ownership or key interests in large areas of the Australian mainland and, in some cases, use feral cats as a food resource or incorporate them into local spirituality and law (Rose 1995). Any control actions taken in these areas would require input from the local Aboriginal people.

Additionally, a strategic approach to pest management follows a methodological approach based on reducing the damage that a pest is doing to acceptable levels rather than concentrating solely on the number of pest animals present (Hone 2007). By setting specific and timed objectives for a control program and monitoring changes in the level of damage, managers have the opportunity to modify the management or control plan as needed to ensure that the desired objectives are achieved (Braysher 1993; Olsen 1998). For feral cats, this requires monitoring the impacts of cats rather than the numbers of cats present. Of the 103 cat control programs surveyed by Reddiex *et al.* (2006), only eight monitored native species. In the light of these findings, adopting a strategic approach to feral cat management will require a change in the current paradigm of feral cat management in many areas.

Assessing the impact of feral cats

Evaluation of the impacts of feral cats prior to the decision to undertake a control program is an essential part of any management plan. Unfortunately, much of the information available on the impacts of feral cats is anecdotal, with few studies having been conducted that measure the level of actual impact (Dickman 2009). While feral cats may be the cause of a given impact, relying on anecdotal evidence alone may result in misdirected recovery efforts for threatened species. A corollary to this is that when a species is in severe decline, action should be taken to attempt to halt that decline while the agent of decline is in the process of being fully identified. Most feral cat control programs (as opposed to eradication programs) gauge success based on a reduction in an index of feral cat abundance with few programs focussing on a reduction, or measuring changes in, the impacts that feral cats are having on the species the programs are designed to protect.

Unless there is a known relationship between the number of feral cats and the impact they are having, measuring changes in abundance of feral cats may not provide an accurate indication of the success or otherwise of the control program. For example, a single cat at each of the two re-introduction sites for *Lagorchestes hirsutus* (rufous hare-wallaby, or mala) appeared to be responsible for all the predation events at each site. Removal of these two individuals resulted in the cessation of deaths from feral cat predation (Gibson *et al.* 1994). Removal of any number of other feral cats would have had little or no effect on reducing predation on *L. hirsutus*. Direct observations of hunting feral cats by Dickman (2009) confirm that different individuals often exhibit different hunting tactics and specialise in catching different categories of prey – birds, small mammals or lizards. It is becoming increasingly clear that populations of many vertebrate species are comprised of individuals with varied ‘personality types’ that may differ in foraging behaviour, habitat use, levels of aggressive behaviour and other attributes (Biro and Stamps 2008; Biro and Dingemanse 2009). Individual differences in the hunting behaviour of feral cats may complicate the already-difficult task of defining density-impact relationships, but will be important to understand if the impacts of cats on target species are to be effectively reduced.

Monitoring feral cats

Evaluating the success of any cat control program requires an effective program of monitoring. However, many feral cat control programs that rely on measuring success by using a reduction in feral cat abundance are hampered by the lack of a reliable technique for assessing the change in feral cat abundance accurately (Robley *et al.* 2004). Due to the cryptic nature of feral cats, most techniques employed to date rely on indices such as track counts on sandpads. Such measures provide, at best, an index of activity rather than abundance unless there is a known relationship between the number of detections and the abundance of cats (Algar and Burrows 2004). Robley *et* *al.* (2008) modelled detection rates for a number of techniques used for assessing the abundance of feral cats and found that, with a grid of 49 remote cameras with a 1 km spacing, changes in abundance of feral cats may be able to be detected. However, this result should be interpreted with caution because of the small sample size of cats (4) detected during the experiment; it is also noted that this research is still ongoing (Robley *et al.* 2008).

Apart from complete eradication, there is no universally accepted level to which feral cat density needs to be reduced to minimise the impact that feral cats have on native animals. The degree of cat density reduction that would minimise impact on native species is likely to vary between seasons, between different habitats, between prey species and also with the mix of 'personality types' in the cat population. Monitoring native prey populations is the only reliable indicator of the success or otherwise of any cat control program and must be interpreted with reference to other factors such as habitat modifications, climatic events, and abundance and impacts of other predators, both native and exotic. Dickman (1996) has outlined some monitoring and experimental protocols that could be implemented to reliably determine the effects of cat control programs.

Cat management and regulatory controls

No one authority controls all the sites that are identified in this report. Control of the sites varies between the Australian Government, state/territory authorities and privately owned or funded sites. While feral cat control for nature conservation is the common goal at each of these sites, there are marked differences in the legislation and rules that govern the sites in relation to available control methods.

The type of control technique that is available to be used at individual sites is governed also by the resources, both financial and material, that are available to the individual organisations. Most of the organisations responsible for the control of the identified sites are conducting feral cat programs within the limits of their available resources.

Most National Parks, Australian Wildlife Conservancy sanctuaries and State Forests agencies have *ad hoc* cat control programs where Pest Control Officers trap, shoot or bait feral cats opportunistically. However, regular detection and shooting of cats on reserved land requires night work, as cats are more crepuscular and nocturnal than diurnal. Frequently, the working regulations of Pest Control Officers do not allow for regular shooting activities outside of normal, diurnal working hours. In New South Wales and Victoria, recreational shooters are permitted to hunt introduced pests in state forests. This approach, however, is controversial, and larger prey, such as pigs, deer and foxes, are more likely to be targeted than the smaller, cryptic feral cat.

Cross tenure or nil tenure pest control programs have been introduced at several sites for the control of other pest species such as wild dogs and foxes (Hunt and Brindabella and Wee Jasper Valley Wild Dog/Fox Working Group 2002). These management programs recognise that the pest problem is not restricted to any particular land tenure and each land manager works with the other for a common goal of pest control across all land tenures. The Brindabella / Wee Jasper cooperative wild dog / fox control plan has successfully reduced the impact of wild dogs and foxes across multiple land tenures by 75% since its implementation (Department of Environment, Climate Change and Water 2009). Few feral cat control programs operate across multiple tenures, allowing reinvasion of feral cats from surrounding areas where no control efforts are employed. A possible cause for this is that feral cats have little, if any, impact on agricultural production; this results in no incentive for surrounding land holders to control feral cats. Additionally some land holders believe that having stray / feral cats on the property is beneficial to rodent control (Hamilton *et al.* 2006).

Control programs at identified sites

Responses from the survey of cat researchers and land managers revealed wide variety in both the level of control action taken and in the techniques employed. Control techniques ranged from exclusion fencing with on-going monitoring and control of feral cats in the surrounding area to *ad hoc* trapping or shooting (Table 7).

Table 7: Feral cat control programs at sites identified where feral cats pose or potentially pose a significant risk to native species

Site	State	Feral cat control programs	Feral cat monitoring
Desert Channels Queensland	QLD	Bounty system (non-ongoing)	Nil
Arid Recovery	SA	Exclusion fencing, ongoing monitoring with control in surrounding areas	
Kosciuszko NP	NSW	Trapping in limited areas	
South East Forests NP	NSW	Intermittent trapping	Limited sand pads
Alpine National Park	VIC	Trapping in limited areas	
Wilsons Promontory NP	VIC	Intermittent trapping	
Grampians NP	VIC	Nil	Sand pads
Christmas Island NP	COM	Trial of Curiosity® cat bait (non-ongoing)	
Dirk Hartog Island	WA	Trial of eradication techniques on 1/3 of island (non-ongoing)	
Lorna Glen	WA	Aerial baiting with Eradicat® cat bait	
Calvert Ranges	WA	Aerial baiting with Eradicat® cat bait	
Peron Peninsula	WA	Aerial baiting with Eradicat® cat bait	
Karara	WA	Aerial baiting with Eradicat® cat bait	
Mt Buller / Mt Stirling ski resorts	VIC	Annual shooting with regular trapping	
French Island NP	VIC	Annual trapping program plus additional trapping as needed.	
Kinglake NP	VIC	Shooting following fires of February 2009 (non-ongoing)	
Mt Hotham ski resort	VIC	Occasional trapping	
Kakadu NP	NT	Relocation of species to predator-free offshore islands and future trials to determine causes of decline in small- and medium-sized mammals	
Norfolk Island NP	COM	Monthly trapping program for 1 week per month with additional trapping following cat sightings	
Uluru / Kata-Tjuta NP	NT	On-going cat trapping	
Monte Bello Islands	WA	Cats eradicated	
Rottnest Island	WA	Cats eradicated	
Garden Island	WA	Cats eradicated	
Tasman Island	TAS	Currently nil but listed for future eradication	
Lakefield NP	VIC	Trial of Curiosity® cat bait (non-ongoing)	

Regional cat eradication and control programs

In 2009, as in previous years, cat eradication operations were confined to offshore islands or predator-proof fenced exclosures on the mainland, although several conservation-focused agencies conducted programs of systematic/incidental cat control at sites were cat impacts on threatened species were known or suspected. Cat eradication has been possible on offshore islands and the necessity for multiple-species eradication/control programs has been recognised. On the mainland, the probability of re-invasion of cats is high, with a constant source of cats being available to disperse from either the domestic, semi-feral or feral populations at sites relatively close to human habitation.

In contrast, few regional cat control programs were identified in this review, with most control efforts being site-specific. In most cases the land surrounding the specific cat-control sites was under different ownership or land tenure, making it difficult or impossible for the control program to be extended.

The large scale or regional control programs identified in this project were:

- Arid Recovery – this program undertakes on-going feral cat control around predator-proof exclosures but cannot eradicate or effectively control feral cats in the surrounding areas. Feral cat densities in the surrounding area are estimated to be only 1 cat km^{-2}; despite this, however, this level is not low enough to prevent the killing of adult and juvenile bilbies and bettongs by cats.
- The Western Australian Department of Conservation and Environment – the department undertakes a number of annual aerial baiting campaigns for feral cat control. These baiting campaigns use the Eradicat® bait injected with 4.5mg 1080 and cover areas up to 2000 km^2 (200 000 ha) (Algar and Burrows 2004).
- A cat bounty instigated by Desert Channels Queensland – this bounty system was trialled for 8 months from November 2008 to June 2009 and involved only licensed kangaroo shooters. No data are available yet on the effectiveness of the program.

Of the above programs, the most innovative – in the sense that no other jurisdiction has tried it – was the trial of the feral cat bounty by Desert Channels Queensland. In this scheme, a bounty was paid to professional kangaroo shooters for feral cats. The shooters had to supply evidence of the numbers of cats shot and provide the locations of where the cats were shot. While no data are available as to the effectiveness of this bounty system, it is unlikely that bounty hunting would eradicate all cats in the area. Bounty programs are not supported or recommended by the Australian Government as they may be subject to fraud; they may not necessarily target those animals that are causing the greatest impact; and they are not usually successful at reducing pest animal abundance as a rate sufficient to have an impact on the population (Hassall and Associates Pty Ltd 1998; Wilson 2008). Nonetheless, the predominantly open landscapes of the Desert Channels region and the tendency for cats to congregate in the drainage systems rather than in the open gibbers (Robin and Dickman 2010) may mean that the program could achieve higher levels of success than in other land systems with structurally more complex environments.

Control and monitoring options

Making site-specific recommendations for feral cat control and monitoring programs is difficult as there is no single formula to apply. Solutions for each site must be based on the required outcomes of the control program and on the legislation that is applicable to each site. Each state/territory has different legislation regarding both feral and domestic cats, and the legislation can be difficult to enforce and requires public acceptance of the necessity of such legislation (Grayson *et al.* 2002; Greenaway 2009).

The implementation of uniform feral cat control programs across the Australian mainland is complex because:

a. at present there is no consistent legislation for the control of feral cats across all jurisdictions;

b. there are few empirical data on the actual impacts of feral cats on any species of threatened vertebrates at the population level;

c. there are few data on the relative abundance of cats throughout the Australian mainland because:
    - i) cat densities may vary in relation to the season of the year, climatic events such as droughts and floods, and the availability of food sources such as rodents and rabbits (Jones and Coman 1982; Newsome 1991); and
    - ii) the detection of cats can vary between habitats and there is no single universally employed methodology for detecting cats or assessing cat densities (Robley *et al.* 2008);

d. feral cats are not universally viewed as a pest animal, with some Indigenous communities utilising them as a food source or having accepted them into Aboriginal law ; and

e. there is an ongoing source of cats into the feral population from the domestic and semi-feral populations (Denny 2005). Hence, long term success in controlling feral cat populations is likely to be greater if domestic source populations are better managed.

Factors determining the initiation of control programs, the control methods used and the resources expended include: habitat characteristics; presence/absence of introduced prey species; the availability of supplementary food sources; presence/absence of other vertebrate predators; and the proximity of cat colonies exploiting highly modified habitats such as rubbish tips to conservation reserves supporting populations of threatened species.

CONCLUSIONS

Cat control on the Australian mainland is a long-term, multi-faceted, labour- and resource-intensive venture requiring site-specific control methods that provide systematic and ongoing downward pressure on feral cat populations. The status of the cat as a pet and pest species, the flexibility of the species' population dynamics, its mobility, and ability to exploit a variety of habitats including habitats highly modified by humans, together suggest that control rather than eradication of feral cats on the mainland is, at present, the most feasible scenario. Feral cat control is intimately associated with controlling recruitment from both the stray and owned domestic cat populations.

Feral cat eradication is currently possible only on offshore islands or inside predator-proof fenced exclosures on the mainland. The size of the fenced area is currently a limiting factor to the probability of eradication, as are the resources that can be directed toward the eradication effort. Continued reclamation of islands through feral pest eradication will provide further sanctuaries for endemic threatened species, as well as for the release of mainland species threatened by predation, habitat modification and disease. Although time- and labour-intensive and expensive to maintain, mainland exclosures provide, at present, the only means of protecting threatened species from cat (and fox) predation (Moseby *et al*. 2009).

There is no single, robust method for estimating cat densities, although cat presence/absence may be determined from indirect detection methods such as tracks, scats, kills, remote photography and hair sampling.

The actual level of impact by cats on native animals at the species level is still largely unquantified. The impacts of cats on islands and at sites where reintroductions of threatened species have occurred have been much better documented (e.g., Burbidge and Manly 2002; Morris *et al.* 2004).

As with most introduced mammalian pests in Australia, human activities such as urban and rural development, agriculture and habitat modification, favour the establishment and maintenance of feral cats. A 'nil tenure' approach to cat control, with control activities encompassing public and privately owned reserved land as well as adjacent urban, rural and semi-rural developments is necessary to reduce the feral cat population on the Australian mainland and offshore islands. There is no universal control technique or program that can be applied to all sites effectively, and recommending a particular control technique for each of the sites identified in this report is a task fraught with difficulty. Consequently, each site identified in this review should be treated as a unique site.

Cats are primarily carnivores, with dietary intake through scavenging varying depending on the season. Scavenging increases during winter and spring when primary prey populations are reduced (Molsher *et al*. 1999). Consequently, bait uptake by cats is relatively low, except at times of food stress when the abundance of prey is low; when naïve juvenile cats are dispersing; or on islands (particularly inhabited islands) where scavenging supplements the cat diet. Baiting programs need to target the times when cats are most likely to take baits.

Recommendations for feral cat control programs

There are ten recommendations for feral cat control programs on the Australian mainland and offshore islands:

1. The decision-making tree should be employed for the prioritisation of feral cat control efforts. This will allow a consistent, measured, comparable and justifiable approach to prioritising sites for control efforts based on the status and characteristics of the TAP (or other) species present at the site, the presence or absence of feral cats and the current levels of feral pest control effort. Additionally, sites with non TAP-listed species should be considered for control against those with TAP-listed species.
2. Feral cat control / eradication programs should be based on the strategic pest control approach of Braysher (1993) and Olsen (1998). Adopting a strategic approach to feral cat management for future feral cat control programs would allow a consistent, measurable and adaptive approach to feral cat control across Australia.
3. A reduction in the impacts of feral cats on the native species they are depredating should be used to monitor the success of feral cat control programs, rather than just changes in the abundance of feral cats. Monitoring of the impacted species populations should occur over extended periods beyond the term of the control program to account for any lag in population response.
4. Cat control programs should be site-specific and employ a variety of control techniques most suited to the specific site and the surrounding region. To be effective, feral cat control programs need to be sufficiently resourced and adaptively managed to ensure a consistent downward pressure on feral cat populations.
5. Baiting campaigns should be timed to occur during periods of high food stress in feral cats, such as in winter, or during declines in primary prey associated with climatic events such as floods, fires and droughts. Such campaigns may be mounted annually in temperate areas, where winter is the most predictable time of food stress, or every few years in low rainfall areas where food resources depend on the arrival of drought-breaking rains.
6. Baiting programs should be targeted at times when the risk of non-target bait take is lowest, or techniques should be employed that minimise non-target bait take (for example, bait suspension devices as employed by Algar and Brazell (2008). Additionally, baits available for uptake by feral cats can be affected significantly by uptake by non-target species such as corvids and varanids (Algar *et al.* 2007).
7. For cat colonies in highly modified habitats, such as near rubbish tips, control programs should be conducted regularly, at least twice a year, especially at times of juvenile dispersal. More regular control is required in these situations (unlike those in 5, above) owing to the higher and more reliable levels of food that these habitats provide.
8. Feral cat control programs should consider undertaking concurrent or follow-up control programs for introduced prey species (e.g., rabbits and rodents) that are exploiting the same habitats to minimise possible mesopredator release

effects or eruptions of previously suppressed prey. This will limit the possibility of increases in introduced prey species following a reduction in cat abundance and minimise prey switching by feral cats following a reduction in prey abundance.

9. Feral cat control programs should be considerate of the beliefs of Aboriginal people when conducted on lands under Aboriginal control.
10. Programs of community consultation and education should be undertaken. These should emphasise: the value to the owner and non-owner of the implementation of companion animal legislation that requires neutering, micro-chipping and confinement of owned, domestic cats; the humaneness of controlling or euthanasing cats living in colonies in highly-modified urban, rural and semi-rural habitats where disease is easily transmitted; and the value of removing cats from the broader landscape to protect native species.

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APPENDICES

APPENDIX A   E.mail asking for contributions, with attached questionnaire

Dear …

We are in the process of preparing a report for the Department of Environment, Water, Heritage and the Arts that identifies sites where there is a significant impact on native species by feral cats and prioritise them for control efforts.

We realise that to make this report as comprehensive as possible, there needs to be more than just a review of the readily available literature undertaken. Consequently, we are contacting researchers who have worked, or who are working, with feral cats and their impacts on native species in order to obtain information on sites that may not be generally available.

We have attached a short list of questions that ask you to identify locations and species that you are aware of where feral cats are having, or potentially may have, an impact. We are also seeking details of any control programs that are currently being undertaken for feral cats and details of any grey literature or reports on feral cats that may not be readily available. If possible, could you please complete the attached form and email it back to us by the 27th March. We apologise for the short time frame!

If you would prefer we rang you rather than complete the form, please reply to this email (to the three addresses below) with both your phone contact details and a time that would be convenient for you and we will ring you to have a talk about the information we are asking for.

If you would like any further information about this, please do not hesitate to contact us.

Thank you for your time in assisting us to make this report as comprehensive as possible.

Regards

Chris Dickman
Liz Denny
Tony Buckmaster

Questionnaire

1. One of the main aims of this review is to identify sites, both on the mainland and offshore islands, where feral cats are having significant direct and indirect impacts on native animal populations. Please identify any sites, and relevant species at those sites, that you are aware of where cats are currently a significant threat.

2. In addition to areas where cats are currently identified as significant threats, are there any areas that you believe that cats may become a significant threat in the future? This includes areas that have high conservation value species where cat predation is not yet a threat but may be at risk in the future, and species / locations where data on feral cat impacts are data deficient. Please list those sites and the relevant species.

3. Are you participating in, or aware of, any feral cat control programs at any of the sites you have listed above, either at a local level or a regional level?

4. In order to provide comprehensive maps of the areas of feral cat impacts, are we able to obtain spatial data (ArcView GIS) layers that show the areas you have listed? If GIS layers are unavailable, place names, lat / longs or other geographical descriptors would be very helpful.

5. In order to gain a comprehensive list of areas where feral cats are having an impact on native fauna, we would like to speak to as many people as possible. Would you be able to suggest any other researchers (Government / postgraduate / NGO etc) that we may be able to contact who would have knowledge of sites where there are current or potential impacts by feral cats?

APPENDIX B 1 Sites on mainland Australia identified in questionnaire responses or from literature searches where cat impacts may, or potentially may, occur

MAINLAND AUSTRALIA			
State	**Site**	**Literature**	**Questionnaire**
ACT	Namadgi National Park	Osborne and Williams (1991)	
COM	Booderee National Park		Suzy O'Brien
NSW	Chaelundi State Forest	Catling and Burt (1995)	
NSW	Clouds Creek	Barnett *et al.* (1976)	
NSW	Kosciuszko National Park		Linda Broome
NSW	Murwillumbah FMA	Catling *et al.* (1997)	
NSW	Royal National Park	Mahood (1980)	
NSW	Western Division	Dickman *et al.* (1993), Dickman (1994)	
NSW	Yathong Nature Reserve		Dave Priddel
NT	Alice Springs (150 km NW)	Edwards *et al. (*2001, 2002)	
NT	Coburg Peninsula		Suzy O'Brien
NT	Davenport Ranges		Kath Moseby
NT	Kakadu National Park		Suzy O'Brien
NT	Rocky outcrop refuges		Suzy O'Brien
NT	Tanami Desert	Lundie-Jenkins *et al.* (1993), Southgate *et al.* (2007)	Kath Moseby
NT	Uluru-Kata Tjuta National Park		Suzy O'Brien
QLD	Astrebla National Park		Alicia Whittington
QLD	Bladensburg National Park		Alicia Whittington
QLD	Channel Country Bioregion		Alicia Whittington, Brett Corlson
QLD	Diamantina National Park		Alicia Whittington
QLD	Idalia National Park		Alicia Whittington
QLD	Lochern National Park		Alicia Whittington
QLD	Simpson Desert	Mahon *et al. (*1998)	
QLD	Simpson Desert National Park		Alicia Whittington
QLD	South west Queensland		Kath Moseby
QLD	Taunton National Park		Damian Byrne
QLD	Welford National Park		Alicia Whittington
SA	Anangu Pitjantjatjara Yankunytjatjara Lands		Kath Moseby
SA	Arid areas		Mel Farrelly
SA	Eyre Peninsula	Thorn (2005)	
SA	Gibber desert		Mike Letnic
SA	Great Victoria Desert		Kath Moseby
SA	North east SA channel country		Kath Moseby
SA	Roxby Downs	Read and Bowen (2001)	
SA	Flinders Ranges National Park	Hart (1994), Holden and Mutze (2002)	
TAS	Lower Gordon River region	Hocking and Guiler (1983)	
VIC	Mount Buller ski resort		Louise Perrin
VIC	Alpine areas		Charlie Pascoe
VIC	French Island		Michael Johnston
VIC	Grampians National Park incl. Major Mitchell Plateau		Mike Stevens
VIC	Mallee	Jones and Coman (1982)	
VIC	Moora Creek		Mike Stevens
VIC	Mount Stirling ski resort		Louise Perrin
VIC	Victoria Range		Mike Stevens
VIC	Victoria Valley		Mike Stevens
VIC	Wilson's Promontory National Park		Georgia Kerr
WA	Calvert Ranges		Dave Algar
WA	Cape Arid National Park		Alan Burbidge
WA	Fitzgerald National Park		Alan Burbidge
WA	Gibson Desert	Christensen and Burrows (1995), Algar	

		and Burrows (2004)	
WA	Heirisson Prong	Risbey *et al*. (2000)	
WA	Kalgoorlie	Algar *et al.* (2007)	
WA	Karara		Dave Algar
WA	Kimberleys		Dave Algar
WA	Kimberleys		Ian Radford
WA	Lorna Glen		Dave Algar
WA	Mount Gibson		Dave Algar
WA	Peron Peninsula	Algar and Burrows (2004)	
WA	Shark Bay	Short and Turner (2005)	
WA	South west Western Australia		Al Glen
WA	Two People's Bay		Dave Algar

APPENDIX B 2 Island sites identified in questionnaire responses or from literature searches where cat impacts may, or potentially may, occur

OFFSHORE ISLAND SITES			
State	**Site**	**Literature**	**Questionnaire**
NSW	Norfolk Island National Park		Suzy O'Brien
TAS	Tasman Island	Brothers (1982)	
TAS	Tasman Island	Bryant and Shaw (2006)	
TAS	Babel Island		Nick Mooney
TAS	Courts Island		Nick Mooney
TAS	Fulham Island		Nick Mooney
TAS	Little Green Island		Nick Mooney
TAS	Mount Chapel Island		Nick Mooney
TAS	Prime Seal Island		Nick Mooney
TAS	Three Hummock Island		Nick Mooney
TAS	Badger Island		Nick Mooney
TAS	Clarke Island		Nick Mooney
TAS	Maria Island		Nick Mooney
TAS	Wedge Island		Nick Mooney
SA	Kangaroo Island		Rick Southgate
VIC	French Island	McTier (2000)	Mick Douglas, Michael Johnston
WA	Bernier Island	Richards (2003)	Dave Algar
WA	Christmas Island National Park		Suzy O'Brien
WA	Dorre Island	Richards (2003)	Dave Algar
WA	Thevenard Island	Moro (2001)	
COM	Cocos Islands	Algar *et al.* (2003)	
WA	Barrow Island		Dave Algar
WA	Monte Bello Islands		Dave Algar
WA	Dirk Hartog Island		Dave Algar
WA	Rottnest Island		Dave Algar
WA	Faure Island		Dave Algar
WA	Garden Island		Dave Algar

APPENDIX C IBRA regions, TAP (2008) -listed threatened species recorded in each bioregion, and assessments of risk of impact from predation from feral cats based on the interactive decision-making tree.

Please see attached spreadsheet.