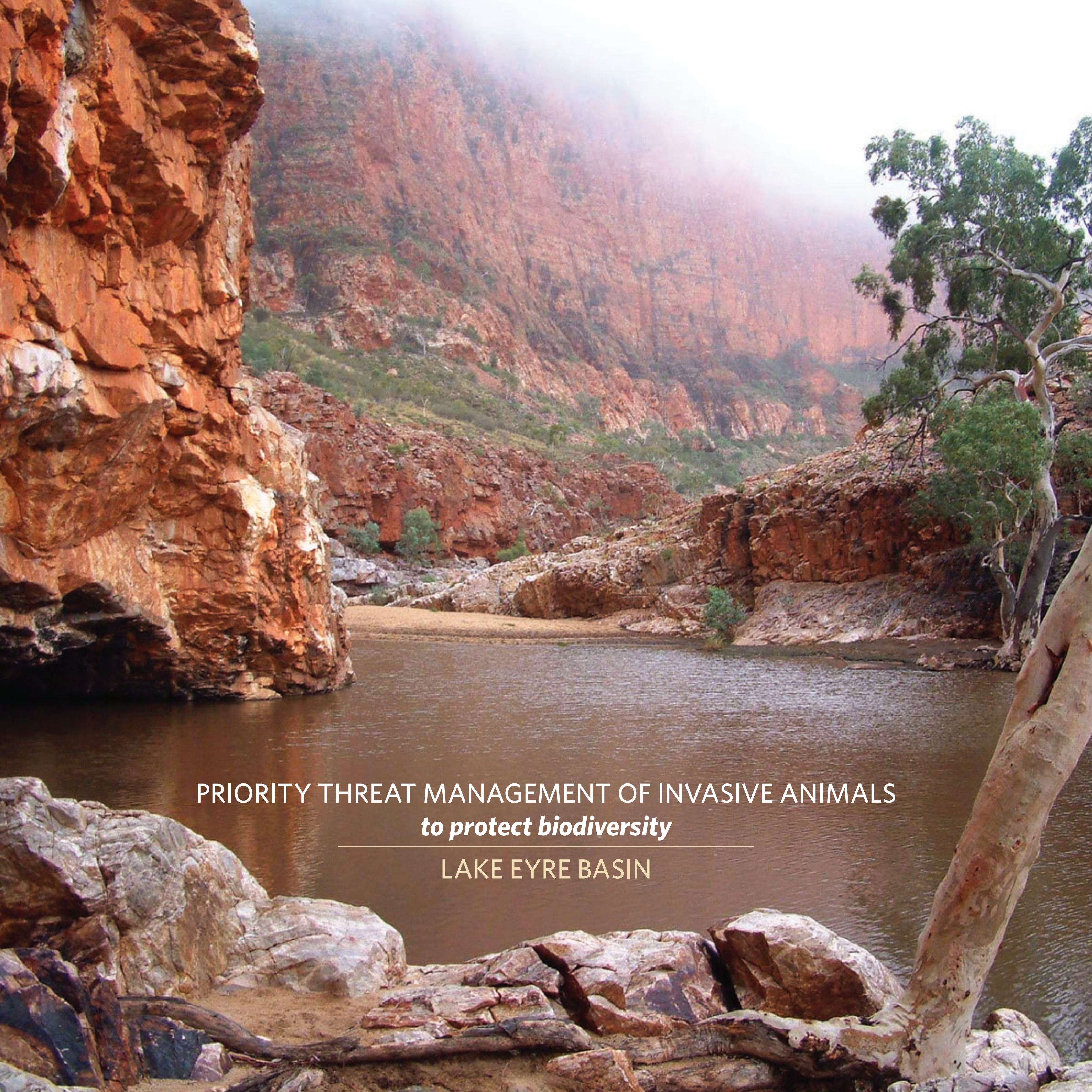

PRIORITY THREAT MANAGEMENT OF INVASIVE ANIMALS
to protect biodiversity

LAKE EYRE BASIN

Grey falcon
(Falco hypoleucos) is an endemic rare falcon of the interior and north of Australia (Vulnerable IUCN Red List)

ANGUS EMMOTT

PRIORITY THREAT MANAGEMENT OF INVASIVE ANIMALS
to protect biodiversity

LAKE EYRE BASIN

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Of the 34 experts and stakeholders involved, the following people agreed to be acknowledged: **Jane Addison** CSIRO Land and Water **Robert Brandle** South Australia, Department of Environment, Water and Natural Resources **Andrew Burrows** Desert Channels Queensland **Chris Dickman** University of Sydney **Angus Duguid** Department of Land Resource Management, Northern Territory Government **Glenn Edwards** Department of Land Resource Management, Northern Territory Government **Angus Emmott** Naturalist, grazier and biologist **Matt Gentle** Queensland Department of Agriculture and Fisheries **Travis Gotch** South Australia, Department of Environment, Water and Natural Resources **Nerissa Haby** South Australia, Department of Environment, Water and Natural Resources **John Hodgon** Queensland Parks and Wildlife Service **Adam Kerezsy** Dr. Fish Contracting **Mark Kleinschmidt** Desert Channels Queensland **David Lord** Thackaringa Station **Greg Patrick** South Australia, Department of Environment, Water and Natural Resources **Chris Pavey** CSIRO Land and Water **John Pitt** Primary Industries and Regions South Australia **Tony Pople** Queensland Department of Agriculture and Fisheries **David Roshier** Australian Wildlife Conservancy **David Schmarr** South Australian Research and Development Institute **Jennifer Silcock** University of Queensland and Queensland Herbarium **Marie Vitelli** AgForce. We acknowledge the participation of the Australian Government Department of the Environment, and the Lake Eyre Basin Scientific Advisory Panel and Community Advisory Committee.

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Front cover: Ormiston Gorge Waterhole, Northern Territory
The waterhole is a site where Black-footed rock wallabies (Vulnerable EPBC Act 1999) are commonly seen

BRUCE THOMSON, NTG

Overview

We recommend an appraised set of strategies for managing the negative impacts of invasive animals on the threatened flora and fauna of Australia's iconic Lake Eyre Basin (hereafter LEB), one of largest internally draining river systems in the world, comprising one-sixth of the Australian continent (*Figure 1*, p.3).

For the first time, we show how considering climate change impacts over the next 50 years alters practical decisions in the LEB today. Climate change is a major threat to global biodiversity that will act synergistically to heighten the severity of other threats, including the devastating impacts of invasive animals (Brooks, 2008; Monastersky, 2014).

Overall we find that decisions on how to invest efforts and budgets to control invasive animals that ignore climate change will likely not identify the most efficient opportunities for conserving biodiversity. We find that 29 threatened native species in the LEB are less likely to persist under the predicted impacts of climate change over the next 50 years, unless additional management strategies are implemented today to avoid impending extinctions. We also find that managing invasive animals for the protection of biodiversity in the LEB will provide significant agricultural co-benefits with increases in productivity estimated between 1% and 15%, depending on the strategy and agricultural sector (*Table 4*, p.20).

We report on 11 management strategies for invasive animals (*Table 1*, p.14 & *Table 2*, p.18), which were drawn from the collective experience and knowledge of 34 experts and stakeholders representing federal, state and local governments, indigenous landholders, pastoralists, and non-government organisations, and members from the LEB advisory committees (Scientific and Community). Assisted by models of current distributions of threatened species and their projected distributions under a future climate scenario[1], workshop participants estimated for each strategy: costs, feasibilities and benefits. Benefits were defined as the probability of improving the functional persistence of 31 species groups within the LEB, representing 148 threatened native flora and fauna species[2]. Functional persistence of a species group is the likelihood that a species group will persist at population levels high enough to achieve their 'ecological function'. To do this, we held two workshops: the first was a three-day workshop (Brisbane, April 2013) to structure the problem and gather expert estimates under current conditions; and the second was a two-day workshop (Alice Springs, April 2014), to gather estimates under a climate change scenario. We then evaluated the relative cost-effectiveness of each strategy, calculated as the expected benefits, divided by the expected management costs (see p. 11 for methods, Carwardine *et al.*, 2012).

considering climate change impacts over the next 50 years alters practical decisions today

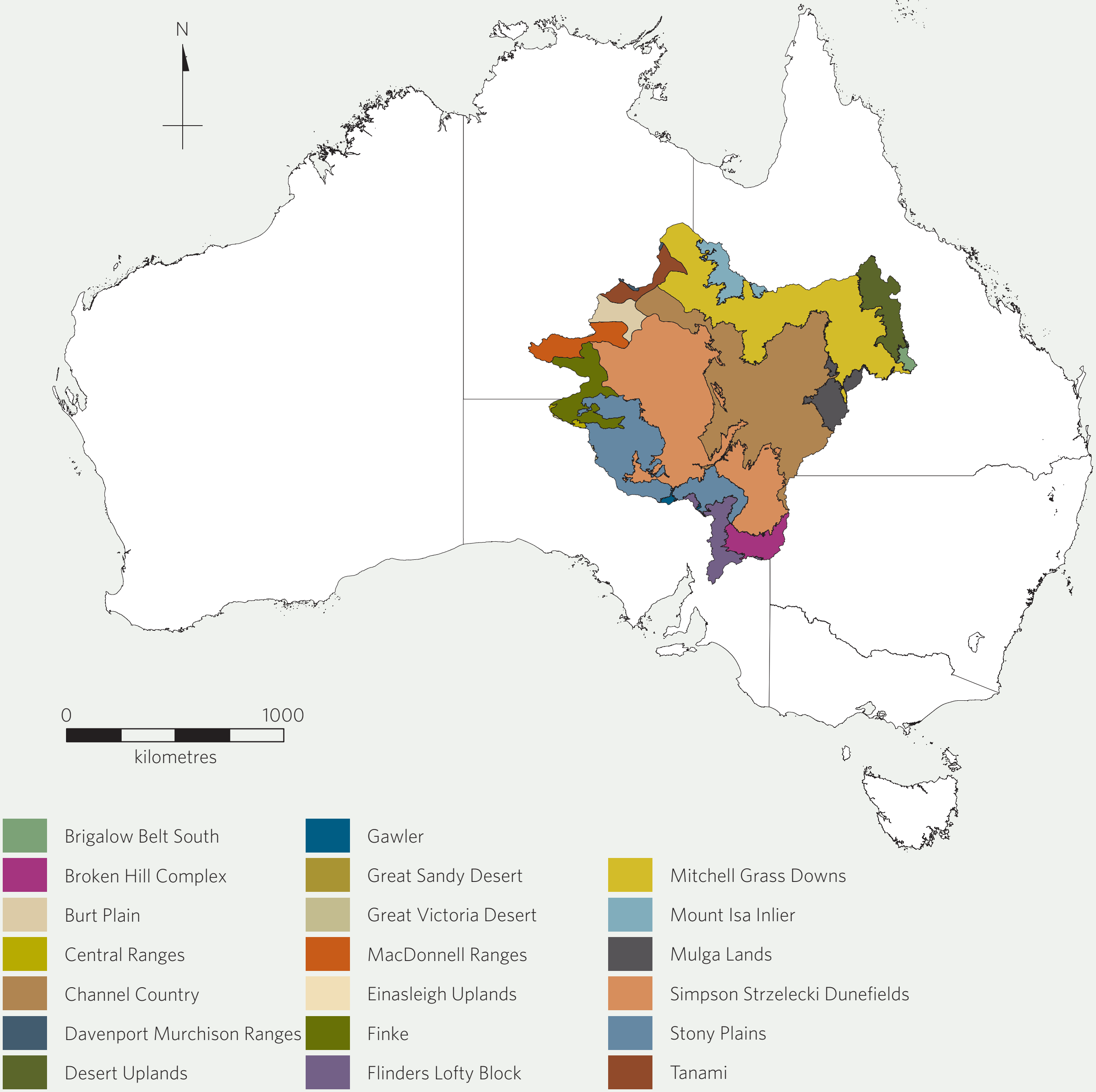
Finally, we provide support to assist decision-making and investment using two analytical approaches:

1. ecological cost effectiveness ranking, a prioritised list of the 11 strategies; and
2. complementarity, bundles of strategies to optimise the number of threatened species saved depending on budgets.

1 Representative Concentration Pathway (RCP) 6 scenario without overshoot pathway leading to 850 ppm CO_2 equivalent

2 As listed in the Australian EPBC Act 1999, the IUCN Red List and an additional seven floral species considered threatened by experts

Figure 1 Map of the study area, the Lake Eyre Basin (LEB) showing Interim Biogeographic Regionalisation for Australia (IBRA), spanning almost one-sixth of the Australian continent



Data sourced from Interim Biogeographic Regionalisation for Australia (IBRA) and Department of Sustainability, Environment, Water, Population and Communities, Australia Commonwealth Government. Compiled by John Hayes and Jennifer Firn.

Key findings

USING A COST EFFECTIVENESS RANKING APPROACH

Overall LEB biodiversity experts predict that threatened species have a lower probability of persisting under climate change over the next 50 years.

The five most cost-effective strategies within the LEB are the control of pigs, horses and donkeys, cane toads, camels, and rabbits. Combined, these strategies have an estimated average annualised cost of $16 million over the next 50 years (*Table 2*, p.18).

- The most cost-effective strategy for improving the overall persistence of native threatened species is the management of feral pigs, at approximately $2 million (average annualised cost) in specific locations throughout the region.
- Invasive predator control is one of the top ranked strategies for the protection of threatened mammals, which supports the current focus on predator control strategies for protecting biodiversity in Australia (Woinarski *et al.*, 2015) (*Table 3*, p.19).
- The total cost of implementing all strategies over the next 50 years is estimated at $33 million under climate change (*Table 2*, p.18).
- The cost-effectiveness of strategies is overall lower under climate change, predominantly because the potential biodiversity benefits would decrease for all but two strategies (i.e. pigs and rabbits). Implementation costs increase under climate change for predator control, with the workshop participants recommending an additional eight research projects on the impacts of climate change on cat populations and mesopredator release effects (*Table 2*, p.18).
- The control of highly competitive invasive aquatic animals such as gambusia, tilapia and red claw is critical to ensure the conservation of threatened aquatic flora and fauna. Research projects on control methods, and modelling / risk assessment to predict the impact of changes to natural river flows are high priorities.
- Participants estimate that the feasibility (defined as the probability of success and likelihood of uptake) of most of the strategies will increase with climate change as invasive animal populations were expected to decline in density and range due to lower rainfall and unpredictable climatic events, making populations easier to locate and control (Spencer *et al.*, 2012).
- Feasibility decreases for strategies focused on the invasive aquatic animals, because of the difficulty of finding populations with less water flowing through the LEB and potentially even more sporadic flooding events (Roshier *et al.*, 2001).
- The naturally variable climate of the LEB and the response of exotic and native species to variable climates suggest that establishing an 'Institution for facilitating natural resource management' is a key strategy (*Table 1*, p.14 & *Table 2*, p.18). The LEB is characterised by a highly variable climate and climate change impacts are predicted to increase this variability (Williams, 2002; Reisinger *et al.*, 2014). This poses a significant challenge as public funding for natural resource management is typically earmarked for an activity in a given financial year. An NRM institution would allow managers to find the funds needed to respond early to rising crises, and would allow funding to be carried over into future years if it is likely to be better spent later, when conditions are more conducive for high invasive animal populations.

Yellow-footed Rock-Wallaby
(Petrogale xanthopus xanthopus) has disjunct populations in South Australia and NSW (Vulnerable EPBC Act 1999)

ANGUS EMMOTT

Regal birdflower
(Crotalaria cunninghamii) is a native perennial leguminous shrub that colonises sand dunes and Mulga communities

GLENN WALKER

Key findings

USING A COMPLEMENTARITY APPROACH

The cost-effectiveness ranking approach evaluates each of the 11 strategies independently; therefore multiple highly-ranked strategies can benefit the same species. If funding is available to implement more than one strategy, strategies selected from the top of the cost-effectiveness list may not be the most complementary set. Complementarity approaches evaluate bundles of strategies to find the sets of strategies that benefit as many different species as possible at a range of budgets (Chades *et al.*, 2014).

without management intervention 29 species are likely to be lost from the LEB over the next 50 years

We use the complementarity approach to recommend bundles of strategies that maximise the number of threatened species potentially secured at a minimum cost over the next 50 years (*Figure 2*, p.16).

- We discover that without management intervention, 29 species have an estimated persistence of < 50% under climate change, meaning that they are at a high risk of being functionally lost from the region.
- Without management intervention, critical weight range mammals (17 species including the greater bilby *(Macrotis lagotis)* and the Julia Creek dunnart *(Smithopsis douglasi)* are estimated to have a 31% probability of persisting functionally in the landscape over the next 50 years under climate change. The implementation of all 11 strategies increases their average estimated persistence to over 50%.
- The majority of threatened flora and fauna in the LEB are likely to reach the persistence threshold of 50% or higher with the implementation of just two strategies, predator and pig control, at an average annualised cost of $12 million (*Figure 2*, p.16). But two species (common yabbie *(Cherax destructor)* – 42% and black-eared miner *(Manorina melanotis)* – 44%) are not estimated to reach this threshold even if all strategies are implemented (*Figure 2*, p.16).
- If targeting a higher species persistence threshold of 70% or greater chance of survival over 50 years, 84 species are estimated to reach this threshold with the implementation of two strategies, pigs and rabbit control, at an average annualised cost of $7 million (*Figure 2*, p.16).
- Under climate change, no threatened native animal species in the LEB are estimated to reach a > 85% chance of survival over 50 years, even if all invasive animal strategies identified in this study are implemented.

***Glinus orygioides*, Simpson Desert**

DAVID ALBRECHT, NTG

How to use this information

Effectively responding to broad-scale threat of invasive animals under climate change, within financial and logistic constraints, is key to successfully meeting the challenge of protecting biodiversity.

We have gathered and appraised a comprehensive set of strategies for managing invasive animals across the Lake Eyre Basin. The Lake Eyre Basin covers an estimated 120 million hectares and spans multiple states – Queensland, South Australia and New South Wales – and the Northern Territory. This makes trans-boundary cooperation pivotal to the effective management of natural resources including invasive animals and threatened species.

Red-finned blue-eye
(Critically Endangered IUCN Red List)
ADAM KEREZSY

The Lake Eyre Basin Intergovernmental Agreement was established in 2001 to avoid or eliminate cross-border impacts.

We did not directly consider the effectiveness of current or future management delivery models, although this is a crucial component of successful invasive species control and eradication for biodiversity benefits. Workshop participants suggested that it would be useful to establish pathways to integrate this study, and the priorities that resulted from it, into further planning and prioritisation approaches at regional and local scales. In particular, the Lake Eyre Basin Intergovernmental Agreement was highlighted as being a critical avenue for the implementation of invasive animal control. One strategy adopted by the Ministerial Forum under its 'Water and Related Natural Resources Policy' is to '(i) identify opportunities for improved coordination and consistency of approaches to aquatic and terrestrial weed and feral animal management activities'.

The Lake Eyre Basin Rivers Assessment (LEBRA) also forms an important component for integrating the information discovered in this project. The information collection and monitoring required and recommended as part of these invasive animal management strategies could be implemented through the LEBRA, which aims to assess the condition of catchments across the basin under the Agreement.

At regional scales, further important avenues for integrating this research include the state, local government, NRM region, catchment and even property-level planning that is undertaken at various levels of governments, NGOs, landholders and management groups.

Because uncertainty exists about most conservation strategies, including the best measures to control invasive animals, an adaptive management framework is essential (McCarthy & Possingham, 2007). Working with a variety of landholders and land managers will be necessary to achieve invasive animal control for the protection of biodiversity. A well-coordinated implementation approach developed in collaboration with stakeholders will also increase the likelihood of realising the estimated biodiversity benefits and agricultural co-benefits from invasive animal control (*Table 4*, p.20).

Caveats

A number of caveats apply to our recommendations.

Due to the lack of empirical data, these recommendations were generated using expert and local knowledge and therefore may not always be formed on the basis of published, peer-reviewed scientific research or on the real costs of management strategies. Workshop participants gave estimates for the persistence of species groups for which they were confident in having the knowledge to do so; therefore variable numbers of estimates were collected for each species group.

We were unable to create species habitat distribution models for all threatened species on the list because presence data was unavailable or insufficient for some species and the technique applied is only robust for terrestrial species.

We assumed that strategies could only be either fully funded or not funded, but in reality strategies could be partially funded. Further, our approach does not directly consider interactions between invasive animal threats, nor additional threats to native species that operate across the basin, such as habitat clearing, fire, cattle grazing or invasive plants.

Finally, we conservatively assume that any combination of strategies delivered the maximum benefit of the independent strategies being combined, where in reality a combined strategy may deliver a higher benefit than the maximum of individual strategies.

Concluding remarks

We provide a basin-wide picture of the flora and fauna most at risk of extinction, and provide a cost-effective approach for selecting invasive animal control strategies in the LEB to best protect them. Climate change and invasive animals are considered two of the leading causes of biodiversity loss globally (Monastersky, 2014). As we show here, the combination of these two threats will have a profound impact on threatened native species already disadvantaged by habitat and environmental conditions (Isaac & Cowlishaw, 2004; Brooks, 2008).

There is an urgent need to re-think how we manage invasive animals for the protection of native biodiversity, as adapting to climate change is a multifaceted problem (Brooks, 2008; Dawson *et al.*, 2011).

Feral pig

ANGUS EMMOTT

Yellow Spotted Monitor
(Varanus panoptes) can die from consuming large cane toads (Vulnerable NT)

ANGUS EMMOTT

Methods

Ecological cost-effectiveness analyses

We estimated the cost-effectiveness of a strategy i (CE_i) by dividing the total expected benefit of the strategy by the estimated costs (C_i). Costs were calculated as expected net present values using a 7% discount rate (Council of Australian Governments 2007). The expected benefit for each strategy was estimated by multiplying the potential benefit (B_i) by the feasibility (F_i,also estimated by workshop participants), providing an indication of the likely improvement in persistence across the threatened species in LEB if that strategy was implemented:

$$CE_i = \frac{B_i F_i}{C_i}$$

The potential benefit B_i of implementing strategy i across the LEB was defined by the cumulative difference in persistence probability of threatened species groups in the region with and without implementation of that strategy, averaged over the experts who made predictions for the species:

$$B_i = \sum_{j=1}^{N} \frac{\sum_{k=1}^{M_j} (P_{ijk} - P_{0jk})}{M_j}$$

Where, P_{ijk} is the probability of persistence of threatened species groups j if strategy i is implemented, estimated by expert k. P_{0jk} is the probability of persistence of species groups j if no strategy is implemented (baseline scenario), estimated by the same expert k. N is the number of species groups; and M_j is the number of workshop participants who made predictions for the species group j.

Complementary sets of strategies depending on budgets

We investigated three thresholds of persistence for the species groups (i.e. probability of functional persistence): >85%, >75% and >50%, over 50 years.

Finding the optimal sets of strategies that secure as many species groups as possible above any one of these thresholds for any given budget requires solving a multi-objective optimisation problem:

$$\max \sum_{i \in S} \sum_{j \in N} p_{ij} x_i \; and \; \min \sum_i C_i x_i,$$

where x_i is a binary decision variable that denotes whether (x_i=1) or not (x_i=0) a strategy is included in the optimal set of strategies. A vector $x \in \{x_1, x_2, \ldots, x_S\}$ represents a combination of selected strategies. The S represents the set of strategies listed in *Table 2*, p.18; p_{ij} identifies whether species j is expected to reach a given persistence threshold if strategy i is implemented; $p_{ij} = 1$ if the expected benefit of applying strategy i for species j is above the persistence threshold

(i.e. $B_{ij}F_i + B_{0j} > \tau$ with $B_{ij} = \sum_{j=1}^{N} \frac{\sum_{k=1}^{M_j} (P_{ijk} - P_{0jk})}{M_j}$);

and $p_{ij} = 0$ if this threshold is not exceeded. The persistence p_{ijk} of each strategy was elicited independently.

Because multi-objective problems rarely have a unique solution that maximises all objectives simultaneously, Pareto optimal solutions are needed. Pareto optimal solutions are solutions that cannot be improved in one objective without degrading at least one other objective (Nemhauser & Ullmann, 1969; Ruzika & Wiecek, 2005). We found the Pareto optimal solutions by formulating our problem as an integer linear programming problem.

Threatened species distribution models

We modelled the current distribution and made projections about the future distribution of the threatened species of the LEB to aid experts to estimate the benefits to biodiversity of implementing different strategies under climate change. The potential distributions of the threatened species in the Lake Eyre Basin under current and future climate conditions were modelled according to the method described in Maggini *et al.* (2013).

Spatial data on the occurrence of threatened native fauna and flora in the LEB were extracted from the Australian Natural Heritage Assessment Tool database. The bioclimatic predictors were related to temperature (annual mean temperature, temperature seasonality) and precipitation (precipitation seasonality, precipitation of the wettest and driest quarters). Substrate predictors were the solum average clay content, hydrological scoring of pedality, solum average of median horizon saturated hydraulic conductivity and mean geological age (Williams *et al.*, 2010; Williams *et al.*, 2012). Species distributions were modelled using the software Maxent (Philips *et al.*, 2006). Presence records were compared against a background sample (10,000 grid cells), which was defined separately for each species and chosen randomly from within the IBRA regions (Interim Biogeographic Regionalisation of Australia, v.7) currently occupied by the species.

Species' distributions were projected (from 1990) into the future under three climate change scenarios and for three time horizons, namely 2015, 2035 and 2055. The climate change scenario used for the projections were three of the new RCPs adopted by the IPCC's fifth assessment report: a high emission business-as-usual scenario RCP 8.5, a moderate mitigation scenario RCP 6 requiring a climate-policy intervention, and a stronger mitigation scenario RCP 4.5 assuming the imposition of a series of emission mitigation policies (Masui *et al.*, 2011; Riahi *et al.*, 2011; Thomson *et al.*, 2011). In order to simplify the task of the experts, workshop participants were only presented results from the intermediate scenario, namely RCP 6 (scenario without overshoot pathway leading to 850 ppm CO_2 eq.), and time horizon 2055.

Species' distributions were projected for 18 different Global Circulation Models (GCMs; see *Table 3* in Maggini *et al.*, 2013) to avoid the bias related to the choice of a particular GCM. Projections were summarised using the median of the predicted probabilities of occurrence across the 18 GCMs within each grid cell. Finally, the realised distribution of a species was obtained by removing from the potential distribution all areas that were not within a currently occupied or neighbouring IBRA region. The assumption behind removing these areas was that species are unlikely to expand their range beyond the neighbouring IBRA regions within the modelled timeframe. The probabilistic map of each species was transformed into a presence/absence map according to a threshold that equated the entropy of the distributions before and after applying the threshold (Philips *et al.*, 2006). The presence/absence maps for all species within each group were stacked into one data layer and used to calculate the species richness within each grid cell to produce maps of the current and future distributions of species groups.

The Blanche Cup mound springs, South Australia
Mound springs are high diversity points of natural water seepage from the Great Artesian Basin (Endangered ecosystems EPBC Act 1999)

GLENN WALKER

Table 1 Description of the 11 management strategies recommended by the workshop participants for the control of invasive animal species to protect biodiversity in the Lake Eyre Basin

1 Institution for facilitating natural resource management (overarching strategy)

- A general contingency fund to respond to unanticipated threats such as new pests or unexpected outbreaks.

2 Predator control i.e. cat *(Felis catus)*, fox *(Vulpes vulpes)*, and dog *(Canis familiaris)* control

- Cat and fox trapping and baiting at key assets
- Fox aerial baiting
- Monitoring
- Early response 'control' team in each state
- Training of guardian dogs community program
- PhD research projects to improve control efforts.

Additional actions with climate change:

- Additional eight research projects on the impacts of climate change on cat populations and mesopredator release effects.

3 Pig *(Sus scrofa)* control

- Aerial baiting and/or shooting around water
- Monitoring program every ten years
- Special asset management
- PhD research projects to improve control efforts.

4 Cane toad *(Bufo marinus)* control

- Asset protection
- PhD research projects on control efforts
- Monitoring and trapping: localised eradication
- Surveillance and biosecurity hotspots
- Education.

5 Gambusia *(Gambusia holbrooki)*

- Chemical control (e.g. rotenone) of gambusia
- Surveillance and biosecurity
- Research program on chemical controls
- Education and public awareness campaigns
- Identification of key threats and triage ranking
- Modelling to predict the impact of changes to natural river flows brought about by irrigation projects and mining in the LEB.

6 Other aquatic species control, e.g. red claw *(Cherax quadricarinatus)*, tilapia (various species) and sleepy cod *(Oxyeleotris lineolata)*

- Research program on eDNA
- Education campaign and signage
- Surveillance and biosecurity
- Increased investment into LEBRA
- Quarantine of pristine GAB mound springs
- Translocation projects
- Protection of natural flows.

7 Horse *(Equus ferus caballus)* and donkey *(Equus asinus)* control

- Education including regular training workshops
- Monitoring program
- Public engagement program
- Aerial culling with helicopters
- Industry partners for meat production market depending on local regulations.

8 Camel *(Camelus dromedaries)* control

- Education including regular training workshops
- Commercial muster for sale
- Fencing with steel spiders for key waterhole/ cultural site protection
- Aerial culling with helicopters
- Monitoring program for control efforts
- Public engagement program.

9 Goat *(Capra hircus)* control

- Education including regular training workshops
- Monitoring program of control efforts
- Public engagement program
- Industry partners for meat production market depending on local regulations
- Incentive/assistance program to encourage mustering of goats
- Aerial culling with helicopters
- Fencing with steel spider structures to protect biodiversity assets.

10 Rabbit *(Oryctolagus cuniculus)* control

- Monitoring program
- Biological control
- Habitat modification (warren destruction)
- Fumigation
- Baiting with 1080
- Education and regular training workshops
- Engagement staff and programs.

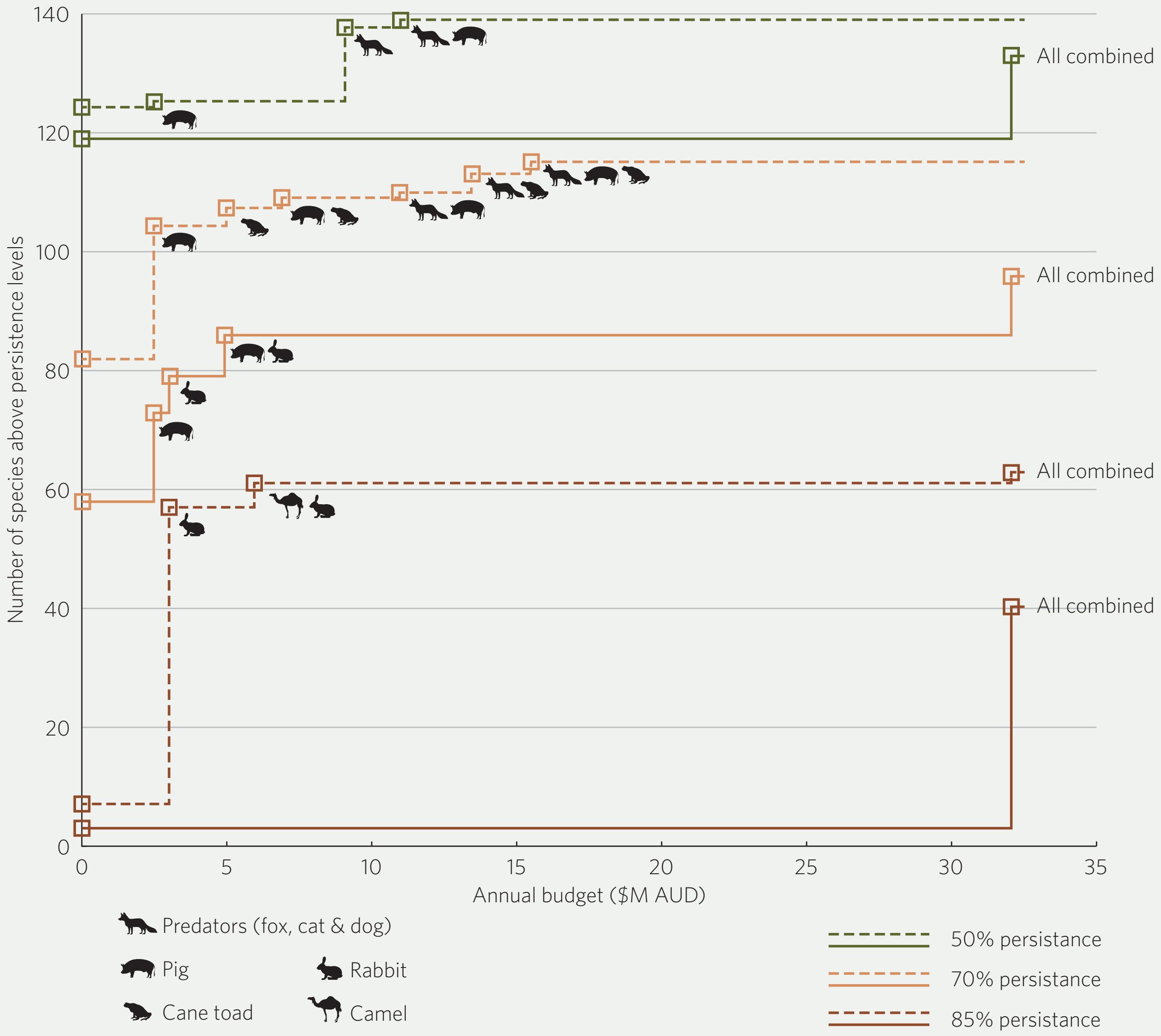
11 Total combined strategies

- All strategies 1 to 10 combined.

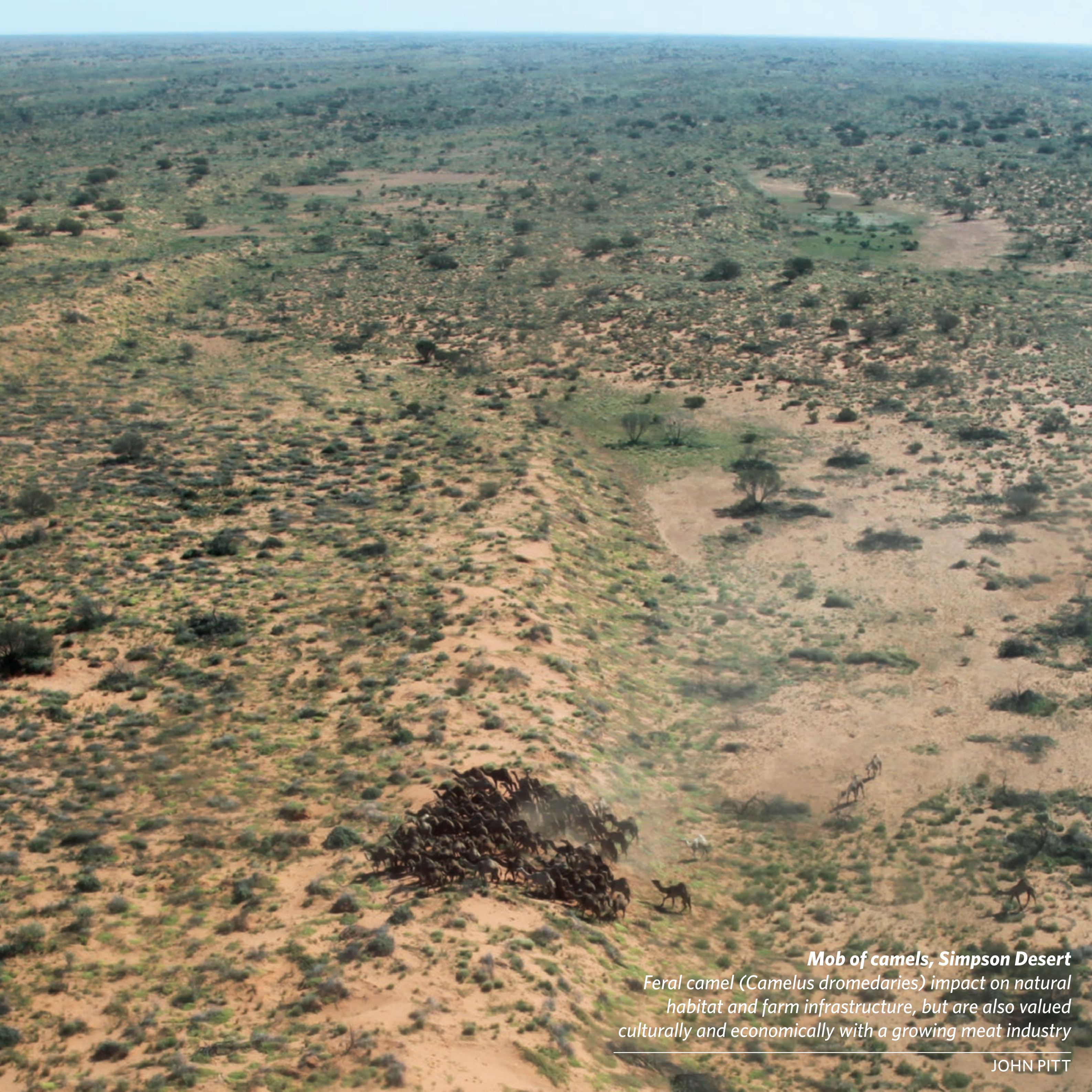
Kite, heron and egret, Cooper Creek

GLENN WALKER

Figure 2 Results from the complementarity approach. Lines show the combination of strategies needed to secure threatened species above three persistence thresholds (50%, 70% and 85%) depending on budgets. Solid lines show results considering climate change and dashed lines without considering climate change.



This complementarity analysis accounts only for the benefits of strategies that improve the persistence of species to exceed each threshold. As shown by the cost-effectiveness ranking approach, there are benefits to undertaking all strategies, but not always sufficient benefits to improve species persistence above these thresholds.



Mob of camels, Simpson Desert

Feral camel (Camelus dromedaries) impact on natural habitat and farm infrastructure, but are also valued culturally and economically with a growing meat industry

JOHN PITT

Table 2 Summary of results using the cost-effectiveness ranking approach including the CE ranks, scores, and estimated uptake, success, persistence benefits for all species groups and costs

Strategy	CE rank	CE score	Uptake (proportion 0-1)	Success (proportion 0-1)	Expected benefit (50 years)	Rank expected benefit	Expected NPV (50 years)	Average annualised cost
Pigs	1 (1)	1.93 (1.79)+	0.93 (0.925)	0.76 (0.75)	543 (504)	3 (3)	$28M ($28M)	$2M ($2M)
Horses & donkeys	2 (2)	1.38 (1.43)+	0.8 (0.8)	0.9 (0.8)	581 (562)	2 (2)	$41M ($41M)	$3M ($3M)
Cane toads	3 (3)	1.12 (1.22)-	0.88 (0.88)	0.8 (0.77)	438 (476)	5 (4)	$39M ($39M)	$3M ($3M)
Camels	4 (4)	1.04 (1)+	0.9 (0.95)	0.8 (0.7)	425 (410)	6 (5)	$41M ($41M)	$3M ($3M)
Rabbits	5 (5)	0.73 (0.57)+	1 (1)	0.5 (0.5)	471 (363)	4 (6)	$64M ($64M)	$5M ($5M)
Gambusia	6 (6)	0.42 (0.55)-	0.67 (0.67)	0.56 (0.63)	83 (109)	8 (9)	$20M ($20M)	$2M ($2M)
All strategies	7 (7)	0.38 (0.38)	0.9 (0.9)	0.8 (0.8)	1698 (1652)	1 (1)	$442M ($439M)	$33M ($32M)
Predators	8 (8)	0.31 (0.29)+	0.72 (0.62)	0.84 (0.87)	374 (353)	7 (7)	$123M ($120M)	$9M ($9M)
Other aquatic	9 (9)	0.19 (0.28)-	0.89 (0.89)	0.64 (0.69)	81 (119)	9 (8)	$43M ($43M)	$3M ($3M)
Goats	10 (10)	0.15 (0.19)-	0.5 (0.5)	0.25 (0.2)	63 (80)	10 (10)	$44M ($44M)	$3M ($3M)
Institution for NRM	na	na	0.6 (0.6)	0.6 (0.6)	na	na	$2M ($2M)	$141,000

Estimated: uptake (%), success (%), average expected benefits, average net present value, annual equivalent value, and cost effectiveness. A discount rate of 7% was used to calculate expected NPV and average annualised costs (Council of Australian Governments 2007). Appraisal values estimated not under the climate change scenario are shown in brackets for comparison. CE = cost-effectiveness, NPV= net present values, NRM = Natural Resource Management, M= millions.

Table 3 Summary of results using the cost-effectiveness ranking approach including the CE ranks and scores for broad species groups of interest such as fauna, flora, birds, mammals etc.

Strategy	Overall		Fauna		Flora		Birds		Mammals		Amphibians		Aquatic		Reptiles		GAB Springs	
		NCC		NCC		NCC		NCC		NCC		NCC		NCC		NCC		NCC
Pigs	**1.93**	**1.79**	**1.44**	**1.55**	0.48	0.29	**0.11**	**0.26**	**0.28**	0.12	**0.01**	**0.03**	**0.74**	0.96	**0.22**	**0.13**	0.68	0.46
Horses & donkeys	1.43	1.38	0.75	0.83	**0.68**	**0.54**	0.10	0.05	0.12	0.08	0	0.003	0.35	0.58	0.16	0.12	0.62	0.30
Cane toads	1.12	1.22	1	1.22	0.12	0	0.01	0.01	0.06	0.06	0.006	0.006	0.73	**1.06**	0.20	0.10	**0.70**	**0.48**
Camels	1.04	1	0.71	0.56	0.33	0.44	0.08	0.04	0.13	0.09	0.006	0.006	0.34	0.32	0.15	0.10	0.35	0.29
Rabbits	0.73	0.57	0.30	0.23	0.44	0.34	0.06	0.05	0.14	0.12	0	0.003	0	0.01	0.08	0.06	0	0
Gambusia	0.42	0.55	0.42	0.55	0	0	0	0	0	0	0	**0.03**	0.41	0.52	0	0	0.41	0.42
All strategies	0.38	0.38	0.23	0.24	0.15	0.14	0.04	0.04	0.10	0.10	0.003	0.004	0.05	0.06	0.02	0.02	0.04	0.05
Predators	0.31	0.29	0.31	0.29	0	0	0.03	0.07	0.22	**0.19**	0	0.002	0	0	0.03	0.03	0	0
Other aquatic	0.19	0.28	0.19	0.28	0	0	0	0	0	0	0.004	0.003	0.18	0.27	0	0	0.12	0.09
Goats	0.14	0.19	0.07	0.09	0.07	0.10	0.01	0.01	0.03	0.03	0	0	0	0.04	0.03	0.02	0.05	0

Estimated cost effectiveness (CE) overall (all threatened flora and fauna), fauna only, flora only, birds, mammals, amphibians, aquatic fish and invertebrates, reptiles and all species recorded as threatened in the Great Artesian Basin (GAB) mound springs. CE values are shown for both with and without consideration of the climate change scenarios (values without consideration of climate change are denoted by NCC). The highest-ranking strategy is shaded in blue and the second and third ranking strategy shaded in yellow.

Table 4 Estimated agricultural co-benefits of the management of invasive animals for protecting biodiversity

Strategy	Agricultural co-benefits	Benefit value
Pigs	Biosecurity benefit as pigs are potential vectors of disease that impact on the health and survival of livestock	< 1% per annum increase in cattle productivity
Cane toads	None estimated	
Camels	Reduced fence and farming structure damage	Increased income of 2–5% per annum
	Reduced water loss from dams and contamination of water holes	Increased productivity of 5% per annum with increased conservation of dams and water holes
Horses & donkeys	Reduced fence and farming structure damage	Increased income of < 1% per annum
	Reduced water loss from dams and contamination of water holes	Increased productivity of 2% per annum with increased conservation of dams and water holes
Gambusia	Research on chemical control could be a benefit for abalone aquaculture	Increased income of < 1% per annum
Rabbits	Increased productivity in semi-arid sheep and cattle country because of more fodder	Increased income of 15% per annum
Predators (cats, dogs and foxes)	Reduced livestock losses including sheep and cattle	Increased income of 10% per annum for sheep
	Fewer landholder distractions therefore increased productivity	Increased income of 2% per annum for cattle
	Biosecurity benefits as cats and dogs are potential vectors of disease that impact on the health and survival of livestock	< 1% per annum increase in livestock productivity with the prevention of disease
Other aquatic species (e.g. red claw, tilapia and sleepy cod)	Increased quality of waterholes which are essential for rangeland farming	No estimate provided
Goats	Increased productivity particularly for landholders raising sheep	Increased income of 10% per annum for landholders particularly in the semi-arid regions of the LEB where goats are present
	Increased goat sales by landholders	
	Biosecurity benefits as goats are potential vectors of disease that impact on the health and survival of livestock	

Collet's snake
(Pseudechis colletti) is a shy and rarely seen inhabitant of central Queensland (Near Threatened Qld)

ANGUS EMMOTT

Diamantina River

After flooding rains, waters from the Diamantina river fill Goyder Lagoon and then continues onto Kati Thanda

GLENN WALKER

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Red claw crayfish in the Thomson River
(Cherax quadricarinatus), a native of far north Australia but is an invasive species in the LEB. Red claw directly competes with common yabbies (Cherax destructor, Vulnerable IUCN Red List)

ANGUS EMMOTT

Cane toad
(Bufo marinus), one of the greatest threats to Australian wildlife, arrived after big rains into the red sands of the LEB Channel Country in 2010

ANGUS EMMOTT