APPENDIX 12 – ECOLOGICAL HEALTH MONITORING FRAMEWORK

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See digital attachment.

Ecological Health Monitoring Framework: Mallee Cliffs

australian wildlife conservancy

Common Dunnart caught in 2017 survey, Mallee Cliffs. Bottom: trapping array. Photos: AWC/ Wayne Lawler

Summary

Australian Wildlife Conservancy (AWC) and the NSW Government have signed an historic agreement (Extinct Mammal Agreement) under which AWC will deliver scientific and land management services on Mallee Cliffs National Park (Mallee Cliffs NP). The Extinct Mammal Agreement gives effect to a commitment under the NSW Government's *Saving our Species* policy. Central to the Extinct Mammal Agreement is a requirement for AWC, on behalf of the NSW Government, to establish a large (8000 ha+) feral predator-free area, protected by a conservation fence, into which mammal species listed as extinct in NSW will be reintroduced to Mallee Cliffs. AWC is also contracted to deliver science and land management services, such as feral animal and weed control, across Mallee Cliffs NP (fenced and unfenced sections).

This Ecological Health Monitoring Framework (EHMF) is designed to measure the changes in ecological health on Mallee Cliffs NP associated with the delivery of the project. In other words, the EHMF will provide for the measurement, assessment and reporting of key impacts and benefits both inside and outside the feral predator-free (fenced) area.

This framework for monitoring the ecological health of Mallee Cliffs NP therefore:

- Provides for the selection of indicators of ecological health (biodiversity indicators, threat indicators and ecosystem process indicators).
- Sets out a rigorous and representative survey design, incorporating a range of survey methods, to measure any changes in the ecological health indicators.
- Incorporates a mechanism for annual reporting of the ecological health of Mallee Cliffs NP.

This EHMF will be integrated with the proposed Research Strategy for Mallee Cliffs NP, noting the role of research in helping improve the measurement and analysis of ecological health and enhance the effectiveness of land management strategies.

Objective of the EHMF

The overarching objective of the project is to improve the *ecological health* of Mallee Cliffs NP. The EHMF is designed to measure performance against this objective – i.e., to measure changes in ecological health.

Ecological health will be considered to have been improved when:

- There is improvement in the status of at least some species, including threatened species, and the status for other significant species is considered acceptable;
- Threats (stressors) are reduced below levels where they have a significant impact on biodiversity; and
- Ecological processes are considered resilient to disturbances.

Changes in health will be measured by reference to selected ecological health indicators.

Ecological health indicators

The EHMF provides for the measurement of a suite of biodiversity and threat indicators within the following categories.

- Species and guilds that are:
    - declining and/or threatened (see below);

    - affected directly or indirectly by mammalian extinctions; and/or
    - strong drivers of ecosystem function.
- Other species and guilds: we will also conduct surveillance monitoring of a range of taxonomic groups, to provide early warning of any unexpected declines.
- Ecological processes – e.g., soil engineering, as well as attributes of the environment affected by, or which provide habitat for, native species (e.g., vegetation structure and composition, habitat attributes such as woody debris and hollows).
- Threatening processes including:
    - feral predators (fox, feral cat, wild dog): density, abundance or activity
    - feral herbivores (goats, pigs, rabbits): density, abundance or activity
    - changed fire regimes (a suite of ecologically relevant metrics)
    - ecologically significant weeds: extent of occupancy, density

A list of indicators is set out in Table 2 (biodiversity and ecological processes) and Table 4 (threats).

Survey design

A spatially-blocked stratified design was used to select 50 sites on Mallee Cliffs NP for monitoring a range of biodiversity and threat indicators. The design was implemented hierarchically, as follows:

1. The primary stratification was by vegetation type. Sites were established in the four main vegetation types present on Mallee Cliffs NP.
2. Replicate sites were established in each vegetation type. Replicates were selected in blocks across Mallee Cliffs NP, to control for underlying spatial variation in environmental factors.
3. Sites were separated by a minimum distance of 2 km, to ensure spatial independence for most taxa.
4. Sites were located a minimum of 500 m from the edge of the reserve.
5. Where possible, sites were established in locations that were moderately accessible from the road network.

In this process, 12 monitoring sites were located within the proposed fenced area at Mallee Cliffs NP. To increase the power of the monitoring program to detect the outcomes of reintroductions, a further eight sites (two replicates of each vegetation type) were added to the fenced area, bringing to 20 the total number of monitoring sites within the fenced area, and the total number of monitoring sites within Mallee Cliffs NP to 58.

Survey methods

A range of methods will be used at each of the 58 monitoring sites to survey vertebrates including live trapping (box, cage, pitfall and funnel), camera traps and observational surveys. Acoustic recorders will be deployed at all sites to survey birds, in addition to standard observational surveys. Habitat attributes and ecological processes will also be measured at each site.

Vegetation will be surveyed in detail at 32 of the 58 standard monitoring sites. Acoustic recorders will be deployed at 20 standard sites at night to survey bats. Nest-boxes will be set up at 24 standard sites to detect Western Pygmy Possums. These surveys will allocate equal effort inside and outside the proposed fenced area.

Macropods and feral animals will be surveyed using cameras and spotlight transects established on the road network across Mallee Cliffs NP.

Targeted surveys will be conducted for Malleefowl, threatened plants and frogs.

The monitoring program has been designed with the intention of providing sufficient statistical power to detect substantial changes in population size, abundance, occupancy and other relevant metrics of indicators. Following the collection of data, the power of the monitoring program to detect change will be subject to formal analysis.

Survey effort

The total annual survey effort, prior to the release of regionally extinct mammals, on Mallee Cliffs NP will be as follows:

- 1856 Pitfall trap nights: 58 sites, 8 traps per site, 4 nights
- 4640 Elliot trap nights: 58 sites, 20 traps per site, 4 nights
- 2784 Funnel trap nights: 58 sites, 12 traps per site, 4 nights
- 928 cage trap nights: 58 sites, 4 traps per site, 4 nights
- 3360 camera trap nights: 120 sites (58 off-road, 62 on-road), 14 nights, twice yearly
- 48 nest-box sites (24 sites, 2 boxes per site)
- 174 bird surveys (standard 2 ha, 20 minute; and Songmeter) (58 sites, 3 replicates)
- 160 bat survey nights (Songmeter) (20 sites, 4 nights), twice yearly
- 160 vehicle spotlight surveys (8 transects of 10 km, 2 repeats)
- 58 surveys of habitat and ecological processes
- 32 vegetation surveys (16 inside fence, 16 outside fence)
- Other surveys will include targeted searches for frogs, Malleefowl and threatened plants, and potentially camera grids for estimating density of feral predators.

The level of effort will increase substantially to monitor survival, population dynamics and other metrics related to reintroduced mammals (as determined in the Translocation Proposal: see below).

The EHMF cannot require an annual average level of effort of more than 4,000 trap nights, 20,000 camera trap nights and 40 vegetation surveys (or the equivalent thereto).

To highlight the significance of the proposed biological survey/monitoring effort under this EHMF, previous monitoring by NSW NPWS on Mallee Cliffs NP has comprised:

- a pitfall-trapping survey for vertebrate fauna at 10 sites conducted on an irregular basis since 2001 (total of 8800 trapnights since 2001, average 550 trapnights/ year).
- surveys of Malleefowl mounds (activity of 149 mounds monitored annually since 1991), and

Monitoring Mallee Cliffs species (regionally extinct mammals)

At least 10 species of ‘extinct in NSW’ mammals (the ‘Mallee Cliffs species’) will be reintroduced to the Mallee Cliffs National Park, initially within a large (>8000 ha) feral predator-free (fenced) area. The species are:

- Western Quoll
- Red-tailed Phascogale
- Numbat
- Western Barred Bandicoot

- Greater Bilby
- Burrowing Bettong
- Brush-tailed Bettong
- Bridled Nailtail Wallaby
- Greater Stick-nest Rat
- Mitchell's Hopping Mouse

The EHMF provides for regular monitoring of populations of Mallee Cliffs species to assess:

- The outcomes (success) of reintroductions of Mallee Cliffs species; and
- The outcomes of reintroductions for ecological health, including consequences for:
    - extant plant and animal species
    - ecological processes.
- The success of reintroductions will be evaluated against short-, medium- and long-term targets. These targets will be specified in the Translocation Proposal to be prepared by AWC as part of the regulatory process for the reintroduction of Mallee Cliffs species. Survey methods to obtain the required information will be incorporated in the EHMF. Targets are expected to include:
    - Short-term: survival of translocated individuals
    - Medium-term: population size, recruitment of young into the population
    - Long-term: population size, genetic diversity.
- The Translocation Proposal will consider the maintenance of genetic diversity in the reintroduced population. Tissue samples will be collected from founding animals and periodically from reintroduced populations for genetic analysis. The analysis will identify any issues in maintenance of genetic diversity and determine what intervention may be required to ensure long-term viability of each species.

Threatened species

The EHMF provides for the monitoring of 24 threatened species or subspecies, comprising 16 birds, three mammals, four birds and a plant: see list below. This includes all threatened birds known to occur on Mallee Cliffs NP, with the exception of two rare raptors; all listed mammals, four of eight threatened reptiles and one of two threatened plants known to occur on the park. The list of threatened species to be monitored will be reviewed annually, taking into account factors such as the detectability of species in surveys.

Taxa	Threatened species
Mammals	Southern Ningaui Western Pygmy-possum Little Pied Bat
Birds	Malleefowl Spotted Harrier Red-tailed Black-Cockatoo Major Mitchell's Cockatoo Flame Robin Hooded Robin Southern Scrub-robin Gilbert's Whistler Varied Sittella

Taxa	Threatened species
	Brown Treecreeper Purple-gaped Honeyeater Black-chinned Honeyeater Pied Honeyeater White-fronted Chat Chestnut Quail-thrush Shy Heathwren
Reptiles	Spinifex Slender Blue-tongued Lizard Western Blue-tongued Lizard Jewelled Gecko Mallee Worm-lizard
Plants	Bitter Quandong

Vegetation and ecological processes

A range of metrics on the ecological health of vegetation will be measured including richness, abundance, frequency, cover and volume (for woody debris).

- Vegetation will be assessed at permanent 1 ha vegetation plots located inside and outside the fenced area proposed for reintroductions. Baseline surveys will be conducted in 2017.

We will also measure soil engineering, via counts of diggings.

Feral animal abundance/distribution

The abundance/distribution of feral animals (or a surrogate measure, such as feral animal activity and/or impacts) will be assessed inside and outside the fence by:

- Camera trap arrays located on/ off tracks at each point
- Spotlight surveys
- If required, track surveys

After feral animals have been removed from within the fenced enclosures, the focus within the fence will be on detecting any incursion of feral animals, through

- Camera trap arrays
- Spotlight surveys
- Track surveys (‘dusting’)

Reporting

The results of monitoring activities will be reported annually, identifying:

- Annual result for indicators.
- An assessment of recent trends for indicators.
- Analysis of overall changes in ecological health.

Review

The Ecological Health Monitoring Framework for Mallee Cliffs will be reviewed annually.

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Introduction

Australia has the worst rate of mammal extinctions in the world. In New South Wales, 25 mammals are listed as extinct under the Threatened Species Conservation Act 1995 (NSW), while over 50% of surviving mammal species are listed as threatened. Extinctions and declines have been particularly severe in the western slopes and plains of NSW (Lunney *et al.* 1996). The loss of native mammals has disrupted important ecological processes including soil and litter turnover, the dispersal of plants and fungi, herbivory and predation, with consequences for ecological health (James and Eldridge 2007; Eldridge and James 2009; James *et al.* 2009; Fleming *et al.* 2014).

Under the Extinct Mammal Agreement, AWC has been contracted by the NSW Government to reintroduce mammal species that are currently listed as extinct in NSW into two places within the national parks estate including Mallee Cliffs National Park. This gives effect to a commitment under the NSW Government's *Saving our Specie*s policy.

On Mallee Cliffs, AWC will establish a large (8000 ha+) feral predator-free area, protected by a conservation fence, into which a suite of 'extinct in NSW' mammals (the 'Mallee Cliffs species') will be reintroduced. The exclusion of feral predators, the primary threat to Australian mammals, is essential to enable reintroduced species to persist on the project site (Short 2009; Dickman 2012). A "beyond the fence" strategy will also be developed, with the objective of releasing Mallee Cliffs species to the unfenced section of Mallee Cliffs, providing an effective feral predator strategy can be developed and deployed.

In conjunction with the mammal reintroductions, AWC will deliver science and land management services, such as feral animal and weed control, across Mallee Cliffs.

The overarching objective of the project is to improve the ecological health of Mallee Cliffs. Ecological health will be considered to have been improved when:

- There is improvement in the status of at least some species, including threatened species, and the status for other significant species is considered acceptable;
- Threats (stressors) are reduced below levels where they have a significant impact on biodiversity; and
- Ecological processes are considered resilient to disturbances.

This document describes the process of selecting the indicators of ecological health of Mallee Cliffs and the manner in which these indicators will be measured, including details of survey design and effort.

Mallee Cliffs

Mallee Cliffs National Park (57,969 ha) was established in 1977 following the purchase of a pastoral leasehold property by the NSW National Parks and Wildlife Foundation. The Park is located in the south-west of NSW, east of the Darling River, approximately 30 km east of Mildura (Figure 1).

Mallee Cliffs NP comprises extensive areas of flat to undulating red sandy plains and sand dunes. Soils are typically calcareous plains of loam or brown solonised sandy loams; some with limestone nodules at the surface. These alternate with an irregular system of low east-west dunes of red earthy sands and sandy solonised brown soils overlying sandy clays. There are no permanent streams or natural water bodies within the national park (NSW NPWS 1998).

The climate is semi-arid. Mean annual rainfall in the region is approximately 300 mm, with substantial year-to-year variation, from 100 mm to over 700 mm. Summers are hot while temperatures often fall below freezing in winter.

The Murray-Mallee region has a rich history of indigenous habitation, with human remains over 30,000 years old discovered at nearby Lake Mungo National Park. Due to the semi-arid climate, the Aboriginal population was concentrated along the Murray River and other watercourses (NSW NPWS 1998). Mallee Cliffs NP is within the traditional lands of the Kureinji people.

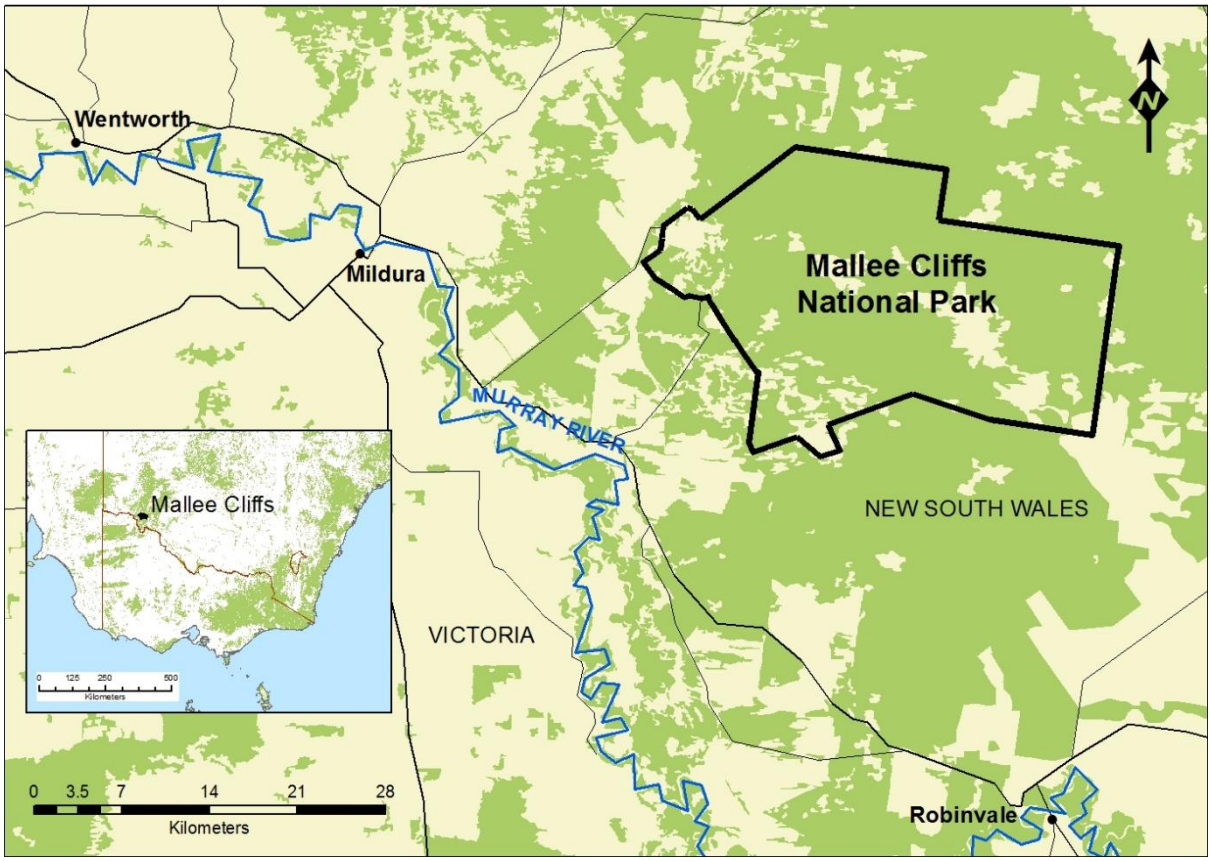

Figure 1. Location and regional context of Mallee Cliffs National Park.

Vegetation

The vegetation of Mallee Cliffs NP has been described and mapped by Morcom and Westbrooke (1990), based on aerial photo interpretation, satellite imagery and floristic surveys of 92 x 0.01 ha quadrats. From these data, 10 vegetation communities were identified, four of which comprise 99% of the area of Mallee Cliffs NP. Detailed descriptions of each of these communities, including full species lists, are provided by Morcom and Westbrooke (1990). Nearly 240 species of native plants have been recorded on the park. A map of the distribution of main vegetation types is presented in Figure 2.

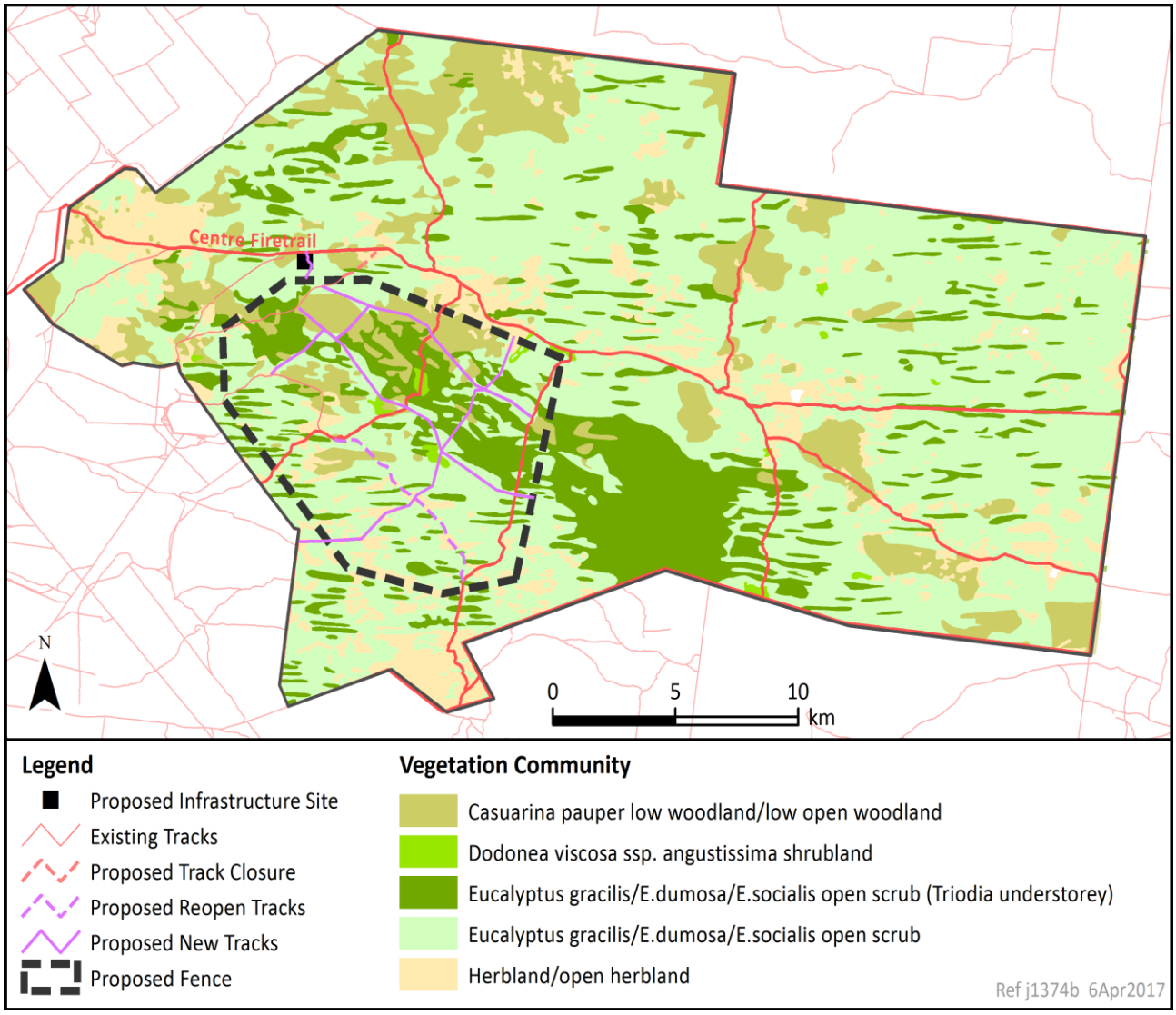

Figure 2. Main vegetation types of Mallee Cliffs National Park

The most common vegetation type on Mallee Cliffs NP, comprising 60% of the park, is Mallee open woodland, dominated by three tree species: Yorrell (*Eucalyptus gracilis*), White Mallee (*E. dumosa*) and Red Mallee (*E. socialis*). A further 16% of the park is Mallee open woodland with a Spinifex (*Triodia* spp.) understorey. Thirteen percent of the park is woodland dominated by Belah (*Casaurina pauper*) and Rosewood (*Alectryon oleifolius*). Small areas (<1%) of other vegetation types are scattered throughout Mallee Cliffs NP, including types characterised by White Cypress Pine (*Callitris glaucophylla*), Black Box (*Eucalyptus largiflorens*), Mulga (*Acacia aneura*), Pearl and Black Bluebush (*Maireanna spp*.) and Narrow-leaved Hopbush (*Dodonaea viscosa*). Approximately 10% of the park is open herbland resulting from historic high-intensity grazing: this vegetation type is thought to have originally been dominated by Bluebush.

Two threatened plants are known from Mallee Cliffs NP: Bitter Quandong *Santalum murrayanum* and a native pea, *Swainsona pyrophila*, a short-lived species that germinates after fire. A number of other threatened plants may be present including as ephemeral herbs or in the soil seed bank. There are three threatened ecological communities in the region, including "Sandhill Pine Woodland in the Riverina, Murray-Darling Depression and NSW South Western Slopes bioregions". Detailed

information on the presence/ condition of threatened ecological communities on Mallee Cliffs NP is not currently available.

Due to a long history of grazing prior to reservation, parts of Mallee Cliffs NP are very weedy. Over 30 species of weeds are known from the park. Only the mallee spinifex and more closed-canopy examples of mallee scrub and Belah woodland are relatively weed free (Morcom and Westbrooke 1990; AWC unpublished).

Vertebrate fauna

Vertebrate fauna surveys have been conducted on Mallee Cliffs NP since the 1990s, including annual monitoring of Malleefowl mound and, since 2001, a trapping program for reptiles and small mammals conducted 11 times in 16 years. Over 210 species of native vertebrates are currently known or considered likely to occur in Mallee Cliffs NP (Appendix 1). The Malleefowl is the only nationally threatened species on Mallee Cliffs NP and is a focus of conservation effort on the park. Another 28 species or subspecies of vertebrates listed as threatened under NSW legislation are known or likely to occur on the park - 17 birds, 8 reptiles and 3 mammal species (Table 1).

The Malleefowl is a focus of conservation effort on Mallee Cliffs NP

Table 1. Threatened vertebrates known or likely to occur on Mallee Cliffs NP. E = Endangered; V = Vulnerable

Scientific name	Common name	Likelihood	EPBC	NSW
BIRDS				
Leipoa ocellata	Malleefowl	Confirmed	V	E
Calamanthus cauta	Shy Heathwren	Confirmed		V
Circus assimilis	Spotted Harrier	Confirmed		V
Hieraaetus morphnoides	Little Eagle	Very Likely		V
Falco subniger	Black Falcon	Very Likely		V
Artamus cyanopterus	Dusky Woodswallow	Confirmed		V
Calyptorhynchus banksii	Red-tailed Black-Cockatoo	Very Likely		V
Lophochroa leadbeateri	Major Mitchell's Cockatoo	Confirmed		V
Certhionyx variegatus	Pied Honeyeater	Confirmed		V
Epthianura albifrons	White-fronted Chat	Confirmed		V
Lichenostomus cratitius	Purple-gaped Honeyeater	Confirmed		V
Melithreptus gularis	Black-chinned Honeyeater	Very Likely		V
Daphoenositta chrysoptera	Varied Sittella	Confirmed		V
Pachycephala inornata	Gilbert's Whistler	Confirmed		V
Drymodes brunneopygia	Southern Scrub-robin	Very Likely		V
Melanodryas cucullata	Hooded Robin	Confirmed		V
Petroica phoenicea	Flame Robin	Very Likely		V
Cinclosoma castanotum	Chestnut Quail-thrush	Confirmed		V
MAMMALS				
Ningaui yvonneae	Southern Ningaui	Confirmed		V
Cercartetus concinnus	Western Pygmy-possum	Confirmed		E
Chalinolobus picatus	Little Pied Bat	Very Likely		V
REPTILES				
Strophurus elderi	Jewelled Gecko	Confirmed		V
Aprasia inaurita	Mallee Worm-lizard	Confirmed		E
Delma australis	Marble-faced Delma	Likely		E
Cyclodomorphus melanops	Spinifex Slender Bluetongue	Very Likely		E
Lerista xanthura	Yellow-tailed Plain Slider	Likely		V
Tiliqua occipitalis	Western Blue-tongued Lizard	Confirmed		V
Echiopsis curta	Bardick	Likely		E
Pseudonaja modesta	Ringed Brown Snake	Likely		E

AWC's Ecohealth Monitoring Framework

The overarching objective of AWC's Extinct Mammal Project is to improve the ecological health of Mallee Cliffs NP. The Ecohealth Monitoring Framework (EHMF) is designed to provide robust information on progress towards that objective, by measuring key indicators of biodiversity (species, guilds and ecological processes) and threats to biodiversity on Mallee Cliffs NP.

Selection of indicators

Biodiversity encompasses the structure, composition and function of ecosystems, considered at a range of scales (Noss 1990). It is not possible to monitor all aspects of biodiversity, so priorities must be identified. In the EHMF, the selection of indicators for monitoring has been guided by conceptual models of interactions between key conservation assets and threats in the region (the term 'indicator' is used in the broad sense of a species or other environmental attribute that provides information on the structure, composition or function of an ecosystem: Noss 1990). An example of one of the conceptual models developed for Mallee Cliffs NP is presented in Figure 3.

Drawing on these models, we have chosen a suite of biodiversity indicators consisting of a number of species or guilds that are:

- declining and/ or threatened
- directly or indirectly affected by mammalian extinctions; and/ or
- strong drivers of ecosystem function.
- In addition, we will conduct surveillance monitoring of a range of taxonomic groups, to provide early warning of any unexpected declines.

Monitoring will extend to a range of indicators of ecological processes, particularly those processes in which reintroduced mammals participate (e.g., soil engineering), as well as attributes of the environment affected by, or which provide habitat for, native species (e.g., vegetation structure and composition, habitat attributes such as woody debris and hollows).

Finally, the EHMF provides for monitoring of a range of indicators of threatening processes, being those threats that are ecologically significant and amenable to management at the project scale:

- introduced predators and herbivores,
- changed fire regimes; and
- weeds.

An additional consideration is that indicators selected for monitoring must be feasible to survey given current techniques and available resources. This is reflected in this EHMF. Some indicators will be sampled by 'omnibus' survey techniques that capture a wide range of species. Additional, targeted surveys will be carried out where omnibus surveys are inadequate including diurnal vehicle based surveys for Numbat, nest boxes for Western Pygmy Possums, targeted surveys for threatened birds and plants and camera grids for estimating density of feral predators.

Biodiversity indicators

Biodiversity indicators selected for monitoring on Mallee Cliffs National Park are listed in Table 2, along with the rationale for their selection and associated metrics. Further details on selected indicators, survey design and methodologies are provided below.

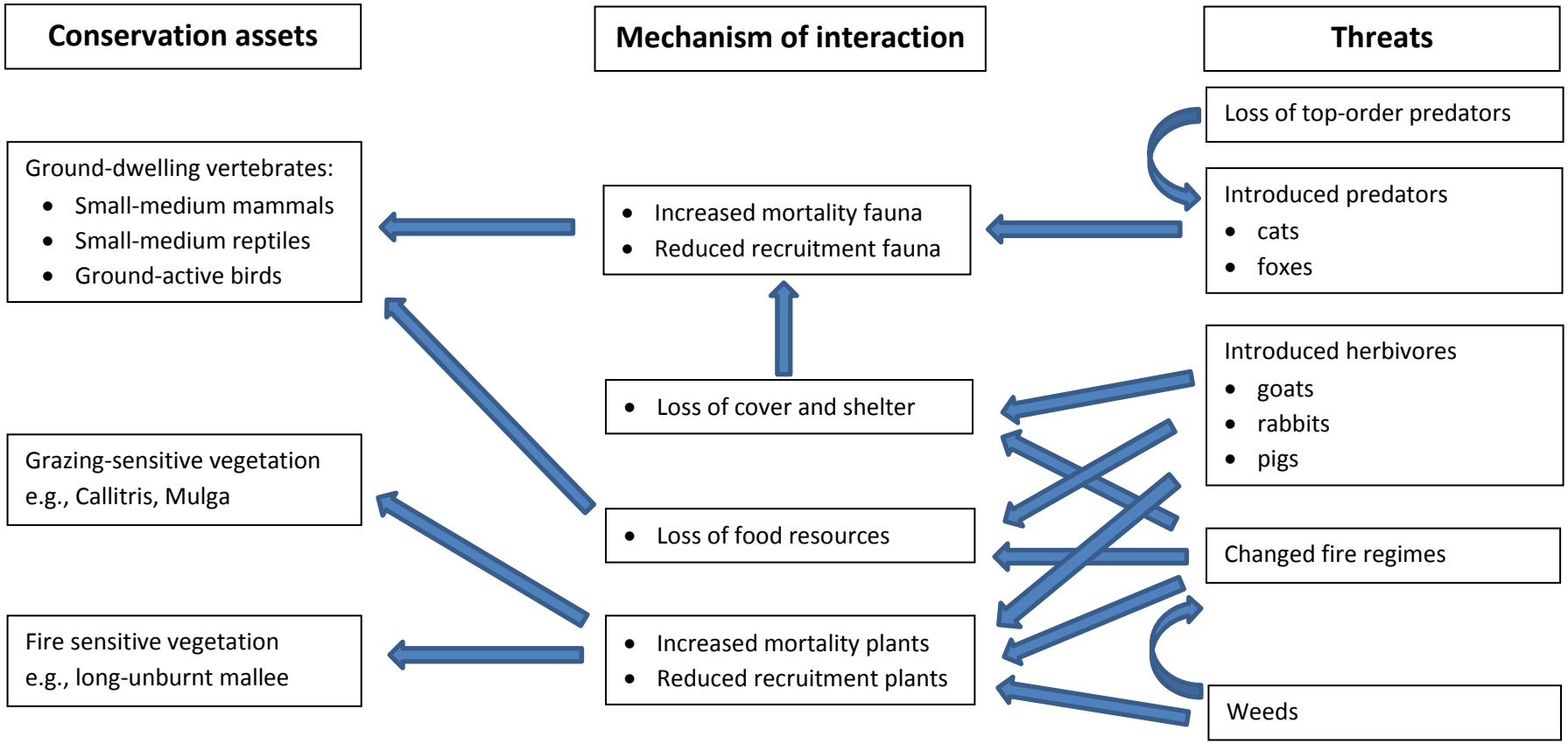

Figure 3. Conceptual model of interactions between conservation assets and threats in Mallee Cliffs NP. Not all assets, threats and their possible interactions have been listed in this model.

Table 2. Biodiversity indicators for ecohealth monitoring framework for Mallee Cliffs. Rationale for selection: T = threatened or declining; A = affected by mammalian extinction; D = strong driver of ecosystem function; S = surveillance monitoring.

Metric definitions: Population size = estimate of number of individuals in project area; abundance = number of individuals or captures/100 trap nights or site; activity = number of records/site; occupancy = proportion of sites recorded; richness = mean number of species/site.

Indicator	**Rationale**				**Survey method**	**Metric/s** (in order of preference)
	T	**A**	**D**	**S**		
Mammals						
Small-medium mammals						
Western Quoll	*	*	*		Cage traps, camera traps	Population size, abundance, occupancy
Red-tailed Phascogale	*	*			Box traps, nest-boxes, camera traps	Population size, abundance, occupancy
Numbat	*	*			Diurnal vehicle-based survey transects	Population size
Western Barred Bandicoot	*	*	*		Cage traps, camera traps	Population size, abundance, occupancy
Greater Bilby	*	*	*		Spotlight transects, cameras	Population size, abundance, occupancy
Burrowing Bettong	*	*	*		Cage traps	Population size
Brush-tailed Bettong	*	*	*		Cage traps	Population size
Bridled Nailtail Wallaby	*	*	*		Spotlight transects, cameras	Population size, abundance, occupancy
Greater Stick-nest Rat	*	*			Box traps, pitfall traps, camera traps	Population size, abundance, occupancy
Mitchell's Hopping Mouse	*	*			Pitfall traps, camera traps	Population size, abundance, occupancy
Short-beaked Echidna				*	Camera traps	Abundance, occupancy
[Yellow-footed Antechinus]				*	Box traps, pitfall traps	Abundance
Southern Ningaui	*			*	Box traps, pitfall traps	Abundance
Common Dunnart				*	Box traps, pitfall traps	Abundance
Fat-tailed Dunnart				*	Box traps, pitfall traps	Abundance
Small-medium mammals – guild (dasyurids, bandicoots, bettongs, rodents)	*	*	*		Box traps, cage traps, pitfall traps	Abundance, richness
Large herbivores						
Red Kangaroo			*	*	Spotlight transects, cameras	Population size, abundance
Eastern Grey Kangaroo			*	*	Spotlight transects, cameras	Population size, abundance

Indicator	**Rationale**				**Survey method**	**Metric/s** (in order of preference)
Western Grey Kangaroo			*	*	Spotlight transects, cameras	Population size, abundance
Euro			*	*	Spotlight transects, cameras	Population size, abundance
Arboreal mammals						
Western Pygmy Possum	*				Nestboxes, box traps, pitfall traps	Abundance, occupancy
Bats						
Little Pied Bat	*				Songmeter SM4BAT detectors	Activity, occupancy
Microbats - guild				*	Songmeter SM4BAT detectors	Activity, richness
Reptiles						
Small-medium-sized reptiles						
Spinifex Slender Blue-tongued Lizard	*				Pitfall traps, funnel traps	Abundance
Western Blue-tongued Lizard	*				Pitfall traps, funnel traps	Abundance
Jewelled Gecko	*				Pitfall traps, funnel traps	Abundance
Mallee Worm-lizard	*				Pitfall traps, funnel traps	Abundance
Small-medium reptiles - guild		*		*	Pitfall traps, funnel traps	Abundance, richness
Birds						
Woodland birds						
Red-tailed Black-Cockatoo	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Major Mitchell's Cockatoo	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Spotted Harrier	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Gilbert's Whistler	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Varied Sittella	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Purple-gaped Honeyeater	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Black-chinned Honeyeater	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Pied Honeyeater	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Woodland birds - guild	*			*	Standard bird survey: 2 ha plot 20-min counts	Abundance, richness
Ground-active birds						

Indicator	**Rationale**				**Survey method**	**Metric/s** (in order of preference)
Malleefowl	*				Mound survey, cameras	Abundance
Brown Treecreeper	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Flame Robin	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Hooded Robin	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Southern Scrub-robin	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Chestnut Quail-thrush	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Shy Heathwren	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
White-fronted Chat	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Ground active birds - guild	*			*	Standard bird survey: 2 ha plot 20-min counts	Abundance, richness
Frogs						
[Frog species – TBD]				*	Targeted surveys on warm, wet nights	Abundance, occupancy
Frogs - guild				*	Targeted surveys on warm, wet nights	Abundance, occupancy
Vegetation						
Tree cover and composition			*	*	Vegetation surveys on 40 x 1 ha plots	TBD
Shrub cover and composition		*	*	*	Vegetation surveys on 1 ha plots	TBD
Ground cover and composition		*	*		Vegetation surveys on 1 ha plots	TBD
Hollow-bearing trees			*		Counts on 1 ha plots	Mean no. habitable tree hollows/site
Hollow logs			*		Counts on 1 ha plots	Mean no. logs with hollows/site
Woody debris			*		Counts by size class on 1 ha plots	Mean volume (m^3/ ha)/ site
Threatened / declining vegetation						
Bitter Quandong (*Santalum murrayanum*)	*				Surveys of known sites/ potential habitat	Abundance (by size class)
Cypress Pine (*Callitris verrucosa, Callitris glaucophylla*)	*				Surveys of known sites/ potential habitat	Abundance (by size class)
Mulga (*Acacia aneura*)	*				Surveys of known sites/ potential habitat	Abundance (by size class)
[Threatened ecological communities TBD]	*				TBD: condition, composition	TBD: metrics of condition, composition
Ecological processes						
Incidence of diggings		*	*		Counts on transects on 1 ha plots	Mean no. diggings/ ha

Mammals

Small- to medium-sized terrestrial mammals

Small to medium-sized (<5.5 kg) terrestrial mammals are particularly vulnerable to predation by foxes and feral cats (Woinarski et al. 2014). Fifteen of the 22 species that formerly occurred in the region of Mallee Cliffs NP have become extinct in NSW; five of these species are globally extinct (Table 3). The only species in the guild present on Mallee Cliffs NP are the Echidna, Fat-tailed Dunnart, Common Dunnart and Southern Ningaui.

Table 3. Small- to medium sized terrestrial mammal fauna of the Mallee Cliffs region (sources: Krefft 1866; NSW NPWS 1998; Woinarski *et al*. 2014). Shading = species to be reintroduced to Mallee Cliffs NP.

Species	Status NSW	Present distribution
Echidna *Tachyglossus aculeatus*		Widespread
Western Quoll *Dasyurus geoffroii*	Extinct	Restricted to south-west WA. Reintroduced to parts of WA, recently to Flinders Ranges, SA
Yellow-footed Antechinus *Antechinus flavipes*		Widespread in eastern forests and SW WA. Not recorded in NPWS surveys of Mallee Cliffs
Red-tailed Phascogale *Phascogale calura*	Extinct	Restricted to remnant eucalypt woodlands in SW WA
Common Dunnart *Sminthopsis murina*		Widespread in woodlands eastern Australia. Recent records Mallee Cliffs NP.
Fat-tailed Dunnart *Sminthopsis crassicaudata*		Widespread in southern and central Australia. Recent records Mallee Cliffs NP.
Southern Ningaui *Ningaui yvonneae*	Vulnerable	Patchy distribution semi-arid NSW, Victoria, SA and WA. Recent records Mallee Cliffs NP.
Numbat *Myrmecobius fasciatus*	Extinct	Restricted to SW WA, reintroduced to several feral predator free AWC sanctuaries
Pig-footed Bandicoot *Chaeropus ecuadatus*	Extinct	Globally extinct
Southern Brown Bandicoot *Isoodon obesulus*	Endangered	Restricted to coastal southern Australia.
Western Barred Bandicoot *Perameles bougainville*	Extinct	Persists on Shark Bay islands; reintroduced to AWC's Faure Island and Arid Recovery
Greater Bilby *Macrotis lagotis*	Extinct	Persists in north of range. Reintroduced to feral predator-free areas inc. AWC sanctuaries
Brush-tailed Bettong *Bettongia penicillata*	Extinct	Persists in south-west WA. Reintroduced to feral predator-free areas inc. AWC sanctuaries
Burrowing Bettong *Bettongia lesueur*	Extinct	Persists several islands in WA. Reintroduced to feral predator-free islands and fenced areas
Eastern Hare Wallaby *Lagorchestes leporides*	Extinct	Globally extinct
Bridled Nailtail Wallaby *Onchyolagea fraenata*	Extinct	One remnant population in Qld; reintroduced to AWC's Scotia sanctuary
White-footed Rabbit-Rat *Conilurus albipes*	Extinct	Globally extinct
Lesser Stick-nest Rat *Leporillus apicalis*	Extinct	Globally extinct

Species	Status NSW	Present distribution
Greater Stick-nest Rat *Leporillus conditor*	Extinct	One remnant population on Franklin Islands, SA; reintroduced to other feral predator-free islands and sanctuaries inc AWC's Mt Gibson
Mitchell's Hopping Mouse *Notomys mitchellii*	Extinct	Semi-arid Victoria, SA and WA.
Desert Mouse *Pseudomys desertor*	Critically Endangered	Largely restricted to central Australia. One recent record from north-west NSW
Gould's Mouse *Pseudomys gouldii*	Extinct	Globally extinct

Indicator species

All small- to medium-sized terrestrial mammals present in the project area will be monitored. These include:

- extant species:
    - Short-beaked Echidna
    - Yellow-footed Antechinus (if present)
    - Southern Ningaui
    - Fat-tailed Dunnart
    - Common Dunnart
- mammals to be reintroduced to Mallee Cliffs (the 'Mallee Cliffs species'):
    - Greater Bilby
    - Brush-tailed Bettong
    - Burrowing Bettong
    - Bridled Nailtail Wallaby
    - Western Quoll
    - Red-tailed Phascogale
    - Numbat
    - Western Barred Bandicoot
    - Greater Stick-nest Rat
    - Mitchell's Hopping Mouse

We will also report on abundance and richness of small- to medium-sized mammals from the following guild: dasyurids, bandicoot, bettongs, and rodents.

Rationale for inclusion

Small- to medium-sized mammals qualify for inclusion in the monitoring program on the following criteria:

- All reintroduced species and one extant species, Southern Ningaui, are threatened.
- Many species in the guild are important drivers of ecosystem processes (soil engineering; other roles including predation, seed and fungal spore dispersal).
- Small- to medium-sized mammals are particularly vulnerable to introduced predators. Several taxa (dasyurids, bandicoots, bettongs and rodents) can be readily trapped. The abundance and richness of species in this guild provide robust metrics that allow ready comparison with other locations (e.g., Woinarski et al. 2010).

Survey methodology

Small- to medium-sized mammals will be surveyed using the following techniques:

- Live traps (box traps, cage traps, pitfall traps) will be used to monitor dasyurids, bandicoots, bettongs and rodents.
- Spotlight transects and cameras will be used to monitor species that do not readily enter traps (Bilbies and Bridled Nailtail Wallabies).
- Diurnal vehicle-based surveys will be used to monitor Numbats
- Cameras will provide records of all medium-sized mammals.

Unit of measurement

Population size is the preferred metric for reintroduced mammals, estimated by live-trapping or transect-based observational surveys (spotlighting or diurnal drive transects). Data from trapping of medium-sized mammals, with individuals marked to identify individuals, will be analysed using capture-mark-recapture (CMR) models. Data from transect surveys will be analysed using a strip transect approach to estimate density and population size. For the Western Quoll, it may be possible to estimate population size from camera images using a spatially-explicit capture-recapture (SECR) model, provided photos can be identified to individuals by analysis of spot patterns.

Abundance (mean capture rate per 100 trap nights) will be calculated for those small mammals that are not identified to individuals. Abundance and richness (mean number of species in the guild captured per site) will also be calculated for the guild of small- to medium-sized mammals (dasyurids, bandicoots, bettongs and rodents).

Camera data will be analysed to provide measures of abundance (number of records per 100 camera trap nights, or other metric of activity) and occupancy (proportion of sites recorded) for all medium-sized mammals. These metrics are likely to be useful where populations are too sparse for robust estimates of population size using the methods outlined above.

Baseline

The mammal species proposed for reintroduction to Mallee Cliffs have not been present in the region for at least a century.

Baseline data are available for three extant species (Common Dunnart, Fat-tailed Dunnart, Southern Ningaui) from live trapping surveys conducted by NSW NPWS at 10 sites on Mallee Cliffs NP on 11 occasions between 2001-14. Capture rates of the Southern Ningaui, the most commonly trapped small mammal, declined markedly from 2001-06 (average capture rate of 3.0%; i.e., 3 per 100 trapnights) to 2008-14 (average capture rate of 0.6%). Capture rates of both dunnarts have remained relatively stable over this period (Common Dunnart 0.8%, Fat-tailed Dunnart 0.1%).

As a guild, small-medium sized mammals have declined in abundance from 2001-06 to 2008-14 (average capture rate has fallen from 3.8% to 1.4%), while richness has remained relatively constant at 2.2 – 2.3 species captured/ survey.

Note that due to the limited number of sites and differences in trap layout, these data are not strictly comparable with data that will collected by AWC's monitoring program.

Large herbivores

The large terrestrial herbivores (>5.5 kg) present on Mallee Cliffs NP are:

- Red Kangaroo
- Eastern Grey Kangaroo
- Western Grey Kangaroo

- Euro

Baseline surveys conducted by AWC in 2016 found that Red Kangaroos and Western Grey Kangaroos were the most commonly encountered macropods in Mallee Cliffs NP, with smaller numbers of Eastern Grey Kangaroos and Euros.

Indicator species

All macropods present on Mallee Cliffs NP will be monitored.

Rationale for inclusion

Large herbivores are potentially strong drivers of ecosystem processes. Macropods may have a substantial effect on vegetation dynamics (Letnic et al. 2012).

Survey methodology

Macropods will be surveyed using a road-based spotlight survey and cameras.

Unit of measurement

Population size will be estimated for macropods using strip transect methods. Cameras will provide a measure of abundance (number of records of each species per 100 camera trap nights, or other metric of activity).

Baseline

Baseline data are not available for macropods in the project area.

Arboreal mammals

One species of arboreal mammal, the Western Pygmy Possum, is known to occur on Mallee Cliffs NP. This species is listed as Endangered in NSW. Two other arboreal mammals, the Common Brushtail Possum and Feathertail Glider, occur in the region and could possibly occur on Mallee Cliffs NP.

Indicator species

- Western Pygmy Possum

Rationale for inclusion

At present, the Western Pygmy Possum is the only arboreal mammal known to occur on Mallee Cliffs NP. It is a threatened species.

Survey methodology

Western Pygmy Possum will be surveyed using nest-boxes and/ or live traps, the optimal method to be determined from trials of both methods. A total of 48 nest-boxes will be deployed permanently or temporarily at 24 sites (two per site), with 12 sites located inside and 12 outside the fence, comprising four replicate sites in the three main vegetation types with tree cover (i.e., mallee shrub, mallee spinifex, Belah/ Rosewood). Western Pygmy Possum will also be captured in live traps (pitfalls, box traps).

Unit of measurement

Nest-box box surveys will provide data on abundance (number of individuals/ 48 next boxes) and occupancy (proportion of sites with records). Trapping surveys will provide data on abundance (number of individuals per 100 trap nights) and occupancy (proportion of sites with records).

Baseline

Capture rates of Western Pygmy Possum declined markedly on Mallee Cliffs NP over the duration of NSW NPWS trapping surveys, from an average capture rate of 2.9% (i.e., per 100 trapnights) in 2001-06 to 0.3% in 2008-14.

Note that due to the limited number of sites and differences in trap layout (and absence of nest-boxes), these data are not directly comparable with data that will be collected by AWC's monitoring plan.

There are no baseline data on the other two species of arboreal mammals that might possibly occur on Mallee Cliffs NP.

Bats

Eight species of microchiropterans ('microbats') are known or likely to occur on Mallee Cliffs NP:

- Inland Free-tailed Bat
- South-eastern Free-tailed Bat
- White-striped Freetail Bat
- Gould's Wattled Bat
- Chocolate Wattled Bat
- Little Pied Bat
- Lesser Long-eared Bat
- Inland Broad-nosed Bat

One microbat, the Little Pied Bat, is listed as threatened in NSW.

Indicator species

Monitoring will focus on species detectable by acoustic recorder. This includes the Little Pied Bat, the only threatened species in the guild on Mallee Cliffs NP.

Analysis will also be conducted of activity and species richness at the guild level (i.e., all microbats detectable by acoustic recorder).

Rationale for inclusion

The microbat selected for monitoring on Mallee Cliffs is threatened and potentially detectable with sound recorders. Guild-level analysis will monitor activity and richness across all species detected with sound recorders.

Survey methodology

Microbats will be surveyed using acoustic recorders (Songmeter SM4BAT detectors), which detect calls primarily associated with feeding activity.

Unit of measurement

Data will provide an index of activity for individual bat species (i.e., number of calls detected per site) and occupancy (proportion of sites occupied). Guild level metrics will be activity (mean number of calls of all species detected per site) and richness (mean number of species per site).

Baseline

Unknown.

Reptiles

Reptiles are a significant component of the vertebrate fauna of Mallee Cliffs NP, with 50 species of small-medium reptiles (skinks, dragons, geckoes, pygopodids), 14 snakes, three blind snakes, and two monitors known or likely to inhabit the project area (See Appendix 1). Eight reptiles are listed as threatened in NSW: two snakes, the Bardick and Ringed Brown Snake; two pygopods, the Mallee Worm-lizard and Marbled Faced Delma; a gecko, the Jewelled Gecko; and four skinks: Spinifex Slender Blue-tongued Lizard, Western Blue-tongued Lizard, and Yellow-tailed Plain Slider.

Indicator species

Monitoring will focus on threatened reptiles likely to be detected in sufficient numbers in trapping surveys:

- Jewelled Gecko
- Spinifex Slender Blue-tongued Lizard
- Western Blue-tongued Lizard
- Mallee Worm-lizard

The abundance and richness of the guild of small- to medium-sized reptiles will also be monitored.

Rationale for inclusion

The Eastern Slender Bluetongue, Western Blue-tongued Lizard, Jewelled Gecko and Mallee Worm-lizard are listed as threatened in NSW.

Surveillance monitoring of small- to medium-sized reptiles is warranted given the diversity of the guild. Evidence from AWC's Scotia sanctuary suggests some small- to medium-sized reptiles may also be affected by mammalian extinctions. The mechanisms of interaction are unclear: it may be direct (e.g., predation) or indirect (reduced thermal refuge or refuge from predation, due to reduced amount of leaf litter as a result of digging by reintroduced mammals: Hayward et al. 2016). In addition, the removal of feral predators from fenced areas may advantage large reptiles that prey on small reptiles.

Survey methodology

Small- to medium-sized reptiles will be surveyed with pitfall and funnel traps.

Unit of measurement

Live traps will provide data on abundance (mean capture rate/100 trap nights) for each species. Metrics of abundance and richness (number of species/site) will be calculated for the guild of small-medium reptiles.

Baseline

Capture rates of both the Mallee Worm Snake and Jewelled Gecko have increased markedly on Mallee Cliffs NP over the duration of NSW NPWS trapping surveys, from an average capture rate of 0.05% (i.e., 0.05 per 100 trapnights) and 0.02%, respectively, in 2001-06 to 0.2% in 2008-14. Capture rates of Western Blue Tongue have remained very low throughout. There are no baseline data on the Spinifex Slender Blue-tongued Lizard.

The guild of small-medium sized reptiles (skinks, dragons, geckoes, pygopodids) has increased in abundance from a mean capture rate of 25% in 2001-06 to 37% in 2008-14, while richness has remained constant (on average, 23 species captured/ survey).

Note that due to the limited number of sites and differences in trap layout, these data are not strictly comparable with data that will collected by AWC's monitoring program.

Birds

Mallee Cliffs NP is known or likely to support 123 species of birds (Appendix 1). Nineteen of these bird species are listed as threatened:

- Malleefowl
- Black Falcon
- Little Eagle
- Spotted Harrier
- Red-tailed Black-Cockatoo
- Major Mitchell's Cockatoo
- Flame Robin
- Hooded Robin
- Southern Scrub-robin
- Gilbert's Whistler
- Varied Sittella
- Brown Treecreeper
- Purple-gaped Honeyeater
- Black-chinned Honeyeater
- Pied Honeyeater
- White-fronted Chat
- Chestnut Quail-thrush
- Shy Heathwren

Indicator species

All threatened birds that can be recorded sufficiently frequently with standard or targeted bird surveys to provide a reliable signal of change will be monitored. A provisional list is below - the list will be refined after the conduct of bird surveys.

Birds will be categorised in two broad guilds sensitive to decline (woodland-dependent and ground-active species), noting that the ground-active guild is largely a subset of the woodland-dependent guild. However, ground-active species are especially vulnerable to feral predators.

1. Woodland-dependent species

- Red-tailed Black-Cockatoo
- Major Mitchell's Cockatoo
- Spotted Harrier
- Gilbert's Whistler
- Varied Sittella
- Purple-gaped Honeyeater
- Black-chinned Honeyeater
- Pied Honeyeater

2. Ground-active species

- Malleefowl
- Flame Robin
- Hooded Robin

- Southern Scrub-robin
- Brown Treecreeper
- White-fronted Chat
- Chestnut Quail-thrush
- Shy Heathwren

In addition, abundance and richness will be monitored at the guild level.

Rationale for inclusion

Bird species selected for monitoring are threatened, and the woodland-dependent and ground-active guilds are generally in decline.

Survey methodology

Diurnal birds will be counted in standard 2 ha, 20 minute searches at each monitoring site, repeated three times per site per survey period.

Standard practice for monitoring Malleefowl breeding density is to visit known mounds and record evidence of activity (Benshemesh 2004). Malleefowl commonly renovate existing mounds during breeding seasons, rather than build new mounds. NSW NPWS have monitored on the activity of 149 Malleefowl mounds on Mallee Cliffs NP on an annual basis since 1991.

Unit of measurement

Malleefowl activity will be recorded from surveys of mounds. NSW NPWS have documented the location of numerous Malleefowl mounds across Mallee Cliffs NP; additional mounds have been located by AWC. A more comprehensive search for mounds may be undertaken using remote sensing.

For other species, abundance (number of records/ site) and occupancy (proportion of sites recorded) will be calculated from standard bird surveys. Abundance (number of records/ site) and richness (mean number of species/ site) will be calculated for woodland-dependent and ground-active bird guilds.

Baseline

NSW NPWS have monitored the activity of Malleefowl mounds on Mallee Cliffs NP on several occasions over the last decade; in the most recent survey, 2016, three of 149 mounds were active. There are no data on other bird species. Most of the threatened birds on Mallee Cliffs NP belong to woodland-dependent and/ or ground-active bird guilds that are generally in decline in southern Australia (Reid 1999; Kavanagh et al. 2007).

Frogs

Five species of frogs are likely to inhabit Mallee Cliffs. None are threatened.

- Eastern Banjo Frog
- Long-thumbed Frog
- Spotted Grass Frog
- Sudell's Frog
- Eastern Sign-bearing Froglet

Indicator species

Frogs that can be recorded in targeted surveys with sufficient rigour to provide a reliable signal of change will be monitored. Frogs will also be reported at the guild level.

Rationale for inclusion

In general, frogs are at risk of decline from multiple causes including trampling of waterholes by feral herbivores and pigs and (for some species) infection by the introduced chytrid fungus.

Survey methodology

Frogs will be surveyed by a combination of listening, call-playback, spotlighting and road-based spotlight surveys on warm, wet nights. Trials of these methods will be conducted to develop an optimal monitoring protocol for Mallee Cliffs NP.

Unit of measurement

Individual frog species, if monitored, will be reported in terms of abundance (number of records/ site) and occupancy (proportion of sites recorded). Abundance and richness (number of species/site) will be measured at the guild level.

Baseline

Unknown.

Vegetation

Vegetation structure and composition

Nearly 240 species of native plants have been recorded on Mallee Cliffs NP. Vegetation composition and structure are fundamental components of habitat for wildlife. Vegetation patterns on Mallee Cliffs NP vary with substrate and the history and intensity of disturbance including grazing and fire (Morcom and Westbrooke 1990). The reintroduction of small-medium sized mammals to Mallee Cliffs NP is expected to partially restore a range of ecological processes including herbivory, seed and spore dispersal, soil engineering and litter disturbance and consequently alter vegetation dynamics and potentially composition and structure in the project area.

Indicators

Indicators will include aspects of:

- Tree cover and composition
- Shrub cover and composition
- Ground cover and composition
- Habitat features: hollow trees, hollow logs, woody debris

Rationale for inclusion

Vegetation is an important component of biodiversity in its own right, while the structure and composition of vegetation are primary determinants of habitat for fauna. Australian vegetation has evolved in the presence of mammal species that participate in a number of important ecological processes. Most of the reintroduced species are herbivores or omnivores; the activities of these species (including herbivory, seed dispersal, seed predation, disturbance of the soil and litter layer) can be expected to influence the structure, composition and dynamics of vegetation. In turn, the availability of palatable vegetation can be expected to influence the abundance of herbivorous/omnivorous mammals reintroduced to Mallee Cliffs NP.

The vegetation of Mallee Cliffs NP has been modified by over a century of grazing and continuing presence of feral herbivores, with limited recruitment of species such as Mulga, Cypress Pine, Belah, Rosewood and Bluebush (NSW NPWS 1998).

The monitoring program is designed to provide information on vegetation dynamics in the project area, the impacts of reintroductions on those dynamics and any knock-on consequences for the carrying capacity of reintroduced mammals. Better knowledge of the impacts of reintroductions on vegetation will provide valuable insights on the functioning of Australian ecosystems in the presence of small-medium sized mammals – until recently, the prevailing conditions under which those ecosystems have evolved.

Survey methodology

Vegetation structure and composition will be monitored on 32 permanent 1 ha vegetation plots comprising 16 sites (four replicates of the four main vegetation types) inside and 16 sites outside the proposed fenced area. Baseline surveys will be conducted in 2017.

Unit of measurement

A range of metrics will be derived from the vegetation monitoring including richness, abundance, frequency, cover and volume (for woody debris).

Baseline

Some baseline data may be available from plots established by Morcom and Westbrooke (1990), and potentially other research projects established on the park (David Eldridge, pers. comm.)

Threatened plant species and communities

Two threatened plants are known from Mallee Cliffs NP: Bitter Quandong and *Swainsona pyrophila*. A number of other threatened plants may be present including ephemeral herbs or species held in the soil seed bank. Three threatened ecological communities in the region may be present on the park including "Sandhill Pine Woodland in the Riverina, Murray-Darling Depression and NSW South Western Slopes bioregions". Detailed information on the presence/ condition of threatened ecological communities on Mallee Cliffs NP is not currently available.

Indicators

- Bitter Quandong
- *Swainsona pyrophila*
- Threatened communities, depending on presence on the park

Rationale for inclusion

The plant species and, if present, vegetation communities selected for monitoring are threatened.

Survey methodology

The threatened plants will require targeted monitoring. Surveys will be conducted in known locations.

Threatened plant communities will be monitored in relation to condition and potentially composition and/ or structure. Methods for assessment are to be determined.

Unit of measurement

For threatened plants, the metric will be abundance (mean number of individuals per transect).

The condition of threatened plant communities will be assessed in relation to the severity and extent of disturbance, and other measures relevant to that community (composition, structure, recruitment).

Baseline

Unknown.

Ecological processes

Important ecological processes relevant to the Extinct Mammals Project include those conducted by reintroduced mammals: soil engineering (diggings and burrows), seed and spore dispersal, herbivory and predation. Processes amenable to rapid survey (i.e., diggings) will be monitored directly; other processes (i.e., seed and spore dispersal, herbivory) will be monitored indirectly through their long-term impacts on vegetation structure and composition.

Indicators

- Diggings.

Rationale for inclusion

Diggings by small-medium sized mammals are an important ecological process, influencing rates of water and nutrient retention, seed germination and plant recruitment.

Survey methodology

Diggings will be surveyed within 1 ha vegetation monitoring plots (survey design to be determined).

Unit of measurement

Mean number of diggings per ha.

Baseline

Given the extinction of small-medium size mammals, baseline values for diggings are likely to be very low.

Threat indicators

Threat indicators selected for monitoring on Mallee Cliffs National Park are listed in Table 4. The table provides the rationale for selecting indicators, survey methods and metrics. Further details on selected indicators, survey designs and methodologies are provided below.

Table 4. Threat indicators for ecohealth monitoring framework for Mallee Cliffs. Metric definitions: Population density = number of individuals/ unit area (ha or km^2); abundance = number of records per 100 trapnights or site; occupancy = proportion of sites recorded.

Indicator	**Rationale**	**Survey method**	**Metric/s** (in order of preference)
Feral predators			
Cat	Major threat to wildlife	Cameras	[Population density], abundance, occupancy
Fox	Major threat to wildlife	Cameras	[Population density], abundance, occupancy
Wild dogs	Potential threat to wildlife	Cameras	Abundance, occupancy
Feral herbivores			
Goat	Threat to wildlife, vegetation	[Aerial survey], spotlight transects, cameras	[Population density], abundance, occupancy
Rabbit	Threat to wildlife, vegetation	[Dung counts], cameras	[Population density], abundance, occupancy
Pig	Threat to wildlife, vegetation, wetlands	[Aerial survey], spotlight transects cameras	[Population density], abundance, occupancy
Weeds			
African boxthorn	Threat to vegetation, listed weed	Vegetation surveys, targeted surveys	Extent of infestation (categorised by density)
Wards Weed	Threat to vegetation, wildlife	Vegetation surveys	Extent of infestation (categorised by density)
Other weeds TBD	[Threat to vegetation]	Vegetation surveys, targeted surveys	Extent of infestation (categorised by density)
Fire			
Suite of ecologically-relevant metrics, calculated for (i) all fire; and (ii) wildfire	Key driver of vegetation dynamics, structure and composition, habitat attributes	Remote sensing, ground traverse	• Extent • Frequency (no. times burnt in given period) • Time since fire • Distance to unburnt (mean, maximum)

Feral predators

Introduced predators present on Mallee Cliffs NP are the feral cat, fox and wild dog.

Indicator species

- Feral cats
- Foxes
- Wild dogs

Rationale for inclusion

Feral cats and foxes are primarily responsible for the decline of small-medium sized mammals (Woinarski *et al*. 2014) and both cats and foxes are serious predators of ground-active birds such as Malleefowl. Cats have been present in the Murray mallee region since the mid 19th century (Abbott 2008) and foxes since the late 19th century (Saunders *et al.* 1995). Wild dogs are generalist predators.

Survey methodology

Feral predators will be surveyed by cameras. AWC has developed a method for estimating cat density in northern Australia from data obtained by cameras set in areas of likely high activity using spatially-explicit capture-recapture (SECR) models (McGregor *et al.* 2015). The method requires that a high proportion of cats in a locality are captured on camera and are identifiable to individuals: the applicability of the survey method to southern Australia is unknown. Further, the method is not suited to foxes and wild dogs.

AWC is currently conducting research at Scotia Wildlife Sanctuary, in western NSW, to develop optimal methods for monitoring foxes and cats. Until this work is complete, we will report activity and occupancy metrics for cats, foxes and wild dogs from an array of cameras deployed across Mallee Cliffs NP (see below).

Unit of measurement

If a method proves feasible in southern Australia, the population density of cats will be estimated from cameras using a spatially-explicit capture-recapture (SECR) model. In the interim, cameras will provide data on abundance (number of records per 100 trapnights or site) and occupancy (proportion of occupied sites) of cats, foxes and wild dogs.

Baseline

There are no data on density or abundance of feral predators on Mallee Cliffs NP.

Feral herbivores

Introduced herbivores can have substantial negative impacts on ecosystems by directly reducing the diversity and abundance of palatable plant species, facilitating the spread of weeds, increasing the abundance of introduced predators and reducing ecosystem resilience to disturbances (Vázquez 2002, Nunez *et al.* 2010). Introduced herbivores particularly. Three introduced herbivores: goats, pigs and rabbits, are present on Mallee Cliffs NP.

Indicator species

- Goats
- Rabbits
- Pigs

Rationale for inclusion

Feral herbivores are a threat to vegetation. Heavily grazed areas reduce ground cover and increase exposure of small-medium mammals and ground-active birds to predation (McGregor *et al.* 2014). Rabbits can support high numbers of feral predators with knock-on effects for predation on native animals (Pedler *et al.* 2016).

Survey methodology

Optimal survey methods for feral herbivores are to be determined in Mallee Cliffs. The density of large feral herbivores can be estimated from aerial survey, however in vegetation types with dense canopy cover aerial surveys may miss many individuals. Alternative methods include spotlight transects, counts at waterholes or camera arrays. A number of methods have been developed for surveying rabbits, including counts of warrens and dung counts (Mutze *et al.* 2014), with optimal methods depending partly on rabbit density. Initially, activity and occupancy of feral herbivores will be measured with spotlight transects and the array of cameras deployed across Mallee Cliffs NP (see below).

Unit of measurement

Cameras will provide data on abundance (number of records per 100 trapnights or site) and occupancy (proportion of sites with records) of feral herbivores. Spotlight transects will provide data on density of goats and pigs, provided there are sufficient records.

Baseline

There are no robust data on the density or abundance of feral herbivores in the project area.

Weeds

Mallee Cliffs NP is very weedy, due to a long history of grazing. Ward's weed (*Cabomba caroliniana*) is the dominant ground cover in open herbfields. One weed, African boxthorn (*Lycium ferocissimum*) is a listed noxious weed, requiring active management.

Indicator species

- African boxthorn
- Wards weed
- [Additional species TBD, following the identification of all ecologically significant weeds on Mallee Cliffs National Park].

Rationale for inclusion

Invasive weeds can be a significant threat to ecosystem structure, composition and function, and to wildlife habitat.

Survey methodology

We will systematically map the distribution of environmentally significant weeds based on NSW NPWS records initially, then from targeted surveys by AWC staff.

Unit of measurement

Weeds will be monitored in terms of (i) extent of occurrence (hectares or km^2, depending on the species and scale of infestation), and (ii) density within infestations (i.e., average number of plants per unit area).

Baseline

Relevant data may be held by NSW NPWS.

Fire

Fire is a major driver of the structure and composition of Australian ecosystems, and hence wildlife habitat. Aboriginal fire regimes in vegetation types with a grassy understorey were characterised by relatively frequent, small-scale, 'cool' fires (Gammage 2011), however regimes in mallee are not well understood.

As a generalisation, particular fire regimes favour some species and disadvantage others. For example, a suite of short-lived plants are associated with recently burnt vegetation – these plants often persist in the soil seed bank between fires. Medium-sized mammals such as Bilbies and hare-wallabies often prefer to forage in recently burnt vegetation because of the richness of food resources provided by these 'fire weeds' (Bolton and Latz 1978; Southgate et al. 2007). Bettongs, which feed heavily on fungi, also often prefer to forage in recently burnt vegetation, presumably because some species of fungi are advantaged by fire or are easier for bettongs to locate following fire (Taylor 1991). A number of species, including some reptiles, are associated with early successional vegetation after fire (Nimmo *et al.* 2014). Conversely, other reptiles, a number of bird species including the Malleefowl and some mammals including the Southern Ningaui are associated with long-unburnt mallee (Kelly et al. 2011, 2012; Nimmo et al. 2013; Berry et al. 2015).

Since European settlement, the mallee has been vulnerable to infrequent, intense stand-replacing wildfires, often started by lightning, particularly following relatively wet years which promote the growth of annual grasses (NSW NPWS 1998). Intense wildfires homogenise vegetation over extensive areas and disadvantage fauna associated with long-unburnt vegetation, by removing key habitat attributes such as hollow trees, logs and dense ground cover. Large wildfires also threaten wildlife populations directly: for example, recent wildfires have caused the decline of the Mallee Emu-wren and the Black-eared Miner in mallee. Furthermore, while mallee itself is highly resilient to fire, reshooting from underground lignotubers, a number of other tree species, such as Cypress Pine and Mulga, are killed by wildfire.

Nearly all of Mallee Cliffs NP was burnt by major wildfires in 1974-75 and much of the western part of the park was burnt again in 1977; since that time, there has been no extensive wildfire in the park. The fire management strategy for Mallee Cliffs NP aims to establish and maintain a diversity of seral stages of vegetation (time since fire) including patches of long-unburnt mallee.

Indicators

The following metrics will be calculated:

- fire extent
- frequency
- time since fire
- distance to unburnt vegetation

These metrics will be calculated for (i) all fire, including prescribed fire; and (ii) wildfire only. In this document "wildfire" refers to an unplanned fire that occurs outside the period for prescribed burning, noting that this definition may be amended to define wildfire by reference to the intensity of the fire.

Rationale for inclusion

Fire is a key driver of vegetation dynamics and habitat for wildlife. Extensive wildfire adversely affects key elements of the biota of Mallee Cliffs NP.

Survey methodology

Fire extent (and, if feasible, severity) will be determined by remote sensing and/or ground traverse. Fire scars will be subject to spatial analysis in a GIS to calculate metrics (as per Legge *et al.* 2011).

Unit of measurement

The following metrics will be calculated for (i) all fire; and (ii) wildfire

- fire extent (area and proportion of project area)
- frequency (% burnt 0, 1…n times within nominated period)
- time since fire (% burnt within 0, 1…n years)
- mean and maximum distance (km) to vegetation unburnt (by any fire, or by wildfire) for a defined period. This metric describes the spatial pattern of fire and is relevant to recolonization.

Baseline

Mallee Cliffs has remained largely unburned following major fires in 1974 and 1977. AWC will conduct spatial analysis of fire maps obtained from NSW NPWS to quantify baseline fire metrics.

Survey design

Important principles of ecological survey design – representativeness, replication, spatial independence and unbiased sampling – have been incorporated into the design of AWC's ecological health monitoring framework for Mallee Cliffs NP. A further consideration, feasibility, necessitates some trade-offs in expression of these principles.

A spatially-blocked stratified sampling design was used to establish monitoring sites on Mallee Cliffs NP. The design was implemented in a hierarchical way, as follows.

Vegetation type was used as the primary stratification. There are major differences in plant species composition and structure between the main vegetation types on Mallee Cliffs NP, which affect their value as habitat for wildlife (e.g., Nimmo et al. 2014). The existence of a robust vegetation map (Morcom and Westbrooke 1990) facilitated adoption of this approach.

Second, we used a spatially-blocked approach to select replicate sites within each vegetation type within different sections of Mallee Cliffs NP (Table 5). This approach controls for any underlying spatial variation in environmental factors such as disturbance history. In heterogeneous landscapes, blocking is also an efficient way of correcting for the effects of spatial autocorrelation in the data, caused by localised differences in environmental factors (Dutilleul 1993; Legendre et al. 2004). As part of the blocking, we ensured that a full set of replicate sites was located within the proposed fenced area.

Third, we ensured spatial independence between sites based on analysis of likely movement patterns of the majority of vertebrate taxa selected as indicators. Based on this analysis, sites were located a minimum distance of 2 km apart.

Fourth, we located sites a minimum of 500 m from the edge of the reserve to reduce the influence of edge effects.

Lastly, where possible we selected sites that were moderately accessible from the existing road network, to facilitate the conduct of field work.

The design resulted in the location of 50 standard monitoring sites across Mallee Cliffs NP (Figure 4).

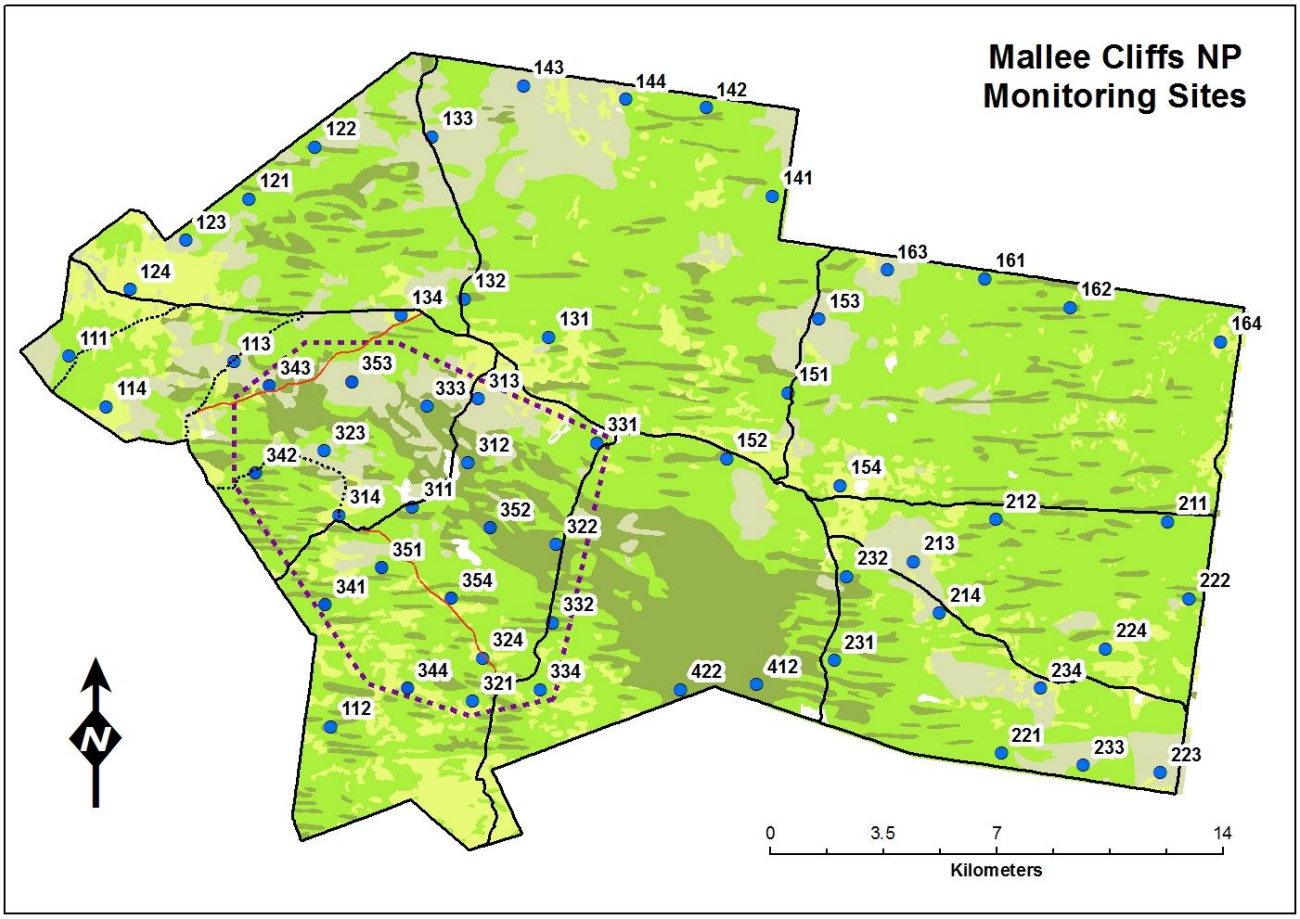

Figure 4. Monitoring site locations on Mallee Cliffs NP. The three-digit site naming convention is as follows:

- First digit: 1 = outside fence; 2 = inside original fence; 3 = inside preferred fence; 4 = supplementary.
- Second digit: block replicate, 1-6.
- Third digit: vegetation community. 1 = mallee/shrubland; 2 = mallee/spinifex; 3 = belah/rosewood; 4 = open herbland.

Table 5. Number of standard monitoring points inside and outside the fence using the a spatially-blocked stratified-sampling approach

Vegetation Type	Number of monitoring points	
	Outside fence	Inside fence
Mallee shrub	9	3
Mallee *Triodia*	11	3
Casuarina pauper low open woodland	9	3
Herbland/open herbland	9	3
Total	38	12

Reintroduction of the Mallee Cliffs species

Overview of project

A core part of AWC's Mallee Cliffs project is the reintroduction of a suite of 'extinct in NSW' mammals. Initially, these mammals will be reintroduced to a large (>8000 ha) fenced area from which feral predators have been eradicated. Species proposed for reintroduction (the 'Mallee Cliff species') are:

- Western Quoll
- Red-tailed Phascogale
- Numbat
- Western Barred Bandicoot
- Greater Bilby
- Burrowing Bettong
- Brush-tailed Bettong
- Bridled Nailtail Wallaby
- Greater Stick-nest Rat
- Mitchell's Hopping Mouse

In addition to increasing the number of secure populations and the global population size of the reintroduced mammals, the project is expected to have benefits for extant species and ecosystems. First, the removal of introduced predators from within the fenced area is expected to reduce threats to extant native species, in particular ground-dwelling and ground-nesting species, a number of which are threatened (Paul and Marlow 2012). Second, the mammals to be reintroduced participate in a number of important ecological processes, including soil and litter turnover, the dispersal of plants and fungi, herbivory and predation (James and Eldridge 2007; Eldridge and James 2009; James *et al.* 2009; Fleming *et al.* 2014). The reintroduction of mammals is expected to help restore these ecological processes.

The reintroduction project may have localised adverse outcomes for a small number of species, such as species for whom the fence is a barrier to movement (Hayward and Kerley 2009).

Location of the fenced area

The location of the fenced area was determined by a number of factors, pragmatic and ecological. The primary ecological consideration was the desire to incorporate a diverse range of vegetation types inside the fenced area to provide habitat for reintroduced species, each of which has somewhat different habitat requirements (Woinarski et al. 2014). The preferred fence location captures the diversity of vegetation present on Mallee Cliffs NP (Table 6).

Table 6. Main vegetation types within Mallee Cliffs NP and the proposed conservation fence.

Vegetation Type	Total Area (ha)	Total %	Fence Area (ha)	Fence %
Mallee open scrub	34031	58	4270	46
Mallee open scrub (*Triodia* understorey)	9053	16	2827	30
Casuarina pauper low open woodland	7986	14	1362	15
Herbland/open herbland	6874	12	705	8
Dodonea shrubland	241	0.4	126	1

The fenceline has been designed to limit impacts of clearing on important conservation values of the park including areas of long-unburnt vegetation and Malleefowl mounds. Other considerations were the need to work within the constraints of the existing road/ fire trail network (as far as possible), the need to avoid potentially waterlogged soils as far as possible and to not disturb Aboriginal and other cultural heritage sites.

Monitoring the outcomes of mammal reintroductions

AWC is required to prepare a Translocation Proposal for 'extinct in NSW' mammals to be reintroduced to Mallee Cliffs NP. For each species, the Translocation Proposal will nominate short-, medium- and long-term targets for the outcomes of reintroductions, based on relevant metrics. Survey methods to obtain the required information to evaluate progress against targets will subsequently be incorporated in the Ecological Health Monitoring Plan. Indicative metrics and associated survey methods are listed in Table 7.

The Translocation Proposal will address issues around the maintenance of genetic diversity in reintroduced populations. Tissue samples will be collected from founding animals and periodically from reintroduced populations for genetic analysis, including at least once during years 8-9 of the initial term of the Agreement. Genetic analysis will determine whether intervention (e.g., additional reintroductions of genetically distinct individuals) may be required to ensure long-term viability of each population.

Table 7. Metrics for monitoring the outcomes of reintroductions, and associated survey methods.

Timeframe	Metrics	Survey methods
Short (<2 yr)	Survival of translocated individuals	Radio-tracking, live-traps, cameras
Medium (2-5 yr)	Population size, recruitment	Live-traps, cameras, transect surveys
Long term (>5 yr)	Population size, genetic diversity	Live-traps, cameras, transect surveys, genetic analysis

Monitoring the outcomes of reintroductions for extant species

To evaluate the outcomes of the reintroduction project for extant species and ecosystems, AWC will monitor biodiversity and threat indicators at sites located inside and outside the fence.

Selection of indicators

The indicators that will be monitored to measure outcomes of the reintroduction project for extant species and ecosystems are the same as those selected to evaluate the overall progress of the project, as described above. In summary, these are indicators of biodiversity, ecological processes and threats. Indicators of biodiversity include threatened or declining species, taxa directly or indirectly by mammalian extinctions, and strong drivers of ecosystem function. Threats include feral predators (expected to be eradicated inside fenced area) and herbivores, changed fire regimes and weeds. Ecological processes include soil engineering.

Survey design

The survey design used to select monitoring sites across Mallee Cliffs NP resulted in 12 monitoring sites being located within the conservation fence. To obtain sufficient data for robust evaluation of outcomes of the reintroduction project, an additional eight monitoring sites were located inside the fenced area (bringing the total to 20 sites). The additional sites were selected using vegetation type as the primary stratification, while ensuring adequate spatial separation between sites in selecting the additional two replicate sites per vegetation type.

Survey methods

A feature of AWC's monitoring plan is that omnibus survey techniques will be used to record data on a wide range of species. Where these methods do not capture selected indicators, additional targeted survey methods will be implemented.

Standard monitoring sites

Monitoring of vertebrates, vegetation and ecological processes will focus on the 50 sites stratified by vegetation type located across the park, supplemented with an additional eight sites inside the fenced area to enable robust contrasts of outcomes inside/ outside the reintroduction site (total of 58 sites: Figure 4). Due to the heterogeneous nature of the topography and vegetation at Mallee Cliffs, all sampling sites will be orientated to align with site topography (dune or swale), and to be constrained within the boundaries of the vegetation type required for sampling. The location of each monitoring plot will be marked with a star picket and a coded cattle tag. A range of sub-plots will be established at each monitoring site to record the relative abundances of species within different taxonomic groups (Figure 5).

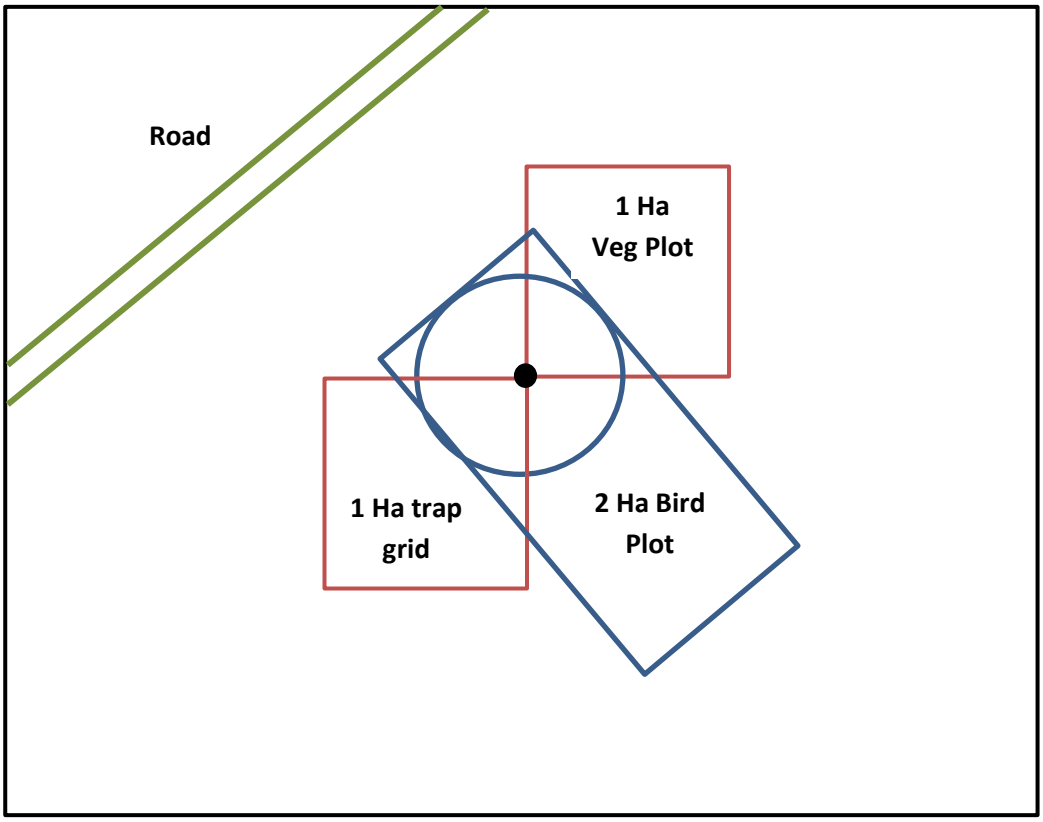

Figure 5. Diagram showing layout of each monitoring plot. Each 2 ha bird plot within embedded 50 m point count will be orientated with the topography at each site or will run perpendicular to the nearest road. Trapping grids will be located SW and veg plots located NE of the site point.

Birds

Birds will be surveyed using a standard 20 minute – 2 ha survey at each monitoring site (Figure 5), comprised of a 10-minute point count followed by a 10-minute active search. During the point count, birds observed or heard will be attributed to 3 distance classes. This distance sampling method will enable us to account for differences in bird detectability between vegetation types. Bird surveys at each site will be repeated on three different occasions. As far as possible, different observers will be used on each repeat sample.

Small- to medium-sized mammals and reptiles

Small mammal abundance will be assessed over four consecutive nights on 1 ha trapping grids situated at each monitoring point (Figure 5). On each trapping grid, we will place 20 Elliott traps, baited with a mixture of peanut butter, oats, honey and fish oil. Following standard small mammal sampling protocols, Elliott traps will be placed in a grid formation with traps 20 m apart (Figure 6). One metal cage trap will be placed in each corner of the trapping grid to assess the abundance of medium-sized mammals. In the centre of the trapping grid, two pitfall trap arrays will be installed. Each pitfall array will have two Y-shaped driftnets with 4 PVC buckets/tubes established in each pitfall array. Funnel traps will be deployed along each of the pitfall arrays as a specific method targeting reptiles that are unlikely to be trapped within buckets, such as geckos and elapid snakes. Captured animals will be identified to species level and marked with an indelible marker-pen or hair-clipped to temporarily identify recaptures within the same sampling period. This will enable us to calculate indices of abundances for small to medium-sized mammals and reptiles at each grid as the mean number of individuals captured per trap night.

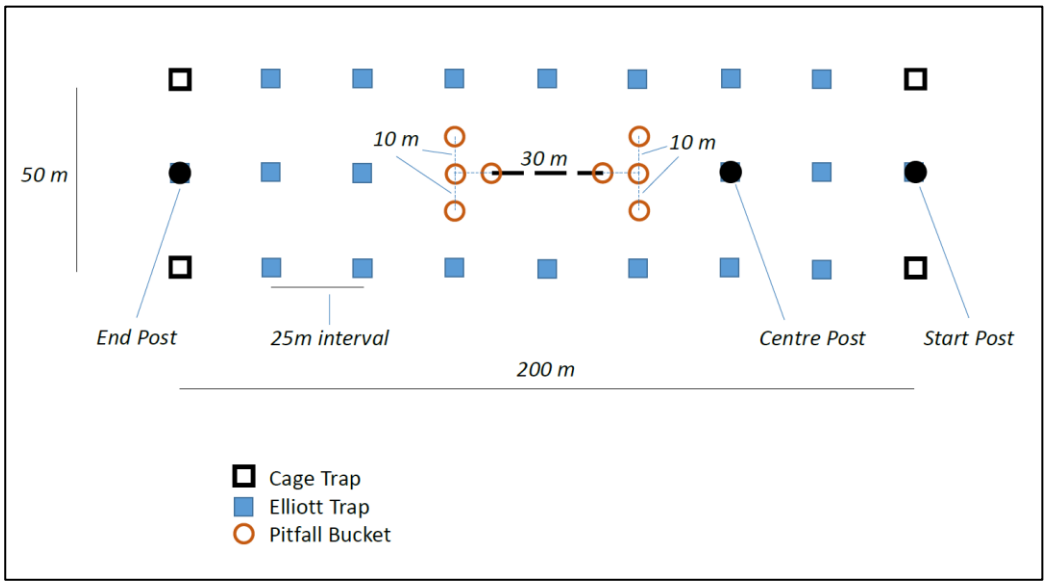

Figure 6. Layout of the trapping grid at each monitoring site in Mallee Cliffs NP.

Bats

Bats will be surveyed at 20 of the 58 standard monitoring points located on Mallee Cliffs NP, with 10 sites located inside and 10 sites located outside the proposed fence. SM4BAT detectors (Wildlife Acoustics) will be used to record the echolocation calls of bats (in particular their foraging calls) over four consecutive nights. Bat species identification from these recorded calls will be determined using an automated procedure based on a bat-call library that has been developed for south-western NSW by Dr Brad Law (NSW Department of Primary Industries).

Vegetation, habitat and ecological processes

Vegetation surveys will be conducted on 1 ha plots located in the north-eastern section of monitoring sites, beginning at the central star picket. A total of 32 sites will be surveyed – comprising 16 sites (four replicates of the four main vegetation types) inside and 16 sites outside the fence. Habitat availability including the density of hollow-bearing trees and woody debris and the incidence of mammal diggings (an important ecological process) will be quantified at each site.

The initial plot set up and ground stratum measurements are based on a systematic two-stage sampling design (Elzinga *et al.* 1998). The base plot for ground structure is 100 x 20 m in size, in which 120 1 m x 1 m sub-plots are placed along five transects to record the frequencies of each ground and shrub layer species. Plant species will also be allocated to guilds that may also show changes in broader groups rather than individual species. Within the 120 sub-plots, a smaller nested size may be used to capture annuals if the densities are very thick and ubiquitous (e.g. 50 x 50 cm record all species, then in remaining 1 x 1 m record perennial species only). Along each of the five transects, the substrate type, ground layer cover, shrub cover, and canopy cover will be recorded at 101 points using a point intercept method. Woody debris and hollow logs will be recorded by size class using a line intercept or transect method. Tree densities will be measured over a larger area than the base plot, which will be nested within a 1 ha plot to capture all size classes.

Each plot will be marked with six star-pickets for the base 100 m x 20 m plot and another additional two pickets on the far corners of the 1 ha plot. A photo plot consisting of one image per monitoring point, facing south or aligned with topography and the extent of the required vegetation type, will be taken to record changes in forest floristics and structure.

Spotlighting transects

A total of eight road-based spotlighting transects, each 10 km long, will be established along the main access tracks in Mallee Cliffs NP (Figure 7). The transects sample the main vegetation types present on the park.

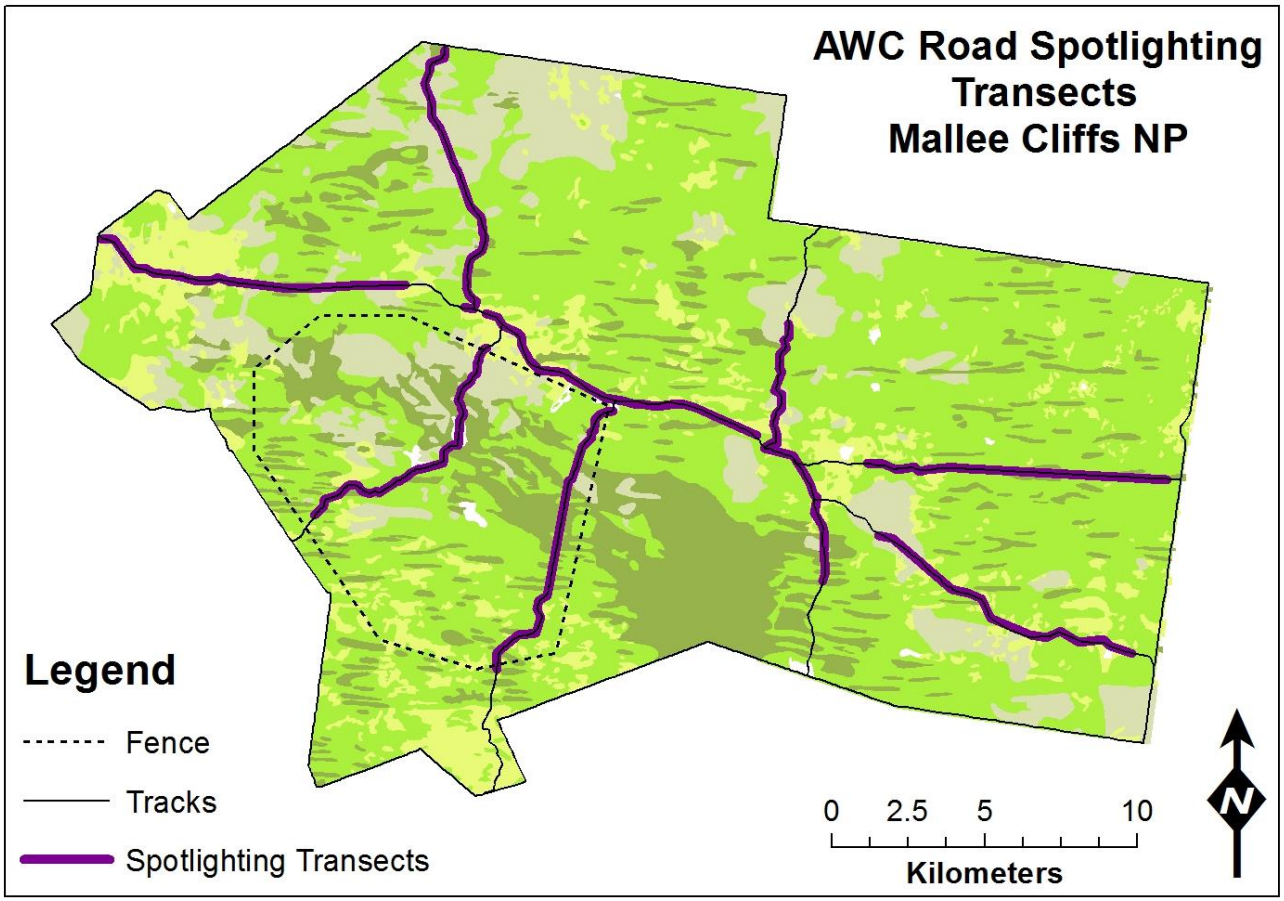

Figure 7. Locations of road-based spotlighting transects on Mallee Cliffs NP. Each transect is 10 km long.

Spotlight transects will be used to monitor macropods and introduced herbivores. Each 10 km transect will be surveyed on two consecutive nights. All surveys will commence in the hour following sunset. During spotlight surveys, two observers will stand on the rear tray of a four-wheel-drive vehicle moving at a speed

of 10 km/n and scan vegetation with a 100 W spotlight. Animals observed during surveys will be counted with angle and distance from observer measured using a laser range-finder. The vegetation type where each observation was made will be recorded Data from these surveys will provide density estimates using a strip transect approach, with the width of the strip estimated from the detection curve for each vegetation type.

Camera surveys

To assess predator activity and abundance, camera traps will be set at 1.5 km intervals along the road network in Mallee Cliffs NP (Figure 8).

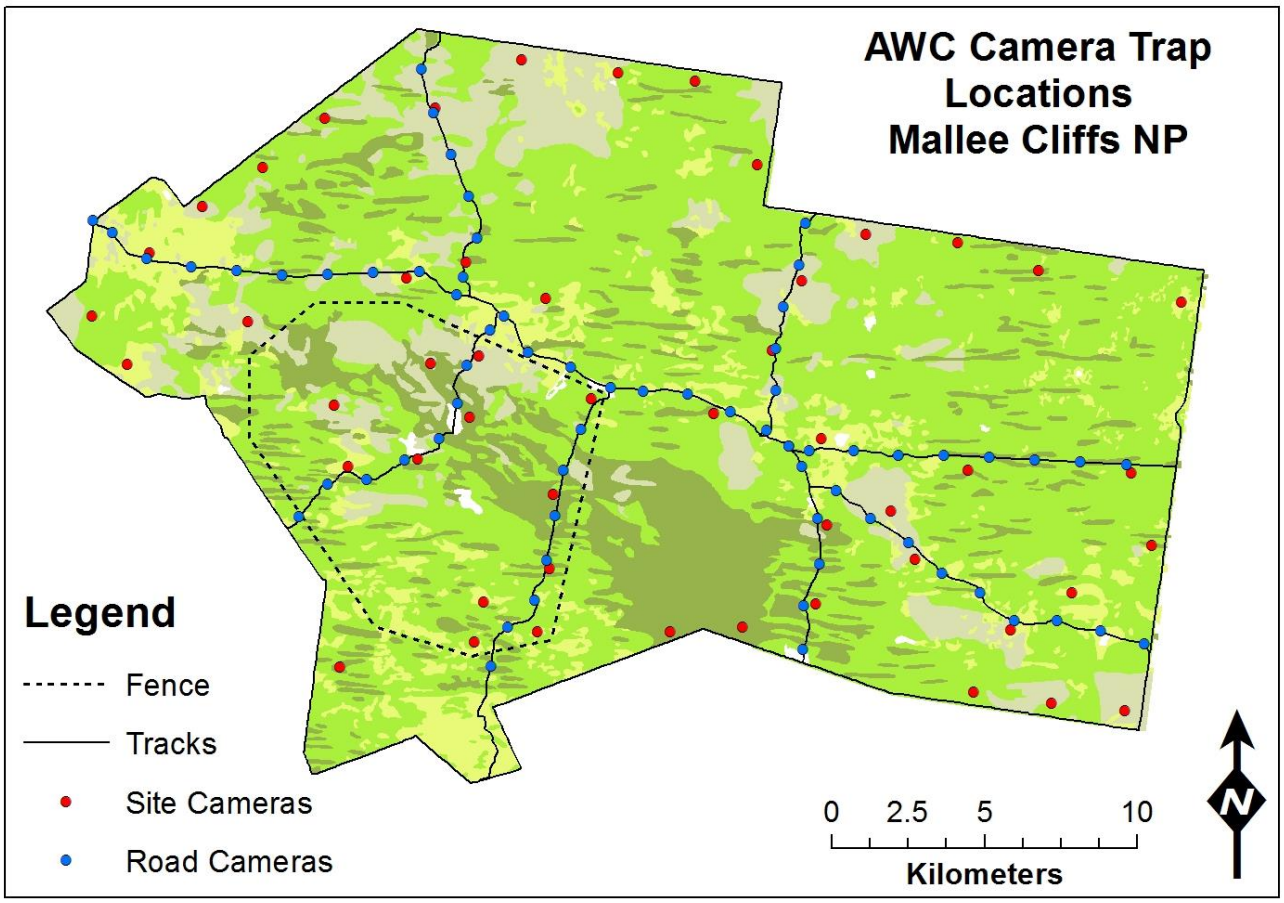

Figure 8. Locations of camera traps along main vehicle tracks.

Canids regularly use roads for travel (Mahon et al. 1998, Read and Eldridge 2010). Cameras will be baited with chicken necks and deployed simultaneously for a total of 14 days. This large camera survey effort is expected to provide a good estimate of fox abundance. We will review camera trapping results from the first season to determine whether additional measures need to be implemented to determine the numbers of feral cats (e.g. Bengsen et al. 2011, McGregor et al. 2015, Stokeld et al. 2015).

Targeted surveys

Malleefowl

Malleefowl are cryptic birds which are hard to record using conventional survey techniques. Malleefowl commonly renovate existing mounds during breeding seasons, rather than building new mounds. Standard practice for monitoring Malleefowl breeding density is to visit known mounds and record evidence of activity (Benshemesh 2004). NSW NPWS have monitored on an annual basis the activity of 149 Malleefowl mounds on Mallee Cliffs NP (Figure 10). There are likely to be more mounds in the park: remote sensing may be required to more comprehensively inventory the location of mounds, to obtain a robust sample of mounds

inside and outside the proposed fence. Data from AWC's Scotia sanctuary shows that mound activity is generally higher inside the fence, where Malleefowl are free from predation by foxes and cats.

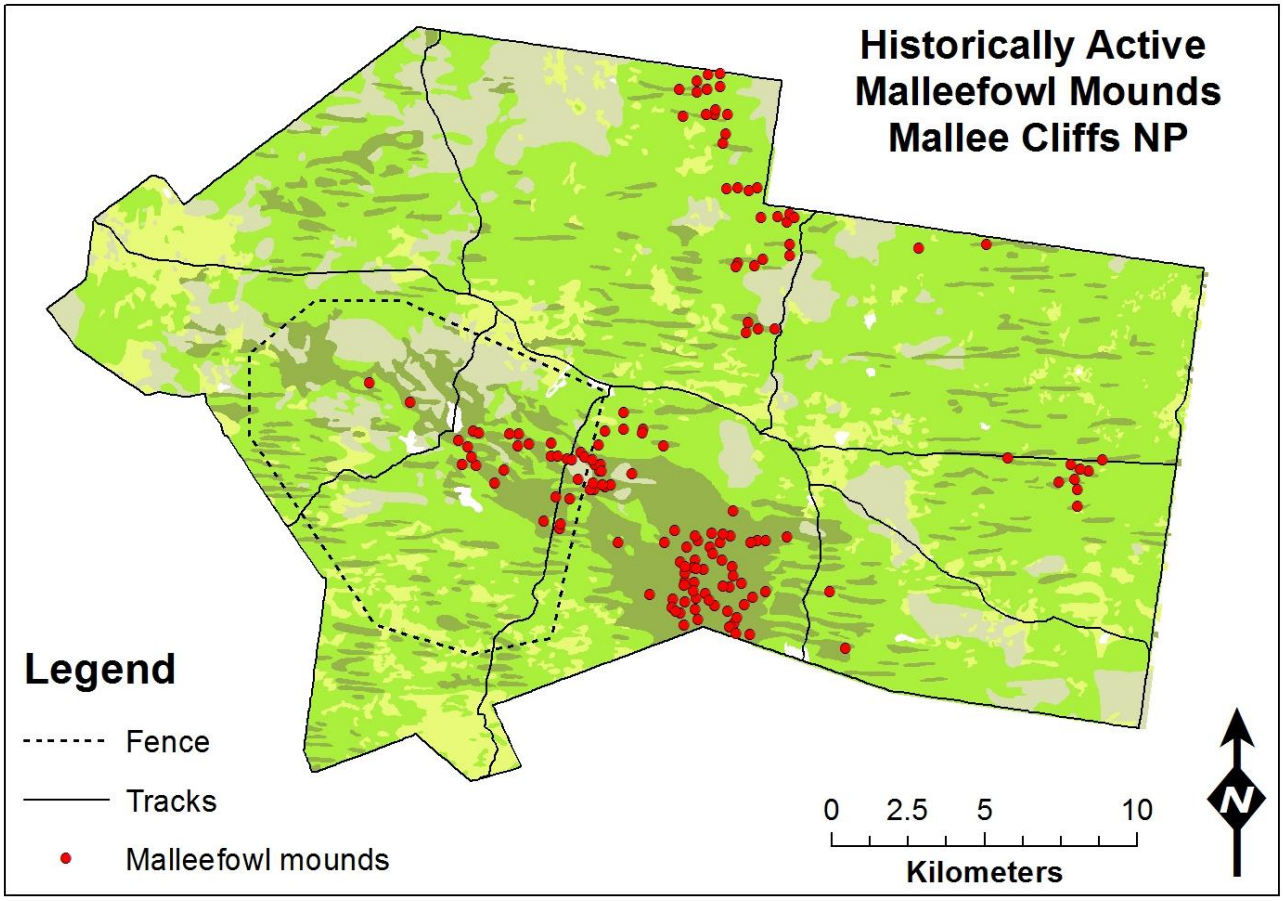

Figure 10. Malleefowl mounds within Mallee Cliffs NP surveyed in 2015.

Frogs

Frogs will be surveyed by a combination of listening, call-playback and spotlighting in targeted surveys around waterbodies and by spotlight surveys along roads on warm, wet nights. Acoustic recorders (Songmeters) may also be used to survey frogs around waterbodies. The optimal methodology will be determined after the various methods have been trialled on the park.

Threatened plants

The threatened plant Bitter Quandong will be surveyed at known sites, on permanent plots/ transects. Plots will also be established to monitor Cypress Pine and the condition of any threatened ecological communities present on Mallee Cliffs NP.

Timing of surveys

To the extent feasible, surveys will be conducted at the time of year when they are expected to be most effective in recording selected indicators. Diurnal birds, most nocturnal birds and arboreal marsupials, introduced predators, large herbivores and vegetation will be surveyed in spring. Small mammals, reptiles, bats, introduced predators and large herbivores will be surveyed in late summer.

Survey effort undertaken in monitoring program

The total **annual** survey effort, prior to the release of regionally extinct mammals, in the Pilliga project area is predicted to be as follows:

- 1856 Pitfall trap nights: 58 sites, 8 traps per site, 4 nights
- 4640 Elliot trap nights: 58 sites, 20 traps per site, 4 nights
- 2784 Funnel trap nights: 58 sites, 12 traps per site, 4 nights
- 928 cage trap nights: 58 sites, 4 traps per site, 4 nights
- 3360 camera trap nights: 120 sites (58 off-road, 62 on-road), 1 camera/site, 14 nights, repeated twice yearly
- Nest-boxes: 2 boxes per site deployed at 24 sites
- 174 bird surveys (standard 2 ha, 20 minute; and Songmeter) (58 sites, 3 replicates)
- 160 bat survey nights (Songmeter) (20 sites, 4 nights), repeated twice yearly
- 160 vehicle spotlight surveys (8 transects of 10 km, 2 repeats)
- 58 surveys of habitat and ecological processes
- 32 vegetation surveys (16 inside fence, 16 outside fence)
- Other surveys will include targeted searches for frogs, Malleefowl and threatened plants, and potentially camera grids for estimating density of feral predators.

The level of effort will increase substantially to monitor survival, population dynamics and other metrics related to reintroduced mammals, once reintroductions to the fenced area commence.

Evaluation of monitoring results

Changes in the status of indicators selected for monitoring will be evaluated by comparison with baseline information, where available. As monitoring data are accumulated, AWC will analyse the power of the monitoring program to detect trends in indicators (e.g., Woinarski *et al.* 2004). Based on this analysis, it may be necessary to change the intensity, frequency or design of surveys.

The concurrent collection of both species and environmental data will facilitate prospective analysis (Mulder *et al*. 1999), in which trends in species metrics can be modelled with concurrent habitat data to predict trends in key biodiversity indicators. The comparison of monitoring results with earlier modelled predictions can provide insight on the outcomes of management actions (Nichols and Williams 2006, Lindenmayer and Likens 2009).

Reporting

The results of monitoring activities will be reported annually. Results will show trends over time for indicators being monitored. A summary will be presented in the AWC scorecard format (Appendix 2).

Review

The EHMF will be reviewed annually. The indicators selected for monitoring and the survey techniques used to obtain data on indicators will be updated as required, for example in response to changes in the conservation status of species, improved knowledge of the ecology of threatened species or threatening processes, or improvements in survey technology.

Integration of monitoring with research

Monitoring will be integrated with a research program aimed at addressing key knowledge gaps relevant to conservation management, including the ecology of threatened species and threatening processes, and the response of biodiversity and threats to management interventions. The outcomes of major management interventions, such as landscape restoration projects, will be evaluated in a research framework using an appropriate experimental design (e.g., Before-After-Control-Impact).

Where feasible, data from AWC's monitoring program will contribute to research projects aimed at evaluating the outcome of management interventions (the integration of monitoring with research aimed at addressing management issues has been termed "question-based" or "adaptive" monitoring: Lindenmayer and Likens 2009; Lindenmayer et al. 2015). If surveys conducted as part of the monitoring program are not at the intensity or scale required to address particular research questions, additional sites may be added to the monitoring program. For example, data from Mallee Cliffs monitoring program will be used to evaluate the outcomes of reintroductions for extant fauna and vegetation, by contrasting outcomes at sites inside and outside the fence. An additional 8 sites have been located inside the fence to increase the sample size and the robustness of the inside/ outside fence contrasts.

AWC's research strategy in Mallee Cliffs will be elaborated in a companion document.

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Appendix 1. Vertebrate species list, Mallee Cliffs

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Amphibia	Limnodynastidae	*Limnodynastes dumerilii*	Eastern Banjo Frog	Likely		
Amphibia	Limnodynastidae	*Limnodynastes fletcheri*	Long-thumbed Frog	Likely		
Amphibia	Limnodynastidae	*Limnodynastes tasmaniensis*	Spotted Grass Frog	Likely		
Amphibia	Limnodynastidae	*Neobatrachus sudellae*	Sudell's Frog	Likely		
Amphibia	Myobatrachidae	*Crinia parinsignifera*	Eastern Sign-bearing Froglet	Likely		
Aves	Acanthizidae	*Acanthiza apicalis*	Inland Thornbill	Confirmed		
Aves	Acanthizidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill	Very Likely		
Aves	Acanthizidae	*Acanthiza lineata*	Striated Thornbill	Very Likely		
Aves	Acanthizidae	*Acanthiza nana*	Yellow Thornbill	Confirmed		
Aves	Acanthizidae	*Acanthiza reguloides*	Buff-rumped Thornbill	Very Likely		
Aves	Acanthizidae	*Acanthiza uropygialis*	Chestnut-rumped Thornbill	Confirmed		
Aves	Acanthizidae	*Aphelocephala leucopsis*	Southern Whiteface	Confirmed		
Aves	Acanthizidae	*Calamanthus cauta*	Shy Heathwren	Confirmed		Vulnerable
Aves	Acanthizidae	*Smicrornis brevirostris*	Weebill	Confirmed		
Aves	Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk	Very Likely		
Aves	Accipitridae	*Accipiter fasciatus*	Brown Goshawk	Very Likely		
Aves	Accipitridae	*Aquila audax*	Wedge-tailed Eagle	Confirmed		
Aves	Accipitridae	*Circus assimilis*	Spotted Harrier	Confirmed		Vulnerable
Aves	Accipitridae	*Elanus axillaris*	Black-shouldered Kite	Very Likely		
Aves	Accipitridae	*Hieraaetus morphnoides*	Little Eagle	Very Likely		Vulnerable
Aves	Accipitridae	*Milvus migrans*	Black Kite	Very Likely		
Aves	Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	Confirmed		
Aves	Alaudidae	*Mirafra javanica*	Horsfield's Bushlark	Very Likely		
Aves	Anatidae	*Anas gracilis*	Grey Teal	Confirmed		
Aves	Anatidae	*Anas superciliosa*	Pacific Black Duck	Very Likely		
Aves	Anatidae	*Biziura lobata*	Musk Duck	Very Likely		
Aves	Ardeidae	*Egretta novaehollandiae*	White-faced Heron	Very Likely		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Aves	Artamidae	*Artamus cinereus*	Black-faced Woodswallow	Confirmed		
Aves	Artamidae	*Artamus cyanopterus*	Dusky Woodswallow	Confirmed		Vulnerable
Aves	Artamidae	*Artamus personatus*	Masked Woodswallow	Confirmed		
Aves	Artamidae	*Artamus superciliosus*	White-browed Woodswallow	Confirmed		
Aves	Artamidae	*Cracticus nigrogularis*	Pied Butcherbird	Confirmed		
Aves	Artamidae	*Cracticus tibicen*	Australian Magpie	Confirmed		
Aves	Artamidae	*Cracticus torquatus*	Grey Butcherbird	Confirmed		
Aves	Artamidae	*Strepera versicolor*	Grey Currawong	Confirmed		
Aves	Cacatuidae	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo	Very Likely		Vulnerable
Aves	Cacatuidae	*Eolophus roseicapillus*	Galah	Confirmed		
Aves	Cacatuidae	*Lophochroa leadbeateri*	Major Mitchell's Cockatoo	Confirmed		Vulnerable
Aves	Cacatuidae	*Nymphicus hollandicus*	Cockatiel	Very Likely		
Aves	Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	Confirmed		
Aves	Campephagidae	*Lalage tricolor*	White-winged Triller	Confirmed		
Aves	Casuariidae	*Dromaius novaehollandiae*	Emu	Confirmed		
Aves	Charadriidae	*Elseyornis melanops*	Black-fronted Dotterel	Very Likely		
Aves	Charadriidae	*Vanellus miles*	Masked Lapwing	Very Likely		
Aves	Charadriidae	*Vanellus tricolor*	Banded Lapwing	Confirmed		
Aves	Climacteridae	*Climacteris affinis*	White-browed Treecreeper	Confirmed		
Aves	Climacteridae	*Climacteris picumnus*	Brown Treecreeper	Confirmed		
Aves	Climacteridae	*Cormobates leucophaea*	White-throated Treecreeper	Very Likely		
Aves	Columbidae	*Ocyphaps lophotes*	Crested Pigeon	Confirmed		
Aves	Columbidae	*Phaps chalcoptera*	Common Bronzewing	Confirmed		
Aves	Corcoracidae	*Corcorax melanorhamphos*	White-winged Chough	Confirmed		
Aves	Corcoracidae	*Struthidea cinerea*	Apostlebird	Very Likely		
Aves	Corvidae	*Corvus bennetti*	Little Crow	Confirmed		
Aves	Corvidae	*Corvus coronoides*	Australian Raven	Confirmed		
Aves	Corvidae	*Corvus mellori*	Little Raven	Confirmed		
Aves	Corvidae	*Corvus orru*	Torresian Crow	Very Likely		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Aves	Cuculidae	*Cacomantis pallidus*	Pallid Cuckoo	Confirmed		
Aves	Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo	Confirmed		
Aves	Cuculidae	*Chalcites osculans*	Black-eared Cuckoo	Confirmed		
Aves	Eurostopodidae	*Eurostopodus argus*	Spotted Nightjar	Very Likely		
Aves	Falconidae	*Falco berigora*	Brown Falcon	Confirmed		
Aves	Falconidae	*Falco cenchroides*	Nankeen Kestrel	Confirmed		
Aves	Falconidae	*Falco longipennis*	Australian Hobby	Very Likely		
Aves	Falconidae	*Falco peregrinus*	Peregrine Falcon	Very Likely		
Aves	Falconidae	*Falco subniger*	Black Falcon	Very Likely		Vulnerable
Aves	Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra	Confirmed		
Aves	Halcyonidae	*Todiramphus pyrrhopygius*	Red-backed Kingfisher	Very Likely		
Aves	Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher	Very Likely		
Aves	Hirundinidae	*Hirundo neoxena*	Welcome Swallow	Very Likely		
Aves	Hirundinidae	*Petrochelidon nigricans*	Tree Martin	Very Likely		
Aves	Laridae	*Chroicocephalus novaehollandiae*	Silver Gull	Very Likely		
Aves	Maluridae	*Malurus cyaneus*	Superb Fairy-wren	Confirmed		
Aves	Maluridae	*Malurus lamberti*	Variegated Fairy-wren	Confirmed		
Aves	Maluridae	*Malurus leucopterus*	White-winged Fairy-wren	Confirmed		
Aves	Maluridae	*Malurus splendens*	Splendid Fairy-wren	Very Likely		
Aves	Megaluridae	*Cincloramphus mathewsi*	Rufous Songlark	Very Likely		
Aves	Megapodiidae	*Leipoa ocellata*	Malleefowl	Confirmed	Vulnerable	Endangered
Aves	Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater	Confirmed		
Aves	Meliphagidae	*Anthochaera carunculata*	Red Wattlebird	Confirmed		
Aves	Meliphagidae	*Certhionyx variegatus*	Pied Honeyeater	Confirmed		Vulnerable
Aves	Meliphagidae	*Epthianura albifrons*	White-fronted Chat	Confirmed		Vulnerable
Aves	Meliphagidae	*Epthianura tricolor*	Crimson Chat	Confirmed		
Aves	Meliphagidae	*Gavicalis virescens*	Singing Honeyeater	Confirmed		
Aves	Meliphagidae	*Lichenostomus cratitius*	Purple-gaped Honeyeater	Confirmed		Vulnerable
Aves	Meliphagidae	*Manorina flavigula*	Yellow-throated Miner	Confirmed		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Aves	Meliphagidae	*Melithreptus brevirostris*	Brown-headed Honeyeater	Confirmed		
Aves	Meliphagidae	*Melithreptus gularis*	Black-chinned Honeyeater	Very Likely		Vulnerable
Aves	Meliphagidae	*Nesoptilotis leucotis*	White-eared Honeyeater	Confirmed		
Aves	Meliphagidae	*Plectorhyncha lanceolata*	Striped Honeyeater	Confirmed		
Aves	Meliphagidae	*Ptilotula ornata*	Yellow-plumed Honeyeater	Confirmed		
Aves	Meliphagidae	*Ptilotula penicillata*	White-plumed Honeyeater	Very Likely		
Aves	Meliphagidae	*Ptilotula plumula*	Grey-fronted Honeyeater	Very Likely		
Aves	Meliphagidae	*Purnella albifrons*	White-fronted Honeyeater	Confirmed		
Aves	Meliphagidae	*Sugomel niger*	Black Honeyeater	Very Likely		
Aves	Meropidae	*Merops ornatus*	Rainbow Bee-eater	Confirmed		
Aves	Monarchidae	*Grallina cyanoleuca*	Magpie-lark	Confirmed		
Aves	Monarchidae	*Myiagra inquieta*	Restless Flycatcher	Very Likely		
Aves	Motacillidae	*Anthus novaeseelandiae*	Australian Pipit	Confirmed		
Aves	Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	Confirmed		Vulnerable
Aves	Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	Confirmed		
Aves	Pachycephalidae	*Oreoica gutturalis*	Crested Bellbird	Confirmed		
Aves	Pachycephalidae	*Pachycephala inornata*	Gilbert's Whistler	Confirmed		Vulnerable
Aves	Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	Confirmed		
Aves	Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	Confirmed		
Aves	Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	Confirmed		
Aves	Pardalotidae	*Pardalotus striatus*	Striated Pardalote	Confirmed		
Aves	Petroicidae	*Drymodes brunneopygia*	Southern Scrub-robin	Very Likely		Vulnerable
Aves	Petroicidae	*Melanodryas cucullata*	Hooded Robin	Confirmed		Vulnerable
Aves	Petroicidae	*Microeca fascinans*	Jacky Winter	Confirmed		
Aves	Petroicidae	*Petroica goodenovii*	Red-capped Robin	Confirmed		
Aves	Petroicidae	*Petroica phoenicea*	Flame Robin	Very Likely		Vulnerable
Aves	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	Very Likely		
Aves	Phasianidae	*Coturnix ypsilophora*	Brown Quail	Very Likely		
Aves	Podargidae	*Podargus strigoides*	Tawny Frogmouth	Confirmed		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Aves	Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed Grebe	Very Likely		
Aves	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe	Confirmed		
Aves	Pomatostomidae	*Pomatostomus ruficeps*	Chestnut-crowned Babbler	Very Likely		
Aves	Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	Very Likely		
Aves	Psittaculidae	*Barnardius zonarius*	Australian Ringneck	Confirmed		
Aves	Psittaculidae	*Northiella haematogaster*	Blue Bonnet	Confirmed		
Aves	Psittaculidae	*Psephotellus varius*	Mulga Parrot	Confirmed		
Aves	Psittaculidae	*Psephotus haematonotus*	Red-rumped Parrot	Very Likely		
Aves	Psophodidae	*Cinclosoma castanotum*	Chestnut Quail-thrush	Confirmed		Vulnerable
Aves	Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail	Confirmed		
Aves	Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail	Confirmed		
Aves	Strigidae	*Ninox novaeseelandiae*	Southern Boobook	Very Likely		
Aves	Turnicidae	*Turnix varius*	Painted Button-quail	Confirmed		
Aves	Tytonidae	*Tyto alba*	Barn Owl	Very Likely		
Mammalia	Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	Very Likely		
Mammalia	Dasyuridae	*Antechinus flavipes*	Yellow-footed Antechinus	Possible		
Mammalia	Dasyuridae	*Ningaui yvonneae*	Southern Ningaui	Confirmed		Vulnerable
Mammalia	Dasyuridae	*Sminthopsis crassicaudata*	Fat-tailed Dunnart	Confirmed		
Mammalia	Dasyuridae	*Sminthopsis murina*	Common Dunnart	Confirmed		
Mammalia	Acrobatidae	*Acrobates pygmaeus*	Feathertail Glider	Possible		
Mammalia	Phalangeridae	*Trichosurus vulpecula*	Common Brushtail Possum	Possible		
Mammalia	Burramyidae	*Cercartetus concinnus*	Western Pygmy-possum	Confirmed		Endangered
Mammalia	Macropodidae	*Macropus fuliginosus*	Western Grey Kangaroo	Confirmed		
Mammalia	Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo	Confirmed		
Mammalia	Macropodidae	*Macropus robustus*	Euro, Common Wallaroo	Confirmed		
Mammalia	Macropodidae	*Macropus rufus*	Red Kangaroo	Confirmed		
Mammalia	Molossidae	*Mormopterus petersi*	Inland Free-tailed Bat	Very Likely		
Mammalia	Molossidae	*Mormopterus planiceps*	South-eastern Free-tailed Bat	Very Likely		
Mammalia	Molossidae	*Tadarida australis*	White-striped Freetail Bat	Very Likely		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Mammalia	Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	Very Likely		
Mammalia	Vespertilionidae	*Chalinolobus morio*	Chocolate Wattled Bat	Confirmed		
Mammalia	Vespertilionidae	*Chalinolobus picatus*	Little Pied Bat	Very Likely		Vulnerable
Mammalia	Vespertilionidae	*Nyctophilus geoffroyi*	Lesser Long-eared Bat	Confirmed		
Mammalia	Vespertilionidae	*Scotorepens balstoni*	Inland Broad-nosed Bat	Very Likely		
Reptilia	Agamidae	*Ctenophorus fordi*	Mallee Military Dragon	Confirmed		
Reptilia	Agamidae	*Ctenophorus pictus*	Painted Dragon	Confirmed		
Reptilia	Agamidae	*Diporiphora nobbi*	Nobbi	Confirmed		
Reptilia	Agamidae	*Pogona barbata*	Bearded Dragon	Confirmed		
Reptilia	Agamidae	*Pogona vitticeps*	Central Bearded Dragon	Confirmed		
Reptilia	Agamidae	*Tympanocryptis lineata*	Lined Earless Dragon	Very Likely		
Reptilia	Agamidae	*Tympanocryptis tetraporophora*	Eyrean Earless Dragon	Likely		
Reptilia	Boidae	*Morelia spilota*	Carpet Python and Diamond Python	Confirmed		
Reptilia	Carphodactylidae	*Underwoodisaurus milii*	Thick-tailed Gecko	Confirmed		
Reptilia	Diplodactylidae	*Diplodactylus tessellatus*	Tessellated Gecko	Likely		
Reptilia	Diplodactylidae	*Diplodactylus vittatus*	Wood Gecko	Confirmed		
Reptilia	Diplodactylidae	*Lucasium damaeum*	Beaded Gecko	Confirmed		
Reptilia	Diplodactylidae	*Lucasium steindachneri*	Box-patterned Gecko	Confirmed		
Reptilia	Diplodactylidae	*Rhynchoedura ormsbyi*	Eastern Beaked Gecko	Confirmed		
Reptilia	Diplodactylidae	*Rhynchoedura ornata*	Western Beaked Gecko	Confirmed		
Reptilia	Diplodactylidae	*Strophurus elderi*	Jewelled Gecko	Confirmed		Vulnerable
Reptilia	Diplodactylidae	*Strophurus intermedius*	Southern Spiny-tailed Gecko	Confirmed		
Reptilia	Diplodactylidae	*Strophurus williamsi*	Eastern Spiny-tailed Gecko	Very Likely		
Reptilia	Elapidae	*Brachyurophis australis*	Coral Snake	Confirmed		
Reptilia	Elapidae	*Demansia psammophis*	Yellow-faced Whipsnake	Confirmed		
Reptilia	Elapidae	*Echiopsis curta*	Bardick	Likely		Endangered
Reptilia	Elapidae	*Notechis scutatus*	Tiger Snake	Likely		
Reptilia	Elapidae	*Parasuta nigriceps*	Short-tailed Snake	Confirmed		
Reptilia	Elapidae	*Parasuta spectabilis*	Spectacled Hooded Snake	Likely		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Reptilia	Elapidae	*Pseudechis australis*	Mulga Snake	Confirmed		
Reptilia	Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake	Likely		
Reptilia	Elapidae	*Pseudonaja aspidorhyncha*	Strap-snouted Brown Snake	Very Likely		
Reptilia	Elapidae	*Pseudonaja modesta*	Ringed Brown Snake	Likely		Endangered
Reptilia	Elapidae	*Pseudonaja textilis*	Eastern Brown Snake	Very Likely		
Reptilia	Elapidae	*Suta suta*	Curl Snake	Confirmed		
Reptilia	Elapidae	*Vermicella annulata*	Eastern Bandy-bandy	Confirmed		
Reptilia	Gekkonidae	*Christinus marmoratus*	Marbled Gecko	Likely		
Reptilia	Gekkonidae	*Gehyra versicolor*	Eastern tree Dtella	Confirmed		
Reptilia	Gekkonidae	*Heteronotia binoei*	Bynoe's Prickly Gecko	Confirmed		
Reptilia	Pygopodidae	*Aprasia inaurita*	Mallee Worm-lizard	Confirmed		Endangered
Reptilia	Pygopodidae	*Delma australis*	Marble-faced Delma	Likely		Endangered
Reptilia	Pygopodidae	*Delma butleri*	Unbanded Delma	Very Likely		
Reptilia	Pygopodidae	*Delma inornata*	Patternless Delma	Likely		
Reptilia	Pygopodidae	*Lialis burtonis*	Burton's Snake-lizard	Confirmed		
Reptilia	Pygopodidae	*Pygopus lepidopodus*	Common Scaly-foot	Very Likely		
Reptilia	Pygopodidae	*Pygopus schraderi*	Eastern Hooded Scaly-foot	Confirmed		
Reptilia	Scincidae	*Cryptoblepharus australis*	Inland Snake-eyed Skink	Likely		
Reptilia	Scincidae	*Cryptoblepharus pannosus*	Ragged Snake-eyed Skink	Confirmed		
Reptilia	Scincidae	*Ctenotus atlas*	Southern Mallee Ctenotus	Confirmed		
Reptilia	Scincidae	*Ctenotus inornatus*	Bar-shouldered Ctenotus	Confirmed		
Reptilia	Scincidae	*Ctenotus regius*	Pale-rumped Ctenotus	Confirmed		
Reptilia	Scincidae	*Ctenotus schomburgkii*	Barred Wedgesnout Ctenotus	Confirmed		
Reptilia	Scincidae	*Cyclodomorphus branchialis*	Common Slender Bluetongue	Very Likely		
Reptilia	Scincidae	*Cyclodomorphus melanops*	Spinifex Slender Bluetongue	Very Likely		Endangered
Reptilia	Scincidae	*Egernia striolata*	Tree Skink	Confirmed		
Reptilia	Scincidae	*Eremiascincus richardsonii*	Broad-banded Sand-swimmer	Likely		
Reptilia	Scincidae	*Lerista bougainvillii*	South-eastern Slider	Likely		
Reptilia	Scincidae	*Lerista labialis*	Southern Sandslider	Likely		

Class	Family	Scientific Name	Common Name	Likelihood	EPBC	NSW
Reptilia	Scincidae	*Lerista muelleri*	Wood Mulch-slider	Confirmed		
Reptilia	Scincidae	*Lerista punctatovittata*	Eastern Robust Slider	Confirmed		
Reptilia	Scincidae	*Lerista timida*	Timid Slider	Confirmed		
Reptilia	Scincidae	*Lerista xanthura*	Yellow-tailed Plain Slider	Likely		Vulnerable
Reptilia	Scincidae	*Liopholis inornata*	Desert Skink	Confirmed		
Reptilia	Scincidae	*Menetia greyii*	Common Dwarf Skink	Confirmed		
Reptilia	Scincidae	*Morethia adelaidensis*	Saltbush Morethia Skink	Confirmed		
Reptilia	Scincidae	*Morethia boulengeri*	South-eastern Morethia Skink	Confirmed		
Reptilia	Scincidae	*Morethia obscura*	Shrubland Morethia Skink	Confirmed		
Reptilia	Scincidae	*Tiliqua occipitalis*	Western Blue-tongued Lizard	Confirmed		Vulnerable
Reptilia	Scincidae	*Tiliqua rugosa*	Shingle-back	Confirmed		
Reptilia	Typhlopidae	*Anilios australis*	Southern Blind Snake	Confirmed		
Reptilia	Typhlopidae	*Anilios bicolor*	Dark-spined Blind Snake	Likely		
Reptilia	Typhlopidae	*Anilios bituberculatus*	Prong-snouted Blind Snake	Very Likely		
Reptilia	Varanidae	*Varanus gouldii*	Gould's Goanna	Confirmed		
Reptilia	Varanidae	*Varanus varius*	Lace Monitor	Likely		

Appendix 2. Draft Scorecard for Mallee Cliffs

[attached]

Performance Scorecard 2016
Mallee Cliffs Sanctuary

Size: 57,969 hectares
Bioregion: Murray Darling Depression

australian wildlife conservancy

BIODIVERSITY METRICS

Definitions: Population size = number of individuals in project area; abundance = number of individuals or captures/100 trap nights or site; activity = number of records/site; occupancy = proportion of sites recorded; richness = mean number of species/site.

Indicator	Unit	Baseline value	Current value	Recent trend	Comment
MAMMALS					
Small-medium mammals					
Western Quoll	Population size	0	0		Species not yet introduced.
Red-tailed Phascogale	Population size	0	0		Species not yet introduced.
Numbat	Population size	0	0		Species not yet introduced.
Western Barred Bandicoot	Population size	0	0		Species not yet introduced.
Greater Bilby	Population size	0	0		Species not yet introduced.
Burrowing Bettong	Population size	0	0		Species not yet introduced.
Brush-tailed Bettong	Population size	0	0		Species not yet introduced.
Bridled Nailtail Wallaby	Population size	0	0		Species not yet introduced.
Greater Stick-nest Rat	Population size	0	0		Species not yet introduced.
Mitchell's Hopping Mouse	Population size	0	0		Species not yet introduced.
Echidna	Abundance	No data	TBD		Survey not yet conducted.
[Yellow-footed Antechinus]	Abundance	No data	TBD		Survey not yet conducted.
Common Dunnart	Abundance	0.8	TBD		Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Fat-tailed Dunnart	Abundance	0.1	TBD		Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Southern Ningaui	Abundance	1.9	TBD		Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Small-medium mammals – guild (dasyurids, bandicoots, bettongs, rodents)	Abundance, Richness	2.8, 2.3	TBD		Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Large herbivores					
Red Kangaroo	Population size	No data			
Eastern Grey Kangaroo	Population size	No data			
Western Grey Kangaroo	Population size	No data			
Euro	Population size	No data			
Arboreal mammals					
Western Pygmy Possum	Abundance	1.7			Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Bats					
Little Pied Bat	Activity	No data			Survey not yet conducted

Microbats – guild	Activity, richness	No data			Survey not yet conducted.
REPTILES					
Small-medium reptiles					
Jewelled Gecko	Abundance	0.1			Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Spinifex Slender Blue-tongued Lizard	Abundance	No data			Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Western Blue-tongued Lizard	Abundance	0.04			Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Mallee Worm-lizard	Abundance	0.1			Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
Small-medium reptiles – guild	Abundance, richness	30, 23			Baseline data from NPWS semi-annual surveys of nine sites 2001-14. AWC survey not yet conducted.
BIRDS					
Woodland birds					
Red-tailed Black-Cockatoo	Abundance	No data			
Major Mitchell's Cockatoo	Abundance	No data			
Spotted Harrier	Abundance	No data			
Gilbert's Whistler	Abundance	No data			
Varied Sittella	Abundance	No data			
Purple-gaped Honeyeater	Abundance	No data			
Black-chinned Honeyeater	Abundance	No data			
Pied Honeyeater	Abundance	No data			
Woodland birds - guild	Abundance, richness	No data			
Ground active birds					
Malleefowl	Abundance	No data			
Brown Treecreeper	Abundance	No data			
Flame Robin	Abundance	No data			
Hooded Robin	Abundance	No data			
Southern Scrub-robin	Abundance	No data			
Chestnut Quail-thrush	Abundance	No data			
Shy Heathwren	Abundance	No data			
White-fronted Chat	Abundance	No data			
Ground active birds - guild	Abundance, richness	No data			
FROGS					
[Frog species – TBD]	Abundance, occupancy	No data			Survey not yet conducted
Frogs - guild	Abundance, richness	No data			Survey not yet conducted
VEGETATION					
Tree cover and composition	TBD	No data			Survey not yet conducted.
Shrub cover and composition	TBD	No data			Survey not yet conducted.
Ground cover and composition	TBD	No data			Survey not yet conducted.
Hollow-bearing trees	Mean no./ ha	No data			Survey not yet conducted.
Hollow logs	Mean no./ ha	No data			Survey not yet conducted.

Woody debris	Mean volume (m^3/ ha)	No data			Survey not yet conducted.
Threatened plants					
Bitter Quandong (*Santalum murrayanum*)	Abundance	No data			Survey not yet conducted.
Cypress Pine (*Callitris verrucosa, Callitris glaucophylla*)	Abundance	No data			Survey not yet conducted.
Mulga (*Acacia aneura*)	Abundance	No data			Survey not yet conducted.
[Threatened ecological communities TBD, eg Sandhill Pine Woodland, if present]	TBD: metrics of condition, composition	No data			Survey not yet conducted.
Ecological processes					
Incidence of diggings	Mean no. diggings/ ha	No data			Survey not yet conducted.

METRICS RELATED TO MANAGEMENT OF KEY THREATS

Definitions: Population density = estimated number of individuals/ unit area in project area; abundance = number of records per 100 trapnights or site; occupancy = proportion of sites recorded.

Expenditure	Activity metrics		Eco Health Metric	Unit	Baseline value	Current value	Recent trend	Comment
FIRE								
($xx)	Number of ignitions	0	Area burnt by fire/ wildfire	ha, % project area	TBD	TBD		Fire-scar data available
	Planned fires (ha)	TBD	Fire/ wildfire frequency (median)	number	TBD	TBD		Fire-scar data available
			Time since fire/ wildfire (median)	years	TBD	TBD		Fire-scar data available
			Mean and maximum distance to unburnt vegetation (defined by time since fire/ wildfire)	km	TBD	TBD		Fire-scar data available
INTRODUCED HERBIVORES								
($xx)	Goats removed	0	Goats	[Population density], abundance, occupancy	No data			
	Rabbits killed	0	Rabbits	[Population density], abundance, occupancy	No data			
	Pigs killed	0	Pigs	[Population density], abundance, occupancy	No data			
($xx)	Cats killed	0	Cats	[Population density], abundance, occupancy	No data			
	Foxes killed	0	Foxes	[Population density], abundance, occupancy	No data			
	Meat baits laid	0	Wild dogs	Abundance, occupancy	No data			
	M44 days	0						
WEEDS								
($xx)	Area of weeds treated (ha)	0	African boxthorn	Extent of infestation (ha) (by density)	TBD			Survey not yet conducted.
	Roadsides treated for weeds (km)		Wards Weed	Extent of infestation (ha) (by density)	TBD			Survey not yet conducted.
			[other weeds TBD]	Extent of infestation (ha) (by density)	TBD			Survey not yet conducted.

Baseline value: Value before or at acquisition if that value was measured and is considered appropriate. Alternatively, the baseline may be the value for a metric in the absence of management (derived from spatial and/or temporal controls), or some other defensible and appropriate estimate (as specified).

Current value: Value in current year or at most recent survey (specify year, if not current year).

Recent trend: Calculated over a suitable period to account for year to year variation in values, e.g. variation associated with prevailing rainfall or other ecological drivers. For threat metrics, improving trends and situations where threats have been maintained at low levels are coloured in green (↑ ↓↔); deteriorating trends are coloured in red (↑ ↓).