Ecological Health Monitoring Framework: Pilliga

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 in the Pilliga State Conservation Area and the Pilliga National Park (Gilgai Section). For the purposes of this document, the area covered by the Extinct Mammal Agreement will be referred to as the "Pilliga project area". It covers approximately 36,000 ha (Figure 1).

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 (5,000 ha+) feral predator-free area, protected by a conservation fence, into which mammal species listed as extinct in NSW will be reintroduced in the Pilliga project area. AWC is also contracted to deliver science and land management services, such as feral animal and weed control, across the Pilliga project area (fenced and unfenced sections).

This Ecological Health Monitoring Framework (EHMF) is designed to measure the changes in ecological health across the Pilliga project area 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 the Pilliga project area 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 the Pilliga project area.

This EHMF will be integrated with the proposed Research Strategy for the Pilliga project area, noting the role of research in helping us 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 the Pilliga project area. 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 (horse, cattle, pig, 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 1 (biodiversity and ecological processes) and Table 2 (threats).

Survey design

The Pilliga EHMF provides for a rigorous and systematic (grid-based) survey design that incorporates a range of survey methods at several spatial scales.

- A total of 50 survey points, located on a 2.5 km grid, have been selected for monitoring a range of biodiversity and threat indicators (outlined below).
- A further 10 survey points will be established on a 1.25 km grid within the fenced area, making a total of 20 survey points within the fenced area. These sites will be used for monitoring the outcomes of proposed reintroductions for small mammals, reptiles and vegetation. Matched sites outside the fence will be used as controls.
- Ten of the survey points are coincident with a 5 km grid covering the Pilliga forests. These points will be surveyed for birds and bats using methods compatible with the Forestry Corporation of NSW (FCNSW) monitoring program, to allow comparison of outcomes for these taxa on the Pilliga project area with adjacent land managed by FCNSW.
- Additional targeted effort at other locations, as set out below.
- AWC's monitoring program has been designed with the intention of providing sufficient statistical power to detect substantial changes in abundance (or other relevant metrics) of key indicators. Following the collection of data, the power of the monitoring program to detect change will be subject to formal analysis.

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

- 1920 pitfall trap nights: 60 sites, 8 traps per site, 4 nights
- 4800 box trap nights: 60 sites, 20 traps per site, 4 nights
- 2880 funnel trap nights: 60 sites, 12 traps per site, 4 nights

- 960 cage trap nights: 60 sites, 4 traps per site, 4 nights
- 3360 camera trap nights: 120 sites (60 off-road, 60 on-road), 1 camera/site, 14 nights, repeated twice yearly
- 150 bird surveys (standard 2 ha, 20 minute; and Songmeter) (50 sites, 3 replicates)
- 48 bat survey nights (Songmeter) (12 sites, 4 nights)
- 100 spotlight surveys (50 transects of 200 m, 2 repeats)
- 100 nocturnal bird/ mammal surveys (active listening and call playback; 50 sites, 2 repeats)
- 60 surveys of habitat and ecological processes
- 30 vegetation surveys (15 inside fence, 15 outside fence)
- Other surveys as noted below, including nest-boxes, targeted searches for frogs, threatened birds and 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, it is important to note that over the past decade NSW NPWS has conducted one live-trapping survey for vertebrate fauna (four sites, total effort 600 trap nights) and a survey of shorebirds in the Pilliga project area (Murphy 2013; NSW NPWS 2013).

Monitoring the Pilliga species (regionally extinct mammals)

At least six species of 'extinct in NSW' mammals (the 'Pilliga species') will be reintroduced to the project area, initially within a large (>5,000 ha) feral predator-free (fenced) area. The species are:

- Western Barred Bandicoot *Perameles bougainville*
- Greater Bilby Macrotis lagotis
- Brush-tailed Bettong *Bettongia penicillata*
- Bridled Nailtail Wallaby *Onchyolagea fraenata*
- Plains Mouse *Pseudomys australis*
- Western Quoll *Dasyurus geoffroii*

In addition, the Northern Hairy-nosed Wombat *Lasiorhinus krefftii* may also be considered for reintroduction, subject to further analysis.

The EHMF provides for regular monitoring of populations of the Pilliga Species to assess:

- The outcomes (success) of reintroductions of the Pilliga 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 the Pilliga 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 up to 31 threatened species: see list below. The list will be reviewed annually, taking into account factors such as the detectability of species in surveys.

Indicator	**Threatened species**
Frogs	[Sloane's Froglet]
Birds	Glossy Black Cockatoo Brown Treecreeper Speckled Warbler Varied Sitella Turquoise Parrot Little Lorikeet Grey-crowned Babbler [Malleefowl] [Bush Stone Curlew] Southern Barking Owl
Mammals	Yellow-bellied Sheath-tailed Bat Large-eared Pied Bat Little Pied Bat Western Quoll Western Barred Bandicoot Greater Bilby Rufous Bettong Brush-tailed Bettong Bridled Nailtail Wallaby Plains Mouse Pilliga Mouse Koala Squirrel Glider Eastern Pygmy Possum Black-striped Wallaby [Northern Hairy-nosed Wombat]
Reptiles	[Pale-headed Snake]
Plants	*Rulingia procumbens* *Tylophora linearis* *Myriophyllum implicatum*

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, based on 2.5 km grid, 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 the Pilliga project area 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 the Pilliga project area. This gives effect to a commitment under the NSW Government's *Saving our Species* policy.

In the Pilliga project area, AWC will establish a large (5,000 ha+) feral predator-free area, protected by a conservation fence, into which a suite of 'extinct in NSW' mammals (the 'Pilliga 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 the Pilliga species to the unfenced section of the Pilliga project area, 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 the Pilliga project area.

The overarching objective of the project is to improve the ecological health of the Pilliga project area. 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 for the Pilliga forests and the manner in which these indicators will be measured, including details of survey design and effort.

The Pilliga forests

The Pilliga forests (total area over 500,000 ha) form the largest consolidated block of semi-arid woodland in temperate eastern Australia. The forests stretch across low hills and flat, sandy plains between Coonabarabran and Narrabri in central-west NSW.

Most of the creeks in the Pilliga run towards the north-west. Over geological time, a depositional landscape, the 'Pilliga outwash', has developed in the north-west of the region. The outwash zone supports higher fertility soils than in the south-east. AWC's project area is located within the outwash zone.

The Pilliga forests are within the traditional lands of the Gamilaroi People. European settlers arrived in the 1830s but the sandy soils of the Pilliga were not favourable to agriculture or pastoralism (Rolls 1981). Subsequently, forestry became the major land-use and most of the Pilliga forests have been selectively logged for over a century. Forests on the Pilliga outwash have been subject to more intensive logging than forests elsewhere.

The Pilliga Nature Reserve, in the south-east of the Pilliga forests, was declared in 1968. In 2005, further areas of state forest in the Pilliga were declared as National Park or State Conservation Area (Figure 1). Half the area of the Pilliga forests are now managed primarily for nature conservation.

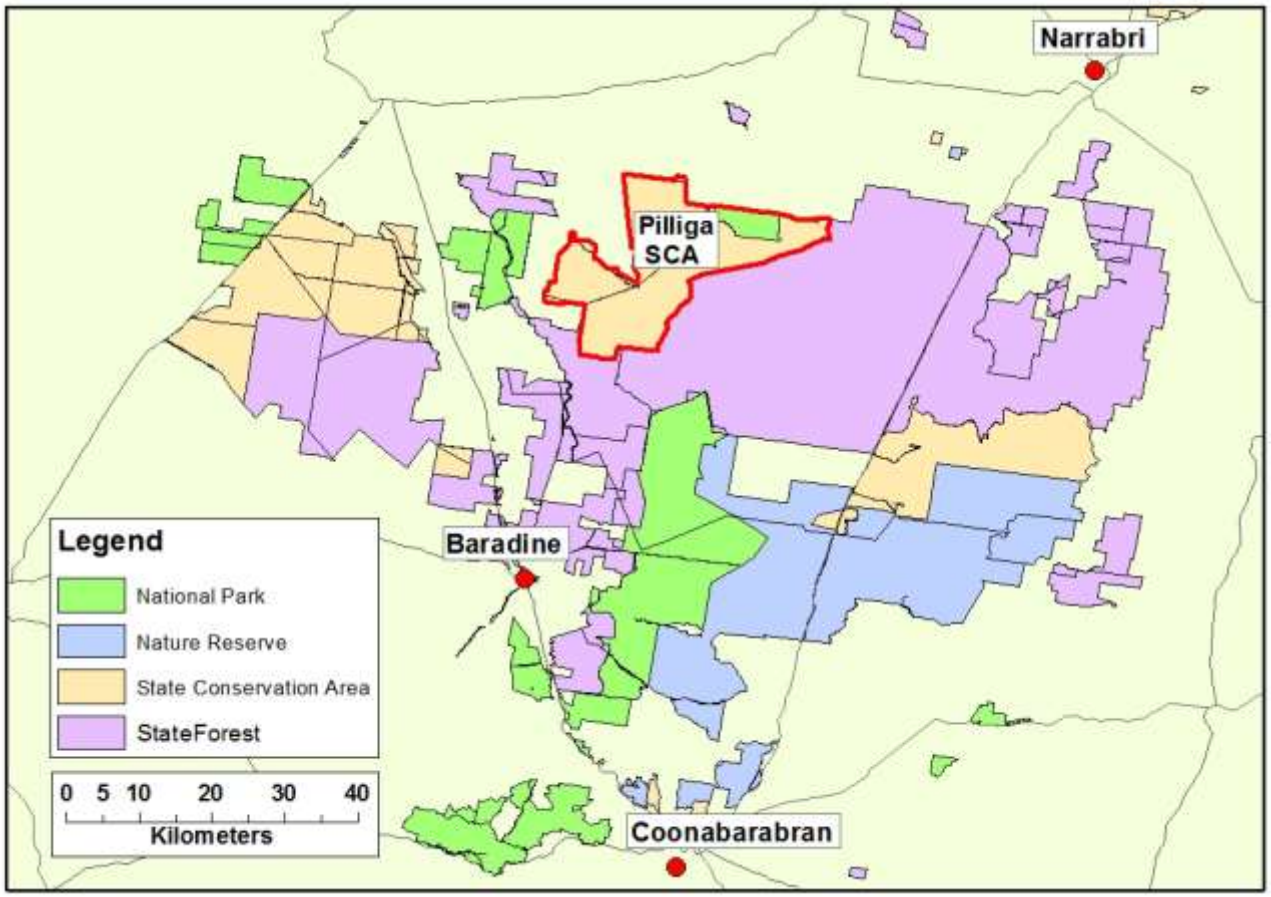

Figure 1. Management tenures in the Pilliga forests. The Pilliga project area (red perimeter) includes the Pilliga State Conservation Area and the adjacent "gilgai" section of Pilliga National Park.

Vertebrate fauna

At least 270 species of native vertebrates are known or likely to occur in the Pilliga project area, with 15% of species listed as threatened under Commonwealth or NSW legislation (see Appendix 1). Most of the small- to medium-sized terrestrial mammals that occurred in the Pilliga at European settlement have since become regionally or globally extinct (see below). Extant, threatened mammals include the Koala, Squirrel Glider, Black-striped Wallaby, Corben's Long-eared Bat and the Pilliga Mouse. Threatened birds include the Barking Owl, Glossy Black Cockatoo, Grey-crowned Babbler, Brown Treecreeper, Speckled Warbler, Varied Sittella, Little Lorikeet and Turquoise Parrot. One threatened reptile, the Pale-headed Snake, is known to occur in the Pilliga. For some species, including the Koala and Barking Owl, the Pilliga forests are a major stronghold for populations in southern Australia.

Systematic fauna surveys of the Pilliga forests under State Forest tenure were conducted in the 1990s (Paull and Date 1996). While some survey work has been conducted since (e.g., Murphy 2013; NSW NPWS 2013), there have been no comprehensive surveys of the vertebrate fauna of the Pilliga project area since its addition to the protected area estate.

Vegetation

A total of 530 vascular plant taxa from 89 families and 271 genera have been recorded within the Pilliga project area and adjoining protected areas (Hunter 2010). White Cypress Pine *Callitris glaucophylla* is the most widespread tree in the project area. Other common trees include Narrow-leaved Ironbark *Eucalyptus creba*, Bull Oak *Allocasuarina luehmannii*, several species of Red Gum (including Blakely's Red Gum *Eucalyptus blakelyi*, River Red Gum *Eucalyptus camaldulensis*), Rough-barked Apple *Angophora floribunda*, Pilliga Box *Eucalyptus pilligaensis* and Poplar Box *Eucalyptus populnea*. A dense shrubby vegetation known as 'broombush' (mostly *Melalueca* spp.) forms a distinctive vegetation type in parts of the project area.

Eight threatened plants are known to occur in the project area (Hunter 2010; AWC unpublished). There is one confirmed Endangered Ecological Community present in the project area: the 'Pilliga Outwash Ephemeral Wetlands in the Brigalow Belt South Bioregion' (Bell et al. 2012).

Vegetation maps of the Pilliga forests are based on a vegetation classification known as the "Lindsay types", developed from extensive field work conducted in the 1940's (Lindsay 1967; Whipp *et al*. 2009). The most recent vegetation map of the project area was produced by Hunter (2010), who collated plot-based information from previous floristic surveys (50 x 0.1 ha plots; Binns and Beckers 2001) and added 59 new 0.04 ha plots to develop a vegetation classification based on a total of 13 vegetation communities in the study area. The resultant map was guided by the work of Lindsay (1967), including the original vegetation polygon boundaries.

There is a widely held view that the structure and composition of the Pilliga forests have changed dramatically since European settlement, as a result of the extinction of native mammals, the introduction of domestic stock and rabbits, altered fire regimes and forestry (Rolls 1981). Date *et al.* (2002) summarised these changes as follows:

"The most common view is that prior to 1830 the Pilliga was open, grassy woodland with a few old eucalypts and cypress pines per hectare and that now there are fewer old trees, but more young trees and shrubs and little grass."

AWC's Ecohealth Monitoring Framework

The overarching objective of AWC's Extinct Mammal Project is to improve the ecological health of the Pilliga project area. 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 in the Pilliga project area.

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 the project area is presented in Appendix 2.

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 and/or habitat components. Additional, targeted surveys will be carried out where omnibus surveys are inadequate, including nest-boxes for Eastern Pygmy Possums, wetland surveys for frogs, targeted surveys for threatened birds and plants, camera grids for estimating density of feral predators.

Biodiversity indicators

Biodiversity indicators selected for monitoring in AWC's Pilliga project area are listed in Table 1, along with the rationale for their selection and associated metrics. Further details on selected indicators, survey design and methodologies are provided below.

Table 1. Biodiversity indicators for ecohealth monitoring framework for the Pilliga project area. 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
Western Barred Bandicoot	*	*	*		Cage traps	Population size, abundance, occupancy
Greater Bilby	*	*	*		Spotlight transects, cameras	Population size, abundance, occupancy
Brush-tailed Bettong	*	*	*		Cage traps	Population size
Bridled Nailtail Wallaby	*	*	*		Spotlight transects, cameras	Population size, abundance, occupancy
Plains Mouse	*	*			Box traps, pitfall traps	Abundance
Echidna				*	Camera traps	Abundance, occupancy
Yellow-footed Antechinus				*	Box traps, pitfall traps	Abundance
Common Dunnart				*	Box traps, pitfall traps	Abundance
Rufous Bettong	*		*		Cage traps, cameras	Population size, abundance, occupancy
Pilliga Mouse	*				Box traps, pitfall traps	Abundance
Small-medium mammals – guild (dasyurids, bandicoots, bettongs, rodents)	*	*	*		Box traps, cage traps, pitfall traps	Abundance, richness
Large herbivores						
Northern Hairy-nosed Wombat	*	*	*		TBD	Population size
Black-striped Wallaby	*				Cameras, [spotlight transects]	Abundance, occupancy
Eastern Grey Kangaroo			*	*	Cameras, [spotlight transects]	Abundance, occupancy
Arboreal mammals						

Indicator	**Rationale**				**Survey method**	**Metric/s** (in order of preference)
Koala	*				Listening, call-playback and spotlight transects	Abundance, occupancy
Squirrel Glider	*				Listening, call-playback and spotlight transects	Abundance, occupancy
Eastern Pygmy Possum	*				Nest boxes	Abundance, occupancy
Common Brushtail Possum	*				Listening, call-playback and spotlight transects	Abundance, occupancy
[Common Ringtail Possum]	*				Listening, call-playback and spotlight transects	Abundance, occupancy
Bats						
Yellow-bellied Sheath-tailed Bat	*				Songmeter SM4BAT detectors	Activity, occupancy
Large-eared Pied Bat	*				Songmeter SM4BAT detectors	Activity, occupancy
Little Pied Bat	*				Songmeter SM4BAT detectors	Activity, occupancy
Microbats - guild				*	Songmeter SM4BAT detectors	Activity, richness
Reptiles						
Small-medium-sized reptiles						
Small-medium reptiles - guild		*		*	Pitfall traps, funnel traps	Abundance, richness
Other reptiles						
[Pale-headed Snake]	*				Spotlighting	Abundance, occupancy
Birds						
Woodland birds						
Glossy Black Cockatoo	*				Counts of dusk visits to dams; standard bird survey: 2 ha plot 20-minute counts	Population size, abundance, occupancy
Brown Treecreeper	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Speckled Warbler	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Varied Sitella	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Turquoise Parrot	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
Little Lorikeet	*				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

Indicator	**Rationale**				**Survey method**	**Metric/s** (in order of preference)
Ground-active birds						
Grey-crowned Babbler	*				Standard bird survey: 2 ha plot 20-min counts	Abundance, occupancy
[Malleefowl]	*				Mound survey, cameras	Abundance, occupancy
Ground active birds - guild	*			*	Standard bird survey: 2 ha plot 20-min counts	Abundance, richness
Nocturnal birds						
[Bush Stone Curlew]	*				Listening, call-playback and spotlighting	Abundance, occupancy
Barking Owl	*	*	*		Listening, call-playback and spotlighting	No. occupied territories, abundance, occupancy
Frogs						
[Sloane's Froglet]				*	Targeted surveys on warm, wet nights	Abundance, occupancy
Frogs - guild				*	Targeted surveys on warm, wet nights	Abundance, richness
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 plants						
Myriophyllum implicatum	*				Searches at wetlands	Abundance
Androcalva/ Rulingia procumbens	*				Searches in potential habitat	Abundance
Tylophora linearis	*				Transects in known sites	Abundance
Pilliga Outwash Ephemeral Wetlands	*				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 mammals

Small to medium-sized (<5.5 kg) terrestrial mammals are highly vulnerable to foxes and feral cats (Woinarski et al. 2014). In the Pilliga, most species in the guild have become regionally extinct; some are globally extinct (Table 2). Extant small to medium-sized mammals in the region include Echidna, Yellow-footed Antechinus, Common Dunnart, Rufous Bettong and Pilliga Mouse.

Table 2. Small- to medium sized terrestrial mammal fauna of the Pilliga (sources: Paull and Date 1999; Ford and Aplin 2008; NSW NPWS 2013; Woinarski *et al*. 2014). Shading = species to be reintroduced to the Pilliga.

Species	Status NSW	Present distribution
Echidna *Tachyglossus aculeatus*		Widespread
Western Quoll *Dasyurus geoffroii*	Extinct	Restricted to south-west WA. Reintroduced to parts of WA and recently to SA
Spotted-tailed Quoll *Dasyurus maculatus*	Vulnerable	Restricted to eastern forests and Tasmania. Sparse records from region.
Yellow-footed Antechinus *Antechinus flavipes*		Widespread in eastern and south-west WA. Recently recorded in Pilliga NP (gilgai section)
Common Dunnart *Sminthopsis murina*		Widespread in woodlands eastern Australia. Occasional records from historical surveys.
Brush-tailed Phascogale *Phascogale tapoatafa*	Vulnerable	Restricted to eastern forests, south-west WA. Present in subfossil record in Pilliga.
Bandicoot *Isoodon* sp.		Declined in semi-arid parts of their ranges. Present in subfossil record in Pilliga.
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
Northern Hairy-nosed Wombat *Lasiorhinus krefftii*	Extinct	One remnant and one small reintroduced population in Qld. Possible reintroduction
Rufous Bettong *Aepyprymnus rufescens*	Vulnerable	Declined from most of NSW, persists in Qld. Sparse records from Pilliga forests.
Brush-tailed Bettong *Bettongia penicillata*	Extinct	Persists in south-west WA. Reintroduced to feral predator-free areas inc. AWC sanctuaries
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
Hopping Mouse *Notomys sp.*	Extinct	No species extant in NSW
Plains Mouse *Pseudomys australis*	Extinct	Remnant populations in SA
Pilliga Mouse *Pseudomys pilligaensis*	Vulnerable	Pilliga endemic, although has been considered within *P. delicatulus*.
Other native rodents: *Pseudomys* and *Rattus* spp.	*Pseudomys* Extinct or Threatened	*P. glaucus*, *P. gouldii* globally extinct; *P. oralis* (Endangered), *P. gracilicaudatus* (Vulnerable), *R. fuscipes, R. lutreolus, R. tunneyi* restricted to eastern forests/ mesic parts of their ranges

Indicator species

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

- presumed extant species:
    - Echidna
    - Yellow-footed Antechinus
    - Common Dunnart
    - Rufous Bettong
    - Pilliga Mouse
- mammals to be reintroduced to the Pilliga (the 'Pilliga species'):
    - Western Quoll
    - Western Barred Bandicoot
    - Greater Bilby
    - Brush-tailed Bettong
    - Bridled Nailtail Wallaby
    - Plains Mouse

We will also report on abundance and richness of small- to medium-sized mammals from the following guild: dasyurids, bandicoots, bettongs and rodents. Species in this guild are particularly vulnerable to introduced predators and can be readily trapped, allowing for a robust metric.

Rationale for inclusion

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

- All reintroduced species and two extant species, the Rufous Bettong and Pilliga Mouse, are threatened. The guild of small- to medium-sized mammals is at risk of decline.
- Many species in the guild are important drivers of ecosystem processes (soil engineering; other roles including predation, seed and fungal spore dispersal).

Survey methodology

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

- live traps (box traps, cage traps, pitfall traps)
- cameras
- spotlight surveys.

The most relevant survey method will depend partly on the behaviour of a species (in particular, whether it readily enters traps) and also on the abundance of a species (see 'unit of measurement', below).

Live traps will be used to monitor dasyurids, bandicoots, bettongs and rodents.

Spotlight transects (if effective in the Pilliga) or cameras will be used to monitor Bilbies and Bridled Nailtail Wallabies, which do not readily enter traps.

Cameras will provide records of all medium-sized mammals, particularly useful when species are rare.

Unit of measurement

Population size is the preferred metric for reintroduced mammals and extant species in the medium-sized guild. For most species, population size will be estimated by live-trapping or spotlighting. Data from trapping of medium-sized mammals, which will be marked to identify individuals, will be analysed using a capture-mark-recapture (CMR) model. Data from spotlighting transects will be analysed using a strip transect

approach to estimate density and hence 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 which are not identified to individuals. Abundance (mean capture rate of all species in the guild per 100 trap nights) and richness (mean number of species 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 the Pilliga have not been present in the region for at least a century. Rigorous baseline data are not available for the other species.

Large herbivores

Large terrestrial herbivores (>5.5 kg) in the Pilliga project area include:

- Black-striped Wallaby
- Eastern Grey Kangaroo
- Wallaroo
- Red-necked Wallaby
- Red Kangaroo
- Swamp Wallaby

In addition, the Northern Hairy-nosed Wombat may be reintroduced to the project area.

Indicator species

Species selected as indicators will include:

- Black-striped Wallaby
- Eastern Grey Kangaroo [and, potentially, other macropods]
- Northern Hairy-nosed Wombat, if reintroduced

Rationale for inclusion

Both the Black-striped Wallaby and the Northern Hairy-nosed Wombat, if reintroduced, are threatened.

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

The Eastern Grey Kangaroo, as the largest and most common of the extant macropods, has been selected for monitoring. However, as the survey methods used will provide data on all macropods present, additional macropods may be selected for monitoring if sufficiently abundant.

Survey methodology

Macropods will initially be surveyed by cameras. Some effort will be directed to determining whether spotlight surveys are suitable for estimating density of macropods in the project area – the vegetation may

be too dense to obtain reliable data. If Northern Hairy-nosed Wombats are reintroduced, targeted survey methods will be employed, such as surveys of active burrows.

Unit of measurement

If spotlight surveys prove tractable, 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).

Population size will be estimated of the Northern Hairy-nosed Wombat, if reintroduced.

Baseline

Northern Hairy-nosed Wombats have not been definitively recorded in NSW for over a century (Swinbourne *et al.* 2017). Baseline data are not available for macropods in the project area.

Arboreal mammals

There are seven species of arboreal mammals in the Pilliga:

- Koala
- Eastern Pygmy Possum
- Sugar Glider
- Squirrel Glider
- Common Ringtail Possum
- Feathertail Glider
- Common Brushtail Possum

Indicator species

Four, possibly five, arboreal mammals will be monitored in AWC's Pilliga project area:

- Koala
- Eastern Pygmy Possum
- Squirrel Glider
- Common Brushtail Possum
- [Common Ringtail Possum] (if sufficiently common)

Rationale for inclusion

The Koala, Eastern Pygmy Possum and Squirrel Glider are listed threatened species. The Pilliga forests were a stronghold of the Koala in NSW (Kavanagh and Barrott 2001; Kavanagh *et al*. 2007a; Kavanagh and Stanton 2009). However, the population crashed during the millennium drought, exacerbated by extended sequences of extremely hot days and a lack of access to free water (Lunney *et al*. 2012; Lunney *et al.* 2017). Both the Ringtail Possum and Brushtail Possum are vulnerable to predation by foxes and feral cats (Woinarski et al. 2014); both species have declined in the Pilliga, with the Ringtail Possum becoming especially rare (Paull 2001). The Ringtail Possum warrants inclusion as an indicator if sufficient numbers can be detected to provide a signal for monitoring.

Survey methodology

The larger arboreal mammals will be surveyed through a combination of techniques (listening, call playback and spotlighting) employed during nocturnal surveys of monitoring sites. Eastern Pygmy Possum will be surveyed using nest-boxes installed at 12 sites.

Unit of measurement

Spotlight/ call playback surveys will provide data on abundance (number of records per site) and occupancy (proportion of sites with records) for each species. Nest-box box surveys will provide data on abundance (number of individuals/ 48 next boxes)

Baseline

Populations of the Koala, Common Ringtail Possum and Common Brushtail Possum are known to have declined substantially in the Pilliga region. Trends in populations of Squirrel Glider and Eastern Pygmy Possum are unknown.

Bats

Around 15 species of microchiropterans ('microbats') are thought to inhabit the Pilliga project area. Five of the microbat species are listed as threatened by the Commonwealth or NSW: Yellow-bellied Sheath-tailed Bat, Large-eared Pied Bat, Little Pied Bat, South-eastern Long-eared Bat and Eastern Cave Bat. One megachiropteran, the nomadic Little Red Flying-fox, also frequents the forests on occasion.

Indicator species

Monitoring will focus on threatened species detectable by acoustic recorder:

- Yellow-bellied Sheath-tailed Bat
- Large-eared Pied Bat
- Little Pied Bat

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 three microbats selected for monitoring in the Pilliga are threatened and potentially detectable with sound recorders. Guild-level analysis will monitor activity and richness across all species present.

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 the Pilliga. Thirty-five species of small-medium reptiles (skinks, dragons, geckoes, pygopodids), 14 snakes, four blind snakes, two monitors and two turtle species are known or likely to inhabit the project area. One reptile is listed as threatened: the Pale-headed Snake

Indicator species

- Small-medium reptiles (guild)
- [Pale-headed Snake] (if feasible)

Rationale for inclusion

The Pale-headed Snake is threatened. However, inclusion of this species in the monitoring program will depend on whether it is readily detected in surveys.

Surveillance monitoring of small-medium reptiles is feasible, given this guild can be systematically surveyed using live traps. Some small-medium reptiles may also be affected by mammalian extinctions. At Scotia Wildlife Sanctuary, some species in this guild have increased while other species have decreased following reintroduction of regionally-extinct mammals, although 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-medium reptiles will be surveyed with pitfall and funnel traps. Pale-headed Snake will be surveyed by spotlight.

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. Abundance (number of records/ site) and occupancy (proportion of sites recorded) will be measured for Pale-headed Snake.

Baseline

There are no robust data on trends in the abundance or richness of small-medium reptiles in the project area. Some data are available for the Pale-headed Snake and other reptiles from four sites surveyed in the Pilliga National Park (gilgai section) by NSW NPWS (2013), although differences in scope and methodology mean this survey will not provide a directly comparable baseline with the program to be implemented across the project area by AWC.

Birds

The Pilliga project area is likely to support over 200 species of birds (Appendix 1). The richness of the avifauna is due partly to the location of the Pilliga forests at the convergence of major biomes (Date *et al.* 2002), and also to the Pilliga forests providing refuge for woodland-dependent birds that have declined in areas cleared for agriculture (Reid 1999). Wetlands and other waterbodies in the Pilliga also support a number of resident and migratory shorebirds (Murphy 2013). The Pilliga forests support at least 26 bird species that are listed nationally or in NSW as threatened at the species or subspecies level:

- Spotted Harrier
- Black-breasted Buzzard
- Little Eagle
- Square-tailed Kite
- Bush Stone Curlew
- Australasian Bittern

- Black Falcon
- Australian Bustard
- Speckled Warbler
- Dusky Woodswallow
- Brown Treecreeper
- Diamond Firetail
- Regent Honeyeater
- Painted Honeyeater
- Black-chinned Honeyeater
- Varied Sittella
- Hooded Robin
- Scarlet Robin
- Flame Robin
- Grey-crowned Babbler
- Red-tailed Black-Cockatoo
- Glossy Black-Cockatoo
- Little Lorikeet
- Turquoise Parrot
- Superb Parrot
- Barking Owl

An additional three threatened birds may possibly occur on the project area: Brolga, Malleefowl and Major Mitchell's Cockatoo. The Pilliga forests are an important stronghold for some threatened birds, including the Barking Owl (Kavanagh and Barrott 2001; Date *et al.* 2002; Kavanagh and Stanton 2009).

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:

- Glossy Black Cockatoo
- Brown Treecreeper
- Speckled Warbler
- Varied Sitella
- Turquoise Parrot
- Little Lorikeet
- Grey-crowned Babbler
- Barking Owl
- [Malleefowl] (if present)
- [Bush Stone Curlew] (if recorded sufficiently frequently)

In addition, the following guilds of birds vulnerable to decline will be monitored:

- woodland-dependent birds
- ground-active birds.

Rationale for inclusion

Bird species selected for monitoring are threatened. In addition, the Barking Owl is a top order predator that is expected to respond to an increase in the abundance of mammalian prey following more effective control of foxes and cats and the reintroduction of small mammals to the Pilliga.

Woodland birds are known to have declined in the western slopes and plains of NSW while ground-active birds are known to have declined in the Pilliga (Reid 1999; Kavanagh *et al.* 2007b; Date *et al.* 2012).

Survey methodology

Diurnal birds will be counted in standard 20 minute searches of 2 ha plots at each monitoring site, repeated three times per site per survey period. In addition, targeted surveys will be conducted of the Glossy Black-cockatoo, via counts of dusk visits to waterholes (an established method for this species in the Pilliga).

Nocturnal birds including the Barking Owl and Bush Stone Curlew will be surveyed by a combination of nocturnal listening, playback of pre-recorded vocalisations and spotlighting.

Unit of measurement

Population estimates will be obtained for the Glossy Black-cockatoo, from counts of dusk visits to waterholes. For the Barking Owl, the number of occupied territories (an index of population size) will be obtained. 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

Woodland-dependent birds and a suite of ground-active birds are in decline in southern Australia (Reid 1999; Kavanagh et al. 2007b). In the Pilliga, ground-active birds and birds dependent on large trees for foraging or nesting are also considered to have declined over the past century (Date *et al.* 2002).

Frogs

Sixteen species of frogs are likely to inhabit the Pilliga project area. One species, *Crinia sloanei*, is threatened.

Indicator species

Richness will be monitored at the guild level. Individual species, particularly the threatened Sloane's Froglet, may be monitored provided survey data are sufficiently robust.

Rationale for inclusion

Frogs are threatened or at risk of decline from multiple causes, including silting of waterways, trampling of waterholes by feral herbivores and pigs and other degradation of habitat, and (for some species) infection by the introduced chytrid fungus.

Survey methodology

Frogs will be surveyed by a combination of listening, call-playback and spotlighting in targeted surveys at dams and wetlands on warm, wet nights.

Unit of measurement

Abundance and richness (number of species/site) will be measured at the guild level. If individual frog species such as Sloane's Froglet are monitored, the metric will be abundance (number of records/ site) and occupancy (proportion of sites recorded).

Baseline

Data on the occurrence of frogs at four sites during a survey of the gilgai section of Pilliga National Park are reported in NSW NPWS (2013). Long-term trends in frog populations are unknown.

Vegetation

Vegetation structure and composition

Over 500 vascular plant taxa are known from the Pilliga project area and adjoining protected areas (Hunter 2010). Vegetation composition and structure varies with factors such as substrate, proximity to water and disturbance by fire and forestry practices. Animals can also influence vegetation composition and structure, through a range of processes including herbivory, seed and spore dispersal, soil engineering and litter disturbance. The reintroduction of small-medium sized mammals to the Pilliga is expected to partially restore these ecological processes and, consequently, historically-prevailing vegetation dynamics 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 the Pilliga.

The monitoring program is designed to provide information on the impacts of reintroductions on vegetation dynamics in the project area, 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 permanent 1 ha vegetation plots located inside and outside the fenced area proposed for reintroductions. Baseline surveys will be conducted in 2017.

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 are 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 are also 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.

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

There is a widely held view that forest structure and, to a lesser extent, floristics of the Pilliga forests have changed significantly over the past century (Date et al. 2002). Some of these changes – a substantial increase in stem density, particularly of Cypress Pine and Bull Oak- have been documented (Whipp et al. 2012); other changes – such as a loss of ground cover - are highly plausible but anecdotal (Rolls 1981).

Threatened plant species and communities

Eight threatened plants are known to occur in the project area (Table 3). One Endangered Ecological Community is present in the project area: the 'Pilliga Outwash Ephemeral Wetlands in the Brigalow Belt South Bioregion' (Bell et al. 2012).

Table 3. Threatened plants recorded in the Pilliga project area (Hunter 2010; AWC unpublished)

Species	EPBC	NSW
Pine Donkey Orchid *Diuris tricolor*		Vulnerable
Greenhood Orchid *Pterostylis corbarensis*		Vulnerable
Rulingia / Androcalva/ Commersonia procumbens (a shrub)	Vulnerable	Vulnerable
Tylophora linearis (a vine)	Endangered	Vulnerable
Winged Peppercress *Lepidium monoplocoides*	Endangered	Endangered
Cyperus conicus (a sedge)		Endangered
Austral Pipewort *Eriocaulon australasicum*	Endangered	Endangered
Myriophyllum implicatum (a herb)		Critically Endangered

Indicators

- *Myriophyllum implicatum*
- *Rulingia procumbens*
- *Tylophora linearis.*
- Pilliga Outwash Ephemeral Wetlands

Rationale for inclusion

The plant species and plant community selected for monitoring are threatened.

Survey methodology

The threatened plants will require targeted monitoring. Surveys will be conducted at wetlands for *Myriophyllum implicatum*. For *Rulingia procumbens*, surveys will be conducted on sites where the species is known to occur and conditions are favourable for its presence (i.e., sites that have been recently burnt). *Tylophora linearis* will be surveyed on fixed transects at known locations.

The Endangered Ecological Community, Pilliga Outwash Ephemeral Wetlands, will be monitored in relation to condition and potentially composition and/ or structure. Methods for assessment are to be determined.

Unit of measurement

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

The condition of the Pilliga Outwash Ephemeral Wetlands will be assessed in relation to the severity and extent of disturbance, and other measures relevant to that community (composition and/or structure).

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 (exact 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 in AWC's Pilliga project area 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 the Pilliga project area. 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			
Horse	Threat to wildlife, vegetation	[Aerial survey], cameras	[Population density], abundance, occupancy
Cattle	Threat to wildlife, vegetation	[Aerial survey], cameras	[Population density], abundance, occupancy
Goat	Threat to wildlife, vegetation	[Aerial survey], cameras	[Population density], abundance, occupancy
Rabbit, hare	Threat to wildlife, vegetation	[dung counts], cameras	[Population density], abundance, occupancy
Pig	Threat to wildlife, vegetation, wetlands	[Aerial survey], cameras	[Population density], abundance, occupancy
Weeds			
Tiger pear	Threat to wildlife, esp. mammals	Vegetation surveys, targeted surveys	Extent of infestation (categorised by density)
Prickly pear	Threat to vegetation	Vegetation surveys, targeted surveys	Extent of infestation (categorised by density)
Mother of millions	Threat to vegetation	Vegetation surveys, targeted surveys	Extent of infestation (categorised by density)
Carrion flower	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

Feral cats and foxes are common in southern Australia including the Pilliga region.

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 central-western NSW since the early 19th century (Abbott 2008) and foxes since the late 19th century (Short 1998). 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 the Pilliga (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 known to be large numbers of foxes in the Pilliga, but no robust data on the density or abundance of foxes, cats or wild dogs in the project area prior to AWC's surveys (J. Abel, NPWS Pest Control Officer, pers. comm.). Initial surveys by AWC have confirmed that foxes are common in the project area and that cats and wild dogs are also present (Appendix 4).

Feral herbivores

The Pilliga region supports feral horses, cattle, goats, rabbits, hare and pigs (OEH 2012; NSW NPWS 2013).

Indicator species

- Feral horses
- Cattle
- Goats
- Rabbits/ hare
- 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). Large feral herbivores, especially pigs, can damage wetlands that, in the Pilliga, support threatened plants and shorebirds (Murphy 2013; NSW NPWS 2013). 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 the Pilliga. The density of large feral herbivores can be estimated from aerial survey, however in thick vegetation aerial surveys may miss many individuals. Alternative methods may include counts at waterholes or cameras. An array 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 the array of cameras deployed cross the Pilliga (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. Density will be used as relevant methods are developed.

Baseline

There are no robust data on the density or abundance of feral herbivores in the project area. Initial surveys by AWC have confirmed that goats are common in the project area and that horses, pigs and rabbits are also present (Appendix 4).

Weeds

At least four species of significant environmental weeds (introduced plants) are known to be present in the project area.

Indicator species

- Tiger pear
- Prickly pear
- Mother of millions
- Carrion flower

Additional weeds may be added to the list over time, given survey effort and potential infestations.

Rationale for inclusion

The weeds listed are those most considered to be environmentally significant in the Pilliga project area. Invasive weeds can be a significant threat to ecosystem structure, composition and function, and to habitat provided for wildlife. Some weeds can pose a direct threat to wildlife due to physical or chemical defences. For example, septicaemia following thorn-stick injury by tiger pear is known to be a significant cause of Koala mortality in the Pilliga (Kavanagh *et al*. 2007).

Survey methodology

We will systematically map the distribution of environmentally significant weeds. Infestations will be located from existing (i.e., NSW NPWS) records and from locations reported by AWC staff in the course of their work, including botanists conducting vegetation surveys.

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

[TBD] Relevant data likely to be held by NSW NPWS.

Fire

Fire is a major driver of the structure and composition of Australian ecosystems, and hence wildlife habitat. During Aboriginal management, it is likely that fire regimes in forests with a grassy understorey were characterised by relatively frequent, small-scale, 'cool' fires (Gammage 2011) – these forest types are presumed to have been widespread in the Pilliga (Rolls 1981; Date *et al.* 2002). Fire was suppressed during the period of forestry management, such that most forests in the western part of the Pilliga have not been burnt by any significant fires for at least 70-100 years. By contrast, the eastern section of the Pilliga has been subject to a regime dominated by wildfire. Fire suppression, combined with a long history of forest harvesting and other manipulations, has led to a widespread and significant thickening of the forest stand structure in the Pilliga project area (Whipp *et al*. 2012).

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 increases the exposure of small-medium mammals and other ground-active vertebrates to predation (McGregor *et al.* 2014).

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

The south-east half of the project area was burnt in the 1951 wildfire, otherwise most of the project area has not been burnt in historical times. A prescribed burning program has begun to be implemented by NSW NPWS on the project area. 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 the Pilliga project area. A further consideration, feasibility, necessitates some trade-offs in expression of these principles.

A core element of the survey design is a systematic sampling of available habitat, determined by overlaying a grid of points on AWC's project area (Figure 2). That is, the primary stratification used in the design is spatial, with the objective of achieving a level of spatial independence that is appropriate for the home-ranges of species that will be monitored. A grid approach to monitoring has been used elsewhere, particularly in Scandinavia (Kavanagh 2007) and in Canada (Boutin *et al*. 2009; Munks *et al*. 2010). A similar design underpins the monitoring program being implemented by the Forestry Corporation of NSW (FCNSW) throughout State Forests in the Pilliga.

Strengths of the grid design include an even geographic spread of the survey points such that spatial variation in environmental drivers (e.g., vegetation, soils, rainfall, fire) and the distribution of species is well-sampled. Further, a systematic design has an advantage of ensuring good spatial independence in surveys (Hurlbert 1984). A potential weakness of a grid design is that it may not efficiently sample key environmental drivers, assuming those drivers are well understood (Lindenmayer and Likens 2010). For example, in a grid design, common vegetation types will be sampled by many survey points, while rare vegetation types will be sampled by few survey points. A commonly-used alternative to grid designs is to stratify survey sites primarily by broad vegetation type, as a surrogate for fauna habitat, with spatial segregation of sites a second-order consideration.

In determining an appropriate survey design for a monitoring program in the Pilliga, a major consideration is the lack of robust, up-to-date vegetation mapping for the project area. As noted above, the available maps are largely based on surveys conducted many decades ago. Subsequent forest management including logging, silvicultural treatment and fire suppression has led to major changes in forest structure and composition, particularly of the understorey (Whipp *et al.* 2012). In this situation, a systematic design is well justified as the primary sampling strategy.

Nested grid design

A 2.5 km grid overlain across the Pilliga SCA and Pilliga NP was selected as the primary approach to locating potential monitoring sites. A grid this scale is expected to provide spatial independence of survey sites for most of the wider-ranging species that are likely to be recorded in surveys. The grid was aligned with a Lamberts grid projection for New South Wales based on GDA 1994. The 2.5 km grid points were nested within a larger 5 km grid that forms the basis for biodiversity surveillance monitoring on adjacent State Forests. This compatibility in approach provides a strong basis for comparison of conservation outcomes across a much broader landscape in the Pilliga (see below).

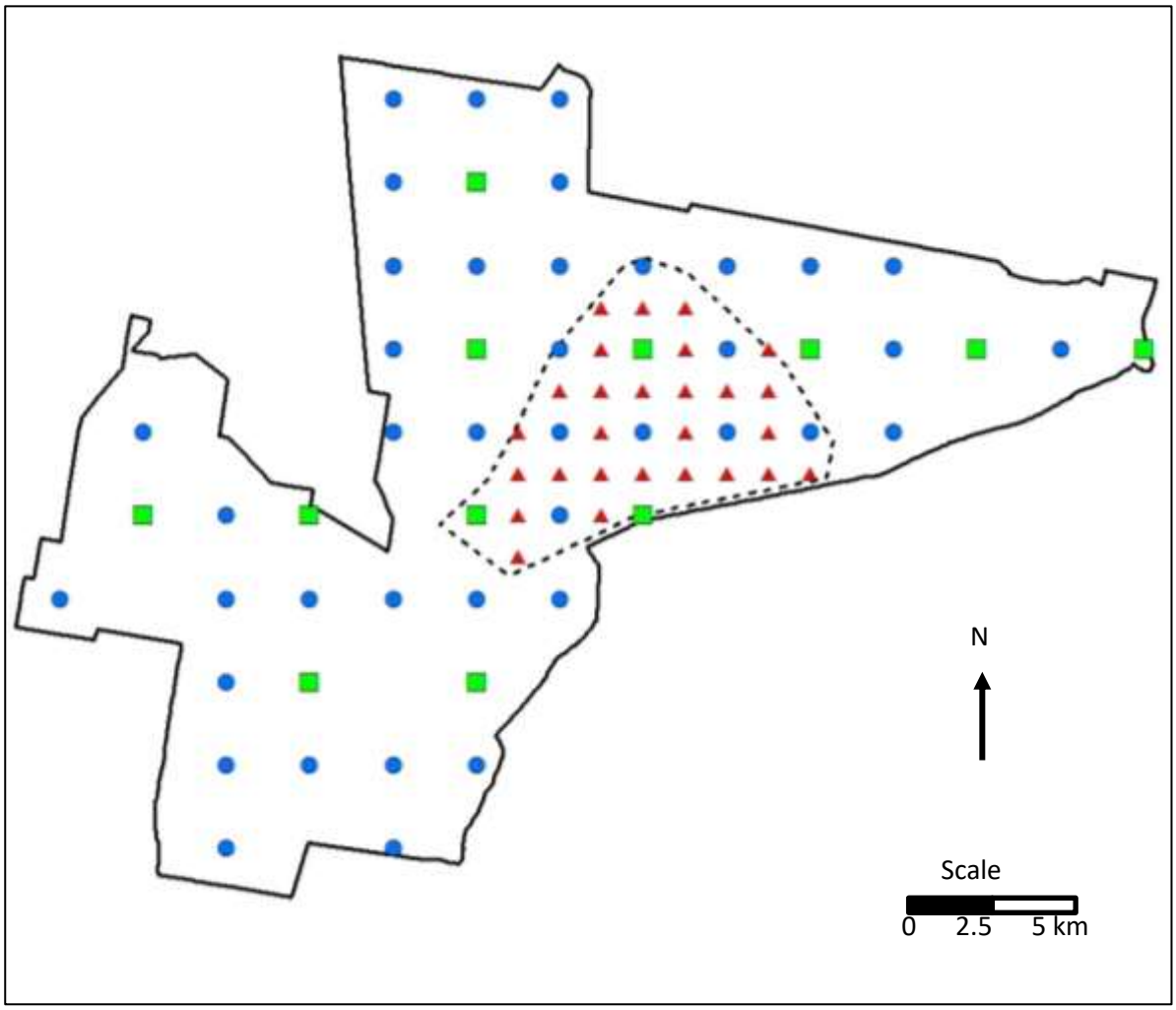

Figure 2. Map showing all potential monitoring site locations in the AWC Pilliga forest project area, based on a nested grid design. Green squares represent an extension of the 5 km grid used by the biodiversity monitoring program within State Forests. The blue dots represent nested 2.5 km grid points. The red triangles represent nested 1.25 km grid points within the feral predator-free fence.

Selection and characteristics of monitoring points

The 2.5 km grid overlay resulted in 57 possible sites within the Pilliga SCA and Pilliga NP (Gilgai section) boundary (Figure 2). Given the logistical constraints of the project, the number of sites available for monitoring was reduced to a total of 50. We developed five hierarchical rules for removing sites, based on scientific and logistical concerns, while maintaining a randomised site-selection approach. In order of implementation, these were:

1. Sites within vegetation types with <10% representation in the area were retained (based on the map produced by Hunter 2010).
2. A minimum of 10 replicates of the 5 km grid points were retained to ensure that there were sufficient sites for comparison with adjacent State Forests managed by FCNSW.
3. When following these rules, any sites adjacent to those previously removed were retained, to ensure that site removal was not spatially biased within the study area.
4. Sites within 500 m from the edge of the project were removed.
5. Sites the greatest distance from the nearest road were removed.

This process resulted in the removal of five sites from the most common vegetation type in the project area (C7), and two sites from the next most common vegetation type (C8), while retaining a representative sample of vegetation proportions within the project area across the selected 50 monitoring points (Figure 3, Table 5). Attributes of each site are described in Appendix 3.

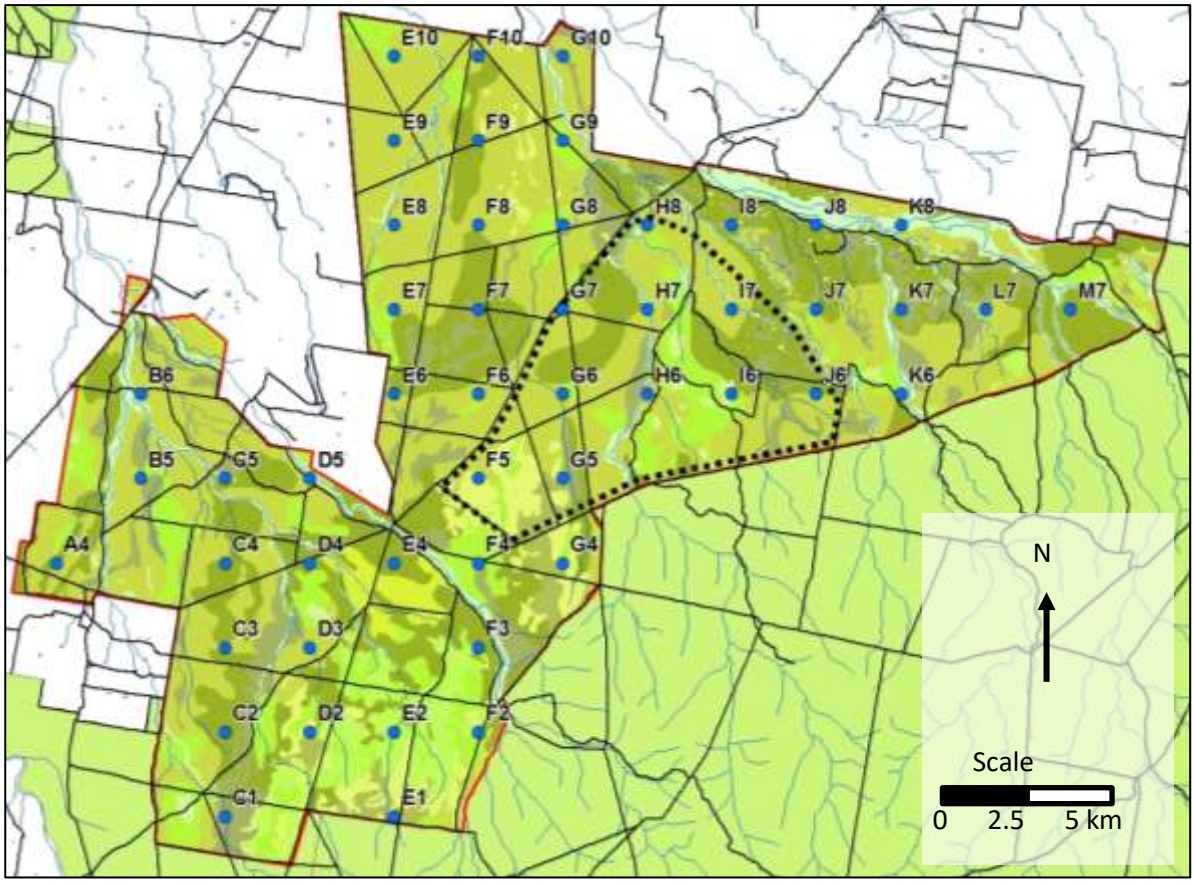

Figure 3. Location of 50 monitoring plots on 2.5 km grid in AWC's Pilliga project area.

Table 5. Number and percentage of mapped vegetation types in AWC's Pilliga project area sampled by 2.5 km grid. (i) all 57 potential grid points; and (ii) the final 50 selected points.

Vegetation Community (Hunter 2010)	Area (%)	All points (n)	All points (%)	50 points (n)	50 points (%)
C7 - Bulloak/ White Cypress/ Pilliga Box	38.6	27	47.4	22	44
C8 – White Cypress/ Bulloak/ Ironbark	23.8	14	24.6	12	24
C9 – White Cypress/ Pilliga Box/ Ironbark	11.2	5	8.8	5	10
C3 – White Cypress/ Dirty Gum	8.8	3	5.3	3	6
C2 – Rough-bark Apple/ River Red Gum	6.2	2	3.5	2	4
C5 - Fringe Myrtle/ Westringia	3.9	3	5.3	3	6
C4 - Broom Bush/ Heath Myrtle	3.7	0	0.0	0	0
C6 - Burrow's Wattle/ Broad-leaf Ironbark/ Brown Bloodwood	1.7	2	3.5	2	4
C1 – White Cypress / Poplar Box	1.2	0	0.0	0	0
C12 - Belah/ Wilga	0.6	1	1.8	1	2
C11 - Tank Herbfield	0.2	0	0.0	0	0
C10 - Five Minute Grass/ Curly Windmill	0.0	0	0.0	0	0

Reintroduction of Pilliga species

Overview of project

A core part of AWC's Pilliga project is the reintroduction of a suite of 'extinct in NSW' mammals. Initially, these mammals will be reintroduced to a large (>5000 ha) fenced area from which feral predators have been eradicated. Species proposed for reintroduction (the 'Pilliga species') are:

- Western Barred Bandicoot *Perameles bougainville*
- Greater Bilby Macrotis lagotis
- Brush-tailed Bettong *Bettongia penicillata*
- Bridled Nailtail Wallaby *Onchyolagea fraenata*
- Plains Mouse Pseudomys australis
- Western Quoll Dasyurus geoffroii

The Northern Hairy-nosed Wombat *Lasiorhinus krefftii* will also be considered for reintroduction.

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).

Monitoring the outcomes of mammal reintroductions

AWC will prepare a Translocation Proposal for 'extinct in NSW' mammals to be reintroduced to the Pilliga forest project site. For each species, the Translocation Proposal will develop 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 6.

Table 6. 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

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.

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 same systematic approach to survey design used across the Pilliga project area has been used to select monitoring sites inside the fenced area. However, the 2.5 km grid used to select 50 sites across the Pilliga project area resulted in only 10 grid points being located within the conservation fence. To obtain sufficient data for robust evaluation of outcomes of the reintroduction project, an additional 10 monitoring sites were required inside the fenced area. Key challenges to establishing additional sites within the fenced area were achieving an appropriate level of sampling while maintaining adequate spatial separation between sites. We addressed these concerns in two ways: (1) using a grid to ensure spatial separation of sites, and (2) ensuring that indicators were monitored at the appropriate scale to avoid pseudo-replication, as described below:

1. Potential monitoring sites within the fenced area were located using a grid with a spacing of 1.25 km between points, nested within the existing 2.5 km grid (Figure 4). This exercise identified 27 additional sites within the fenced area, of which 17 points were removed due to proximity (< 500 m) to the proposed fence, and/or over-representation of common vegetation types. The resulting total of 20 sites (10 sites on a 1.25 km grid, together with the 10 existing sites on the 2.5 km grid) should provide sufficient levels of replication to compare responses between vegetation types. The 20 sites are representative of vegetation assemblages across the Pilliga project area (Table 7). For the purpose of monitoring outcomes of the reintroduction project, the 20 sites inside the fence will be paired with 20 sites outside the fence, these sites to be matched by vegetation type.
2. Indicators will be surveyed at an appropriate spatial scale. Terrestrial animals and vegetation will be monitored on the 20 sites on the 1.25 km grid. Birds and bats will be sampled at the 10 sites on the 2.5 km grid.

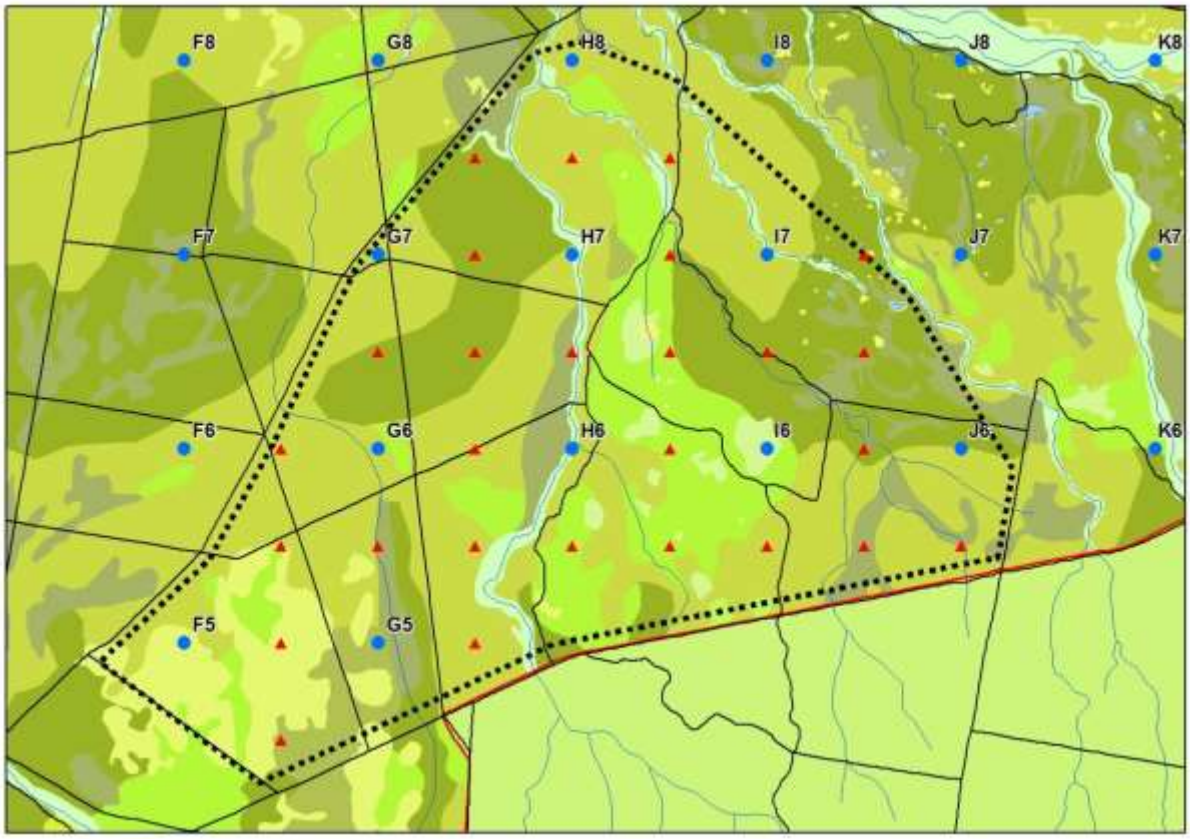

Figure 4. Distribution of monitoring sites in and adjacent to the proposed fenced area, Pilliga. The map shows monitoring sites on a 2.5 km grid (blue dots) and additional 1.25 km sites (red triangles) from which another 10 sites have been selected to survey terrestrial animals and vegetation.

Table 7. Number and percentage of mapped vegetation types in fenced area in Pilliga project area sampled by AWC's monitoring program.

Vegetation Community (Hunter 2010)	**Fenced area (ha)**	**Fenced area (%)**	**2.5 km points (n)**	**1.25 km points (n)**	**Total monitoring points (%)**
C7 - Bulloak/ White Cypress/ Pilliga Box	2338	44	4	6	36
C8 – White Cypress/ Bulloak/ Ironbark	993	19	0	4	14
C9 – White Cypress/ Pilliga Box/ Ironbark	858	16	0	5	18
C3 – White Cypress/ Dirty Gum	320	6	0	3	11
C2 – Rough-bark Apple/ River Red Gum	159	3	2	0	7
C5 - Fringe Myrtle/ Westringia	430	8	1	1	7
C4 - Broom Bush/ Heath Myrtle	15	0	0	0	0
C6 - Burrow's Wattle/ Broad-leaf Ironbark/ Brown Bloodwood	163	3	1	1	7
C1 – White Cypress / Poplar Box	0	0	0	0	0
C12 - Belah/ Wilga	99	2	0	0	0
C11 - Tank Herbfield	6	0	0	0	0
C10 - Five Minute Grass/ Curly Windmill	0	0	0	0	0

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.

Most surveys will be conducted at or near the centre of each grid point, conceptualised as the centre of a particular sampling area, the size of which is dependent on the home-range, movements and behaviour of the taxa that are being surveyed. For wide-ranging fauna, the effective sampling area may be at least 500 m radius around the centre of the grid point; whereas for small mammals and reptiles, the sampling area will be smaller. The sampling area for vegetation is a 1 ha plot located at the grid point centre. Surveys for introduced predators, large herbivores and bats will also be conducted at the edge of the road nearest to each grid point.

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 autumn.

Survey methods used at each grid scale

As described above, 50 grid points, located on a 2.5 km grid overlay, have been selected for monitoring in AWC's Pilliga project area, while a further 10 monitoring sites have been established on a 1.25 km grid within the proposed fenced area. Ten of the 2.5 km grid points are coincident with a 5 km grid covering the Pilliga forests. Methods employed at points at each grid scale are presented below.

2.5 km grid points

A standard set of survey methods will be applied at each of the 2.5 km grid sites. These sites are representative of the different vegetation communities in the study area with enough spatial separation to provide independence and to avoid pseudo-replication in surveys for most of the species that will be encountered. Each of the sites will be surveyed using an array of techniques to capture the diversity of fauna in the region while concurrently targeting priority indicators, including the Barking Owl and Koala (Figures 5 and 6).

Listening, call-playback and spotlighting surveys will be conducted on three nights in spring from the centre of each grid point. Before commencing playback, one observer will listen for animal calls for a 10-minute period. Then, pre-recorded calls of the Barking Owl and the Koala will be broadcast for a total of 10 minutes using a megaphone with responses recorded from these and other nocturnal species that are present. Spotlight surveys will then be conducted for 20 minutes by one observer along a 400 m transect centred at each grid point over three nights. Spotlighting transects will be aligned perpendicular to the nearest road access point.

Bird surveys will also be conducted in spring using the standard Birdlife Australia 20-minute count method on a 2 ha plot (blue rectangle; Figure 5) located near the centre of each grid point and on three consecutive mornings. As far as possible, different observers will be used on each morning to conduct the bird survey counts at each grid point. In addition, observers will simultaneously record bird calls for archival purposes using a portable Songmeter (SM4) during each 20-minute census count.

Two motion-sensitive Reconyx cameras will be located at each grid point in both the spring and autumn surveys to target medium-sized mammals, as well as introduced predators and herbivores. One camera will be situated at the edge of the nearest road and one near the grid point (Figure 5; red dots). These cameras will be set to collect data for a period of two weeks in each sampling period. Cameras will be baited with chicken pieces inserted in a sealed perforated lure tube. This level of survey effort will result in the placement of 50 cameras on road edges distributed evenly throughout the Pilliga project area with another 50 cameras set concurrently in the forest interior adjacent to each grid point. This large camera survey effort is expected to provide a good index of the density of target species, including feral predators. However, the optimisation of survey methods for feral predators is an area of active research by AWC and others (e.g. Bengsen et al. 2011, McGregor et al. 2015, Stokeld et al. 2015; Andrew Carter, pers. comm.). Depending on the results of the camera surveys, it may be necessary to supplement grid-based camera surveys with other methods, such as targeted camera grids (for cats) or sandplots (for canids) (Funston et al. 2010).

Small mammal abundance will be assessed over four consecutive nights in Autumn on 1 ha trapping grids situated in the south-western quadrat near each grid point (Figure 5; yellow square). On each trapping grid, we will place 20 aluminium box traps, baited with a mixture of peanut butter, oats, honey and fish oil. Box traps will be placed around the perimeter of the 1 ha trapping grid with five traps on each side (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 (Figure 6). Two reptile funnel traps will also be placed on each of the two Y-shaped drift fence arrays. Pitfalls will target small mammals and reptiles and will be deep (60 cm), sufficient to capture hopping mice if present. 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.

Two nest boxes will be installed at each of 24 grid points (12 inside, 12 outside the fenced area, matched by vegetation type) to detect the presence of the Eastern Pygmy Possum and potentially the Feathertail Glider (Figure 5). All or most available sites located in uncommon vegetation types have been sampled, as well as an adequate sampling of common vegetation types. Nest boxes will be placed at about breast height on either a trunk or leaning branch, preferably where there are some large understorey/mid-storey shrubs nearby – and preferably near some flowering trees or shrubs, with the hollow entrance facing the branch or trunk that the box is attached. Nest boxes will be inspected at intervals of 3-4 weeks or longer.

Vegetation surveys will be conducted on a 1 ha plot located in the north-eastern quadrat of sites, beginning at the centre of the grid point (green rectangle; Figure 6). A photo plot consisting of one image per grid point, facing south from the centre of the grid point (south-western corner of the vegetation plot), will be taken to record changes in forest floristics and structure. Surveys will also quantify important habitat attributes, such as the density of old, hollow-bearing trees and logs, the incidence of diggings, and the amount of grass cover for herbivores. [The intensity of herbivory at each grid point may be estimated, based on counts of recent dung (indicated by the presence of a black patina) on two 100 m x 1 m belt transects at each grid point (Johnson *et al.* 1987; Terpstra and Wilson 1989; Landsberg and Stol 1996; Woolnough 2005).]

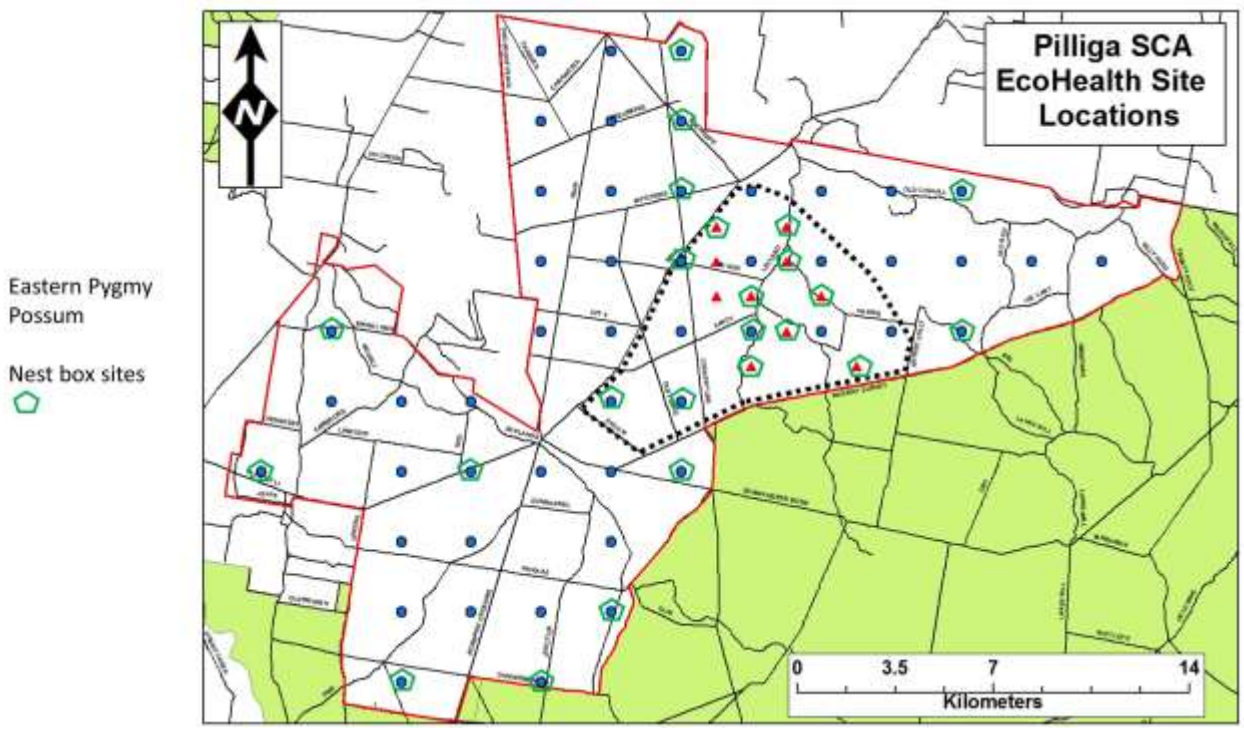

Figure 5: Locations of nest-boxes for surveying Eastern Pygmy Possum.

1.25 km grids

An additional 10 grid points will be established at 1.25 km intervals inside the fenced area, nested within the main 2.5 km grid that covers the study area, to bring the total number of sampling locations within the proposed fence to 20 grid points. These grid points will be surveyed for small mammals and reptiles using the trapping protocol described above for these species, and for medium-sized mammals and predators using cameras (Figures 6 and 7). Vegetation structure and floristics will also be assessed on standard 1 ha vegetation plots at these sites.

5 km grid points

The study design is nested with a 5 km grid that incorporates 10 of the 2.5 km grid points described above. Excluding two points close to the boundary, a total of 10 of these 5 km grid points occur within the Pilliga project area (two are inside the proposed fence). Surveys on this grid have the additional benefit of enabling comparison with the outcomes of the biodiversity monitoring program established in State Forests of the region. At these points, we will survey bats using the same methods as those used by FCNSW. At each grid point, two Songmeter SM4BAT detectors will be positioned adjacent to the two camera traps at each grid point (i.e. one situated at the edge of the nearest road and one near the grid point). These SM4BAT detectors will 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 the Pilliga forests by Dr Brad Law (NSW Department of Primary Industries).

Road sampling

Trials of road-based spotlighting surveys will be conducted within the AWC project area to estimate the abundance of macropods. The feasibility of the method is uncertain, given the density of the vegetation. In this survey method, macropods will be counted while conducting spotlight surveys along single lane dirt tracks within each area (Letnic *et al.* 2009). 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 and scan with a 100 W spotlight, moving at a speed of 10 km/h. We will perform two replicate surveys on different tracks for distances of 5-10 km each. We will record the angle and distance (or perpendicular distance from the centre of the road), and the vegetation type, for each animal sighted and use this information to estimate population density.

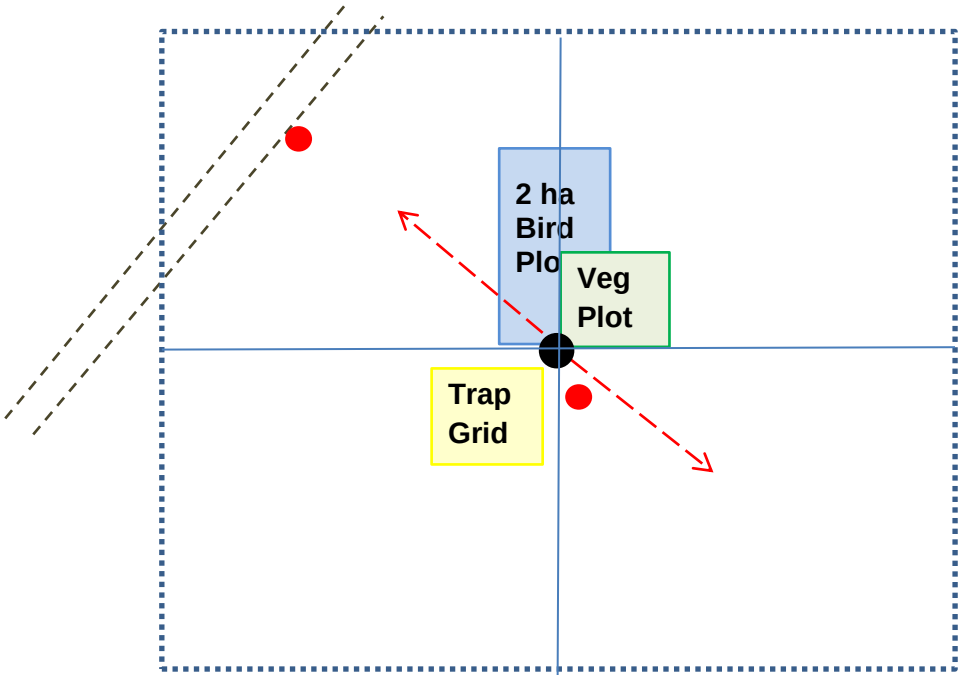

Figure 6: Survey effort at each 2.5 km grid point.

Legend for Figures 6 and 7

● Centre point of plot – location for passive listening and call-playbacks

● Camera traps (2) - one situated at the edge of the nearest road and one near the grid point

– – –→ Spotlighting transect (400 m)

★ Bat-call detectors (2) - one situated at the edge of the nearest road and one near the grid point. Bat-call detectors placed near camera traps, but only on 5 km grid points

● Cage traps (4) – located in each corner of the small mammal/reptile trapping plot

● Elliott traps (20) – five traps located 20 m apart on all four sides of the small mammal/reptile trapping plot

O Pitfall traps (8) – located on two Y-shaped drift fence arrays within the small mammal/reptile trapping plot. Note: two reptile funnel traps will also be placed on each of the two Y-shaped drift fence arrays

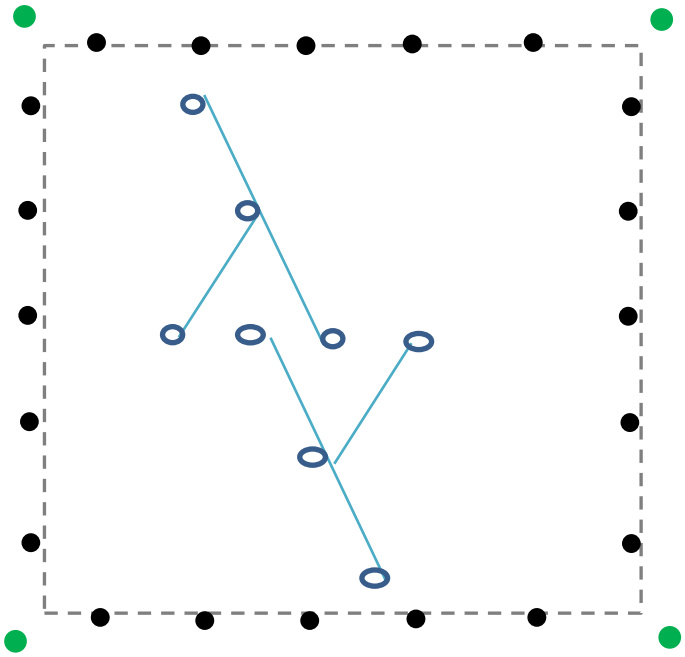

Figure 7: Sampling design for the 1 ha small mammal/reptile trapping plots

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:

- 1920 Pitfall trap nights: 60 sites, 8 traps per site, 4 nights
- 4800 Elliot trap nights: 60 sites, 20 traps per site, 4 nights
- 2880 Funnel trap nights: 60 sites, 12 traps per site, 4 nights
- 960 cage trap nights: 60 sites, 4 traps per site, 4 nights
- 3360 camera trap nights: 120 sites (60 off-road, 60 on-road), 1 camera/site, 14 nights, repeated twice yearly
- 150 bird surveys (standard 2 ha, 20 minute; and Songmeter) (50 sites, 3 replicates)
- 48 bat survey nights (Songmeter) (12 sites, 4 nights)
- 100 spotlight surveys (50 transects of 200 m, 2 repeats)
- 100 nocturnal bird/ mammal surveys (active listening and call playback) (50 sites, 2 repeats)
- 60 surveys of habitat and ecological processes
- 30 vegetation surveys (15 inside fence, 15 outside fence)
- Other surveys as noted above, including nest-boxes (4 boxes to be installed at each of 10 sites), targeted searches for frogs at designated dams and wetlands, targeted surveys of Glossy Black Cockatoos, targeted surveys for 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. In addition, the monitoring program has been designed, in part, to facilitate comparison with results obtained on adjacent FCNSW land subject to a different management regime, strengthening inference about drivers of change (see below).

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).

Comparison of outcomes with adjacent FCNSW forests

This EHMF has been developed primarily to monitor changes in ecological health in AWC's Pilliga project area. Nevertheless, AWC's monitoring program has been designed, in part, to be compatible with monitoring of bats conducted by FCNSW on State Forests in the region. This will allow direct comparison of metrics related to bat abundance between AWC's project area and State Forests in the region. Because AWC's project area is subject to different management regimes than State Forests, the comparison will allow stronger inference about factors driving changes in ecological health. For example, if numbers of a bat species were to increase on AWC's Pilliga project area, comparison with the adjacent Pilliga East State Forest would help determine whether the increase was a general phenomenon in the region, driven by factors acting at a regional scale (e.g., rainfall), or whether the increase was restricted to AWC's Pilliga project area, potentially as a response to AWC's management.

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 4).

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 (eg, Before-After-Control-Impact).

Where feasible, data from AWC's monitoring program will contribute to research projects such as the evaluation of management interventions (this approach has been termed "question-based" or "adaptive"

monitoring: Lindenmayer and Likens 2009; Lindenmayer *et al*. 2015). Where 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 the Pilliga 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. Additional sites have been added inside the fence to increase the sample size and the robustness of comparisons.

AWC's research strategy in the Pilliga project area will be elaborated in a companion document.

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Appendix 1. Vertebrate species list, Pilliga

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Amphibia	*Cylclorana alboguttata*	Striped Burrowing Frog	Confirmed			
Amphibia	*Litoria caerulea*	Green Tree Frog	Confirmed			
Amphibia	*Litoria latopalmata*	Broad-palmed Frog	Confirmed			
Amphibia	*Litoria peronii*	Peron's Tree Frog	Confirmed			
Amphibia	*Litoria rubella*	Desert Tree Frog	Confirmed			
Amphibia	*Limnodynastes dumerilii*	Eastern Banjo Frog	Likely			
Amphibia	*Limnodynastes salmini*	Salmon-striped Frog	Confirmed			
Amphibia	*Limnodynastes tasmaniensis*	Spotted Grass Frog	Confirmed			
Amphibia	*Limnodynastes terraereginae*	Northern Banjo Frog	Confirmed			
Amphibia	*Neobatrachus sudellae*	Sudell's Frog	Likely			
Amphibia	*Platyplectrum ornatum*	Ornate Burrowing Frog	Confirmed			
Amphibia	*Crinia parinsignifera*	Eastern Sign-bearing Froglet	Confirmed			
Amphibia	*Crinia signifera*	Eastern Common Froglet	Very Likely			
Amphibia	*Crinia sloanei*	Sloane's Froglet	Very Likely		Vulnerable	site-managed
Amphibia	*Pseudophryne bibronii*	Brown Toadlet	Likely			
Aves	*Accipiter cirrocephalus*	Collared Sparrowhawk	Likely			
Aves	*Accipiter fasciatus*	Brown Goshawk	Confirmed			
Aves	*Accipiter novaehollandiae*	Grey Goshawk	Likely			
Aves	*Aquila audax*	Wedge-tailed Eagle	Confirmed			
Aves	*Circus approximans*	Swamp Harrier	Likely			
Aves	*Circus assimilis*	Spotted Harrier	Likely		Vulnerable	landscape
Aves	*Elanus axillaris*	Black-shouldered Kite	Likely			
Aves	Haliaeetus leucogaster	White-bellied Sea-Eagle	Confirmed			
Aves	*Haliastur sphenurus*	Whistling Kite	Likely			
Aves	*Hamirostra melanosternon*	Black-breasted Buzzard	Confirmed		Vulnerable	partnership
Aves	*Hieraaetus morphnoides*	Little Eagle	Likely		Vulnerable	landscape
Aves	*Lophoictinia isura*	Square-tailed Kite	Likely		Vulnerable	landscape
Aves	*Milvus migrans*	Black Kite	Likely			
Aves	*Anas gracilis*	Grey Teal	Confirmed			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Anas superciliosa*	Pacific Black Duck	Confirmed			
Aves	*Aythya australis*	Hardhead	Confirmed			
Aves	*Chenonetta jubata*	Australian Wood Duck	Confirmed			
Aves	*Dendrocygna eytoni*	Plumed Whistling-Duck	Confirmed			
Aves	*Apus pacificus*	Fork-tailed Swift	Likely			
Aves	*Hirundapus caudacutus*	White-throated Needletail	Confirmed			
Aves	*Aegotheles cristatus*	Australian Owlet-nightjar	Confirmed			
Aves	*Eurostopodus argus*	Spotted Nightjar	Likely			
Aves	*Eurostopodus mystacalis*	White-throated Nightjar	Confirmed			
Aves	*Podargus strigoides*	Tawny Frogmouth	Confirmed			
Aves	*Burhinus grallarius*	Bush Stone-curlew	Very Likely		Endangered	landscape
Aves	*Elseyornis melanops*	Black-fronted Dotterel	Confirmed			
Aves	*Erythrogonys cinctus*	Red-kneed Dotterel	Confirmed			
Aves	*Vanellus miles*	Masked Lapwing	Confirmed			
Aves	*Vanellus tricolor*	Banded Lapwing	Very Likely			
Aves	*Himantopus leucocephalus*	Black-winged Stilt	Confirmed			
Aves	*Turnix pyrrhothorax*	Red-chested Button-quail	Likely			
Aves	*Turnix varius*	Painted Button-quail	Confirmed			
Aves	*Turnix velox*	Little Button-quail	Confirmed			
Aves	*Ardea alba*	Great Egret	Confirmed			
Aves	*Ardea pacifica*	White-necked Heron	Confirmed			
Aves	*Botaurus poiciloptilus*	Australasian Bittern	Confirmed			
Aves	*Egretta novaehollandiae*	White-faced Heron	Confirmed			
Aves	*Nycticorax caledonicus*	Nankeen Night-Heron	Very Likely			
Aves	*Pelecanus conspicillatus*	Australian Pelican	Very Likely			
Aves	*Platalea flavipes*	Yellow-billed Spoonbill	Confirmed			
Aves	*Platalea regia*	Royal Spoonbill	Confirmed			
Aves	*Threskiornis molucca*	Australian White Ibis	Confirmed			
Aves	*Threskiornis spinicollis*	Straw-necked Ibis	Confirmed			
Aves	*Geopelia cuneata*	Diamond Dove	Likely			
Aves	*Geopelia humeralis*	Bar-shouldered Dove	Confirmed			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Geopelia striata*	Peaceful Dove	Confirmed			
Aves	*Ocyphaps lophotes*	Crested Pigeon	Confirmed			
Aves	*Phaps chalcoptera*	Common Bronzewing	Confirmed			
Aves	*Ceyx azureus*	Azure Kingfisher	Likely			
Aves	*Eurystomus orientalis*	Dollarbird	Confirmed			
Aves	*Dacelo novaeguineae*	Laughing Kookaburra	Confirmed			
Aves	*Todiramphus pyrrhopygius*	Red-backed Kingfisher	Likely			
Aves	*Todiramphus sanctus*	Sacred Kingfisher	Confirmed			
Aves	*Merops ornatus*	Rainbow Bee-eater	Confirmed			
Aves	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	Confirmed			
Aves	*Cacomantis pallidus*	Pallid Cuckoo	Confirmed			
Aves	*Cacomantis variolosus*	Brush Cuckoo	Confirmed			
Aves	*Centropus phasianinus*	Pheasant Coucal	Likely			
Aves	*Chalcites basalis*	Horsfield's Bronze-Cuckoo	Confirmed			
Aves	*Chalcites lucidus*	Shining Bronze-Cuckoo	Confirmed			
Aves	*Chalcites osculans*	Black-eared Cuckoo	Likely			
Aves	*Eudynamys orientalis*	Eastern Koel	Likely			
Aves	*Scythrops novaehollandiae*	Channel-billed Cuckoo	Confirmed			
Aves	*Falco berigora*	Brown Falcon	Confirmed			
Aves	*Falco cenchroides*	Nankeen Kestrel	Confirmed			
Aves	*Falco longipennis*	Australian Hobby	Confirmed			
Aves	*Falco peregrinus*	Peregrine Falcon	Confirmed			
Aves	*Falco subniger*	Black Falcon	Likely		Vulnerable	landscape
Aves	*Leipoa ocellata*	Malleefowl	Possible	Vulnerable	Endangered	iconic
Aves	*Coturnix pectoralis*	Stubble Quail	Confirmed			
Aves	*Coturnix ypsilophora*	Brown Quail	Likely			
Aves	*Grus rubicunda*	Brolga	Possible		Vulnerable	partnership
Aves	*Ardeotis australis*	Australian Bustard	Likely		Endangered	partnership
Aves	*Acanthiza apicalis*	Inland Thornbill	Confirmed			
Aves	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill	Confirmed			
Aves	*Acanthiza lineata*	Striated Thornbill	Confirmed			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Acanthiza nana*	Yellow Thornbill	Confirmed			
Aves	*Acanthiza pusilla*	Brown Thornbill	Confirmed			
Aves	*Acanthiza reguloides*	Buff-rumped Thornbill	Confirmed			
Aves	*Acanthiza uropygialis*	Chestnut-rumped Thornbill	Confirmed			
Aves	*Aphelocephala leucopsis*	Southern Whiteface	Likely			
Aves	*Calamanthus pyrrhopygia*	Chestnut-rumped Heathwren	Confirmed			
Aves	*Chthonicola sagittata*	Speckled Warbler	Confirmed		Vulnerable	landscape
Aves	*Gerygone fusca*	Western Gerygone	Confirmed			
Aves	*Gerygone olivacea*	White-throated Gerygone	Confirmed			
Aves	*Sericornis frontalis*	White-browed Scrubwren	Confirmed			
Aves	*Smicrornis brevirostris*	Weebill	Confirmed			
Aves	*Mirafra javanica*	Horsfield's Bushlark	Likely			
Aves	*Artamus cinereus*	Black-faced Woodswallow	Confirmed			
Aves	*Artamus cyanopterus*	Dusky Woodswallow	Confirmed		Vulnerable	unknown
Aves	*Artamus leucorynchus*	White-breasted Woodswallow	Likely			
Aves	*Artamus minor*	Little Woodswallow	Likely			
Aves	*Artamus personatus*	Masked Woodswallow	Likely			
Aves	*Artamus superciliosus*	White-browed Woodswallow	Confirmed			
Aves	*Cracticus nigrogularis*	Pied Butcherbird	Confirmed			
Aves	*Cracticus tibicen*	Australian Magpie	Confirmed			
Aves	*Cracticus torquatus*	Grey Butcherbird	Confirmed			
Aves	*Strepera graculina*	Pied Currawong	Confirmed			
Aves	*Coracina maxima*	Ground Cuckoo-shrike	Likely			
Aves	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	Confirmed			
Aves	*Coracina papuensis*	White-bellied Cuckoo-shrike	Confirmed			
Aves	*Coracina tenuirostris*	Cicadabird	Confirmed			
Aves	*Lalage tricolor*	White-winged Triller	Confirmed			
Aves	*Climacteris picumnus*	Brown Treecreeper	Confirmed		Vulnerable	landscape
Aves	*Cormobates leucophaea*	White-throated Treecreeper	Confirmed			
Aves	*Corcorax melanorhamphos*	White-winged Chough	Confirmed			
Aves	*Struthidea cinerea*	Apostlebird	Confirmed			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Corvus coronoides*	Australian Raven	Confirmed			
Aves	*Corvus mellori*	Little Raven	Likely			
Aves	*Corvus orru*	Torresian Crow	Confirmed			
Aves	*Lonchura castaneothorax*	Chestnut-breasted Mannikin	Likely			
Aves	*Neochmia modesta*	Plum-headed Finch	Likely			
Aves	*Neochmia temporalis*	Red-browed Finch	Confirmed			
Aves	*Stagonopleura guttata*	Diamond Firetail	Likely		Vulnerable	landscape
Aves	*Taeniopygia bichenovii*	Double-barred Finch	Very Likely			
Aves	*Taeniopygia guttata*	Zebra Finch	Likely			
Aves	*Cheramoeca leucosterna*	White-backed Swallow	Likely			
Aves	*Hirundo neoxena*	Welcome Swallow	Likely			
Aves	*Petrochelidon ariel*	Fairy Martin	Likely			
Aves	*Petrochelidon nigricans*	Tree Martin	Likely			
Aves	*Malurus cyaneus*	Superb Fairy-wren	Confirmed			
Aves	*Malurus lamberti*	Variegated Fairy-wren	Confirmed			
Aves	*Malurus leucopterus*	White-winged Fairy-wren	Likely			
Aves	*Cincloramphus cruralis*	Brown Songlark	Possible			
Aves	*Cincloramphus mathewsi*	Rufous Songlark	Confirmed			
Aves	*Megalurus gramineus*	Little Grassbird	Likely			
Aves	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater	Confirmed			
Aves	*Acanthorhynchus tenuirostris*	Eastern Spinebill	Likely			
Aves	*Anthochaera carunculata*	Red Wattlebird	Likely			
Aves	*Anthochaera phrygia*	Regent Honeyeater	Likely	Cr. Endangered	Cr Endangered	site-managed
Aves	*Caligavis chrysops*	Yellow-faced Honeyeater	Confirmed			
Aves	*Entomyzon cyanotis*	Blue-faced Honeyeater	Confirmed			
Aves	*Epthianura tricolor*	Crimson Chat	Likely			
Aves	*Gavicalis virescens*	Singing Honeyeater	Confirmed			
Aves	*Grantiella picta*	Painted Honeyeater	Likely	Vulnerable	Vulnerable	landscape
Aves	*Lichenostomus melanops*	Yellow-tufted Honeyeater	Likely			
Aves	*Lichmera indistincta*	Brown Honeyeater	Confirmed			
Aves	*Manorina flavigula*	Yellow-throated Miner	Likely			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Manorina melanocephala*	Noisy Miner	Confirmed			
Aves	*Meliphaga lewinii*	Lewin's Honeyeater	Likely			
Aves	*Melithreptus brevirostris*	Brown-headed Honeyeater	Confirmed			
Aves	*Melithreptus gularis*	Black-chinned Honeyeater	Likely		Vulnerable	landscape
Aves	*Melithreptus lunatus*	White-naped Honeyeater	Confirmed			
Aves	*Myzomela sanguinolenta*	Scarlet Honeyeater	Likely			
Aves	*Nesoptilotis leucotis*	White-eared Honeyeater	Confirmed			
Aves	*Philemon citreogularis*	Little Friarbird	Confirmed			
Aves	*Philemon corniculatus*	Noisy Friarbird	Confirmed			
Aves	*Plectorhyncha lanceolata*	Striped Honeyeater	Confirmed			
Aves	*Ptilotula fusca*	Fuscous Honeyeater	Confirmed			
Aves	*Ptilotula ornata*	Yellow-plumed Honeyeater	Likely			
Aves	*Ptilotula penicillata*	White-plumed Honeyeater	Confirmed			
Aves	*Grallina cyanoleuca*	Magpie-lark	Confirmed			
Aves	*Myiagra cyanoleuca*	Satin Flycatcher	Confirmed			
Aves	*Myiagra inquieta*	Restless Flycatcher	Confirmed			
Aves	*Myiagra rubecula*	Leaden Flycatcher	Confirmed			
Aves	*Anthus novaeseelandiae*	Australian Pipit	Confirmed			
Aves	*Dicaeum hirundinaceum*	Mistletoebird	Confirmed			
Aves	*Daphoenositta chrysoptera*	Varied Sittella	Confirmed		Vulnerable	landscape
Aves	*Oriolus sagittatus*	Olive-backed Oriole	Confirmed			
Aves	*Colluricincla harmonica*	Grey Shrike-thrush	Confirmed			
Aves	*Falcunculus frontatus*	Crested Shrike-tit	Confirmed			
Aves	*Oreoica gutturalis*	Crested Bellbird	Confirmed			
Aves	*Pachycephala pectoralis*	Golden Whistler	Confirmed			
Aves	*Pachycephala rufiventris*	Rufous Whistler	Confirmed			
Aves	*Pardalotus punctatus*	Spotted Pardalote	Confirmed			
Aves	*Pardalotus striatus*	Striated Pardalote	Confirmed			
Aves	*Eopsaltria australis*	Eastern Yellow Robin	Confirmed			
Aves	*Melanodryas cucullata*	Hooded Robin	Confirmed		Vulnerable	landscape
Aves	*Microeca fascinans*	Jacky Winter	Confirmed			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Petroica boodang*	Scarlet Robin	Confirmed		Vulnerable	landscape
Aves	*Petroica goodenovii*	Red-capped Robin	Confirmed			
Aves	*Petroica phoenicea*	Flame Robin	Likely		Vulnerable	landscape
Aves	*Petroica rosea*	Rose Robin	Likely			
Aves	*Pomatostomus superciliosus*	White-browed Babbler	Confirmed			
Aves	*Pomatostomus temporalis*	Grey-crowned Babbler	Confirmed		Vulnerable	landscape
Aves	*Cinclosoma punctatum*	Spotted Quail-thrush	Confirmed			
Aves	*Ptilonorhynchus maculatus*	Spotted Bowerbird	Likely			
Aves	*Rhipidura albiscapa*	Grey Fantail	Confirmed			
Aves	*Rhipidura leucophrys*	Willie Wagtail	Confirmed			
Aves	*Zosterops lateralis*	Silvereye	Confirmed			
Aves	*Anhinga novaehollandiae*	Australian Darter	Confirmed			
Aves	*Microcarbo melanoleucos*	Little Pied Cormorant	Confirmed			
Aves	*Phalacrocorax sulcirostris*	Little Black Cormorant	Confirmed			
Aves	*Tachybaptus novaehollandiae*	Australasian Grebe	Confirmed			
Aves	*Cacatua galerita*	Sulphur-crested Cockatoo	Confirmed			
Aves	*Cacatua sanguinea*	Little Corella	Likely			
Aves	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo	Confirmed		Vulnerable	landscape
Aves	*Calyptorhynchus lathami*	Glossy Black-Cockatoo	Confirmed		Vulnerable	landscape
Aves	*Eolophus roseicapillus*	Galah	Confirmed			
Aves	*Lophochroa leadbeateri*	Major Mitchell's Cockatoo	Possible		Vulnerable	landscape
Aves	*Nymphicus hollandicus*	Cockatiel	Confirmed			
Aves	*Alisterus scapularis*	Australian King-Parrot	Likely			
Aves	*Aprosmictus erythropterus*	Red-winged Parrot	Confirmed			
Aves	*Barnardius zonarius*	Australian Ringneck	Confirmed			
Aves	*Glossopsitta concinna*	Musk Lorikeet	Confirmed			
Aves	*Glossopsitta pusilla*	Little Lorikeet	Confirmed		Vulnerable	landscape
Aves	*Melopsittacus undulatus*	Budgerigar	Likely			
Aves	*Neophema chrysostoma*	Blue-winged Parrot	Likely			
Aves	*Neophema pulchella*	Turquoise Parrot	Confirmed		Vulnerable	landscape
Aves	*Northiella haematogaster*	Blue Bonnet	Likely			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Aves	*Platycercus adscitus*	Pale-headed Rosella	Likely			
Aves	*Platycercus elegans*	Crimson Rosella	Likely			
Aves	*Platycercus eximius*	Eastern Rosella	Confirmed			
Aves	*Polytelis swainsonii*	Superb Parrot	Confirmed	Vulnerable	Vulnerable	landscape
Aves	*Psephotus haematonotus*	Red-rumped Parrot	Likely			
Aves	*Psephotus varius*	Mulga Parrot	Confirmed			
Aves	*Trichoglossus haematodus*	Rainbow Lorikeet	Confirmed			
Aves	*Ninox connivens*	Barking Owl	Confirmed		Vulnerable	landscape
Aves	*Ninox novaeseelandiae*	Southern Boobook	Very Likely			
Aves	*Tyto alba*	Barn Owl	Confirmed			
Aves	*Dromaius novaehollandiae*	Emu	Confirmed			
Mammalia	*Saccolaimus flaviventris*	Yellow-bellied Sheath-tailed Bat	Likely		Vulnerable	landscape
Mammalia	*Mormopterus petersi*	Inland Free-tailed Bat	Very Likely			
Mammalia	*Mormopterus planiceps*	South-eastern Free-tailed Bat	Likely			
Mammalia	*Tadarida australis*	White-striped Freetail Bat	Confirmed			
Mammalia	*Pteropus scapulatus*	Little Red Flying-fox	Likely			
Mammalia	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat	Likely			
Mammalia	*Chalinolobus dwyeri*	Large-eared Pied Bat	Likely	Vulnerable	Vulnerable	data-deficient
Mammalia	*Chalinolobus gouldii*	Gould's Wattled Bat	Confirmed			
Mammalia	*Chalinolobus morio*	Chocolate Wattled Bat	Likely			
Mammalia	*Chalinolobus picatus*	Little Pied Bat	Very Likely		Vulnerable	landscape
Mammalia	*Nyctophilus corbeni*	South-eastern Long-eared Bat	Likely	Vulnerable	Vulnerable	partnership
Mammalia	*Nyctophilus geoffroyi*	Lesser Long-eared Bat	Confirmed			
Mammalia	*Nyctophilus gouldi*	Gould's Long-eared Bat	Confirmed			
Mammalia	*Scotorepens balstoni*	Inland Broad-nosed Bat	Confirmed			
Mammalia	*Scotorepens greyii*	Little Broad-nosed Bat	Confirmed			
Mammalia	*Vespadelus troughtoni*	Eastern Cave Bat	Very Likely		Vulnerable	landscape
Mammalia	*Vespadelus vulturnus*	Little Forest Bat	Confirmed			
Mammalia	*Antechinus flavipes*	Yellow-footed Antechinus	Confirmed			
Mammalia	*Dasyurus maculatus*	Spotted-tailed Quoll	Possible	Endangered	Vulnerable	landscape
Mammalia	*Sminthopsis murina*	Common Dunnart	Very Likely			

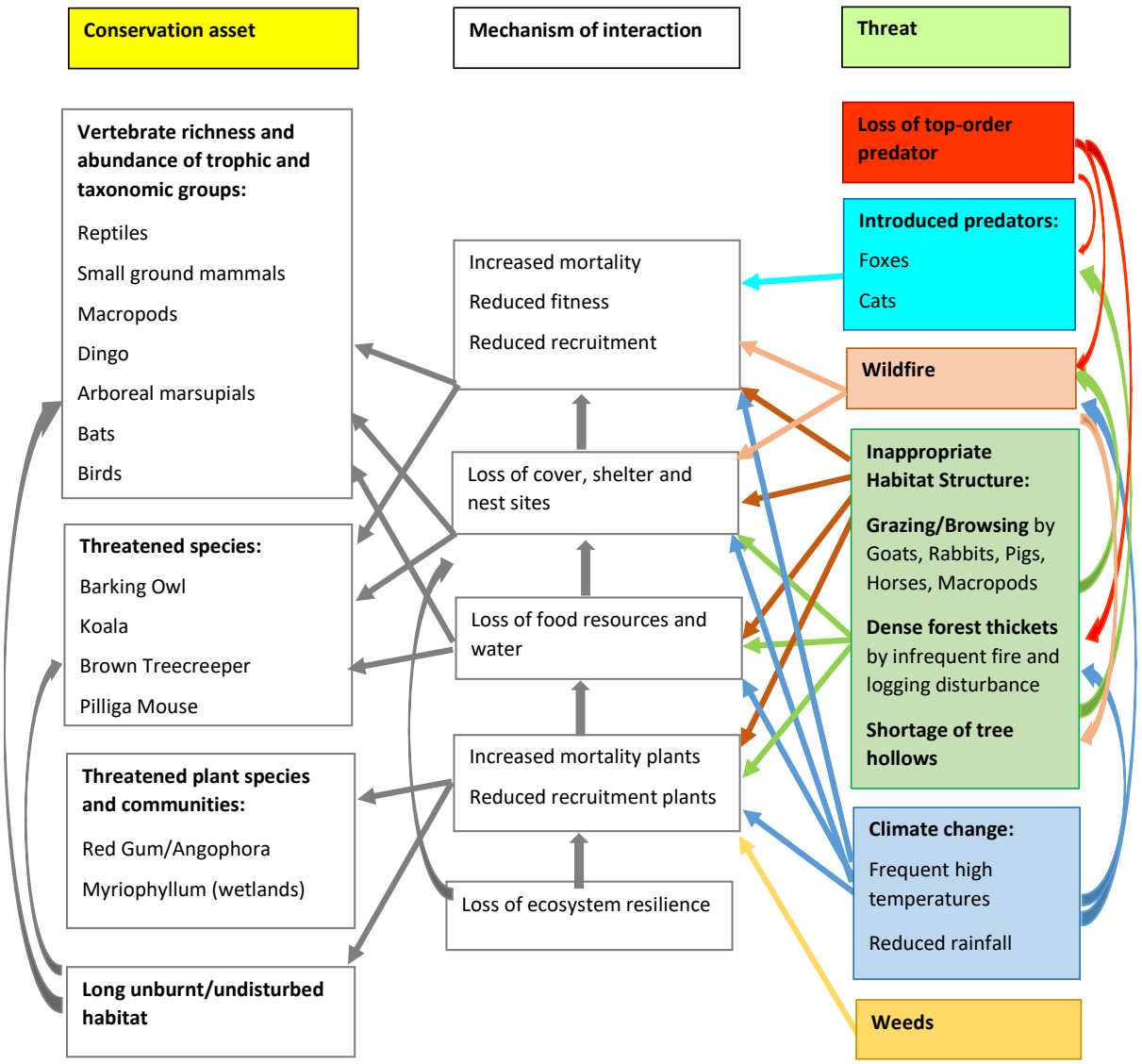
Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Mammalia	*Cercartetus nanus*	Eastern Pygmy-possum	Likely		Vulnerable	landscape
Mammalia	*Macropus dorsalis*	Black-striped Wallaby	Confirmed		Endangered	partnership
Mammalia	*Macropus giganteus*	Eastern Grey Kangaroo	Confirmed			
Mammalia	*Macropus robustus*	Euro, Common Wallaroo	Confirmed			
Mammalia	*Macropus rufogriseus*	Red-necked Wallaby	Confirmed			
Mammalia	*Macropus rufus*	Red Kangaroo	Confirmed			
Mammalia	*Wallabia bicolor*	Swamp Wallaby	Confirmed			
Mammalia	*Petaurus breviceps*	Sugar Glider	Confirmed			
Mammalia	*Petaurus norfolcensis*	Squirrel Glider	Likely		Vulnerable	landscape
Mammalia	*Pseudochierus peregrinus*	Common Ringtail Possum	Confirmed			
Mammalia	*Acrobates pygmaeus*	Feathertail Glider	Confirmed			
Mammalia	*Trichosurus vulpecula*	Common Brushtail Possum	Confirmed			
Mammalia	*Phascolarctos cinereus*	Koala	Confirmed	Vulnerable	Vulnerable	iconic
Mammalia	*Aepyprymnus rufescens*	Rufous Bettong	Possible		Vulnerable	site-managed
Mammalia	*Tachyglossus aculeatus*	Short-beaked Echidna	Confirmed			
Mammalia	*Hydromys chrysogaster*	Water-rat	Likely			
Mammalia	*Pseudomys pilligaensis*	Pilliga Mouse	Confirmed		Vulnerable	site-managed
Reptilia	*Amphibolurus burnsi*	Burn's Dragon	Confirmed			
Reptilia	*Diporiphora nobbi*	Nobbi	Likely			
Reptilia	*Pogona barbata*	Bearded Dragon	Confirmed			
Reptilia	*Morelia spilota*	Carpet Python	Likely			
Reptilia	*Underwoodisaurus milii*	Thick-tailed Gecko	Likely			
Reptilia	*Diplodactylus vittatus*	Wood Gecko	Confirmed			
Reptilia	*Nebulifera robusta*	Robust Velvet Gecko	Likely			
Reptilia	*Oedura monilis*	Ocellated Velvet Gecko	Likely			
Reptilia	*Strophurus williamsi*	Eastern Spiny-tailed Gecko	Very Likely			
Reptilia	*Acanthophis antarcticus*	Southern Death Adder	Likely			
Reptilia	*Austrelaps ramsayi*	Highlands Copperhead	Likely			
Reptilia	*Brachyurophis australis*	Coral Snake	Likely			
Reptilia	*Demansia psammophis*	Yellow-faced Whipsnake	Likely			
Reptilia	*Furina diadema*	Red-naped Snake	Very Likely			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Reptilia	*Hoplocephalus bitorquatus*	Pale-headed Snake	Confirmed		Vulnerable	landscape
Reptilia	*Parasuta spectabilis*	Spectacled Hooded Snake	Confirmed			
Reptilia	*Pseudechis australis*	Mulga Snake	Likely			
Reptilia	*Pseudechis guttatus*	Spotted Black Snake	Likely			
Reptilia	*Pseudechis porphyriacus*	Red-bellied Black Snake	Likely			
Reptilia	*Pseudonaja textilis*	Eastern Brown Snake	Confirmed			
Reptilia	*Suta suta*	Curl Snake	Likely			
Reptilia	*Vermicella annulata*	Eastern Bandy-bandy	Likely			
Reptilia	*Gehyra dubia*	Dubious Dtella	Confirmed			
Reptilia	*Gehyra variegata*	Tree Dtella	Confirmed			
Reptilia	*Heteronotia binoei*	Bynoe's Prickly Gecko	Confirmed			
Reptilia	*Delma inornata*	Patternless Delma	Likely			
Reptilia	*Delma plebeia*	Leaden Delma	Likely			
Reptilia	*Delma tincta*	Excitable Delma	Likely			
Reptilia	*Lialis burtonis*	Burton's Snake-lizard	Very Likely			
Reptilia	*Pygopus lepidopodus*	Common Scaly-foot	Likely			
Reptilia	*Anomalopus leuckartii*	Two-clawed Worm-skink	Likely			
Reptilia	*Cryptoblepharus australis*	Inland Snake-eyed Skink	Likely			
Reptilia	*Cryptoblepharus pannosus*	Ragged Snake-eyed Skink	Confirmed			
Reptilia	*Cryptoblepharus virgatus*	Striped Snake-eyed Skink	Likely			
Reptilia	*Ctenotus allotropis*	Brown-blazed Wedgesnout Ctenotus	Confirmed			
Reptilia	*Ctenotus robustus*	Robust Ctenotus	Likely			
Reptilia	*Ctenotus taeniolatus*	Copper-tailed Skink	Likely			
Reptilia	*Egernia saxatilis*	Black Rock Skink	Likely			
Reptilia	*Egernia striolata*	Tree Skink	Confirmed			
Reptilia	*Lerista bougainvillii*	South-eastern Slider	Likely			
Reptilia	*Lerista muelleri*	Wood Mulch-slider	Confirmed			
Reptilia	*Lerista punctatovittata*	Eastern Robust Slider	Likely			
Reptilia	*Liopholis modesta*	Eastern Ranges Rock-skink	Likely			
Reptilia	*Liopholis whitii*	White's Skink	Likely			
Reptilia	*Lygisaurus foliorum*	Tree-base Litter-skink	Confirmed			

Class	Scientific Name	Common Name	Likelihood	EPBC	NSW	SOS stream
Reptilia	*Menetia greyii*	Common Dwarf Skink	Confirmed			
Reptilia	*Morethia boulengeri*	South-eastern Morethia Skink	Confirmed			
Reptilia	*Tiliqua rugosa*	Shingle-back	Likely			
Reptilia	*Tiliqua scincoides*	Eastern Blue-tongued Lizard	Likely			
Reptilia	*Anilios bituberculatus*	Prong-snouted Blind Snake	Likely			
Reptilia	*Anilios ligatus*	Robust Blind Snake	Likely			
Reptilia	*Anilios proximus*	Proximus Blind Snake	Likely			
Reptilia	*Anilios wiedii*	Brown-snouted Blind Snake	Likely			
Reptilia	*Varanus gouldii*	Gould's Goanna	Confirmed			
Reptilia	*Varanus varius*	Lace Monitor	Confirmed			
Reptilia	*Chelodina expansa*	Broad-shelled River Turtle	Likely			
Reptilia	*Chelodina longicollis*	Eastern Snake-necked Turtle	Confirmed			

Appendix 2. Conceptual model of interactions between conservation assets and threats in the Pilliga forests

An example of one of the conceptual models describing relationships between a range of conservation assets and threats developed for the Pilliga project area. Not all assets, threats and their possible interactions have been listed in this model.



Appendix 3. Attributes of monitoring plots in Pilliga forest project site.

Site ID	Vegetation community (Hunter 2010)	Distance from nearest road (m)	Distance from boundary (m)
C1	C3: White Pine - Dirty Gum	329	1100
E1	C6: Burrow's Wattle - Broad-leaved Ironbark	165	170
C2	C5: Fringe Myrtle - Westringia	561	2305
D2	C9: White Pine - Pilliga Box	574	2645
E2	C9: White Pine - Pilliga Box	110	615
F2	C7: Bulloak - White Pine	460	1516
C3	C7: Bulloak - White Pine	408	3982
D3	C8: White Pine - Bulloak	458	1492
F3	C8: White Pine - Bulloak	369	980
A4	C8: White Pine - Bulloak	762	1903
C4	C8: White Pine - Bulloak	131	2440
D4	C8: White Pine - Bulloak	375	1448
E4	C9: White Pine - Pilliga Box	100	2992
F4	C5: Fringe Myrtle - Westringia	401	1123
G4	C7: Bulloak - White Pine	721	2305
B5	C8: White Pine - Bulloak	433	1654
C5	C7: Bulloak - White Pine	23	303
D5	C5: Fringe Myrtle - Westringia	682	2516
F5	C6: Burrow's Wattle - Broad-leaved Ironbark	549	1231
G5	C8: White Pine - Bulloak	167	143
B6	C7: Bulloak - White Pine	96	1714
E6	C7: Bulloak - White Pine	312	313
F6	C7: Bulloak - White Pine	352	2782
G6	C7: Bulloak - White Pine	441	3437
H6	C2: White Pine - Apple	251	2594
I6	C12: Belah - Wilga	420	2121
J6	C7: Bulloak - White Pine	366	1621
K6	C9: White Pine - Pilliga Box	132	960
H7	C7: Bulloak - White Pine	541	4332
I7	C7: Bulloak - White Pine	779	4091
E7	C7: Bulloak - White Pine	840	854
F7	C8: White Pine - Bulloak	5	2958
G7	C7: Bulloak - White Pine	90	4789
J7	C3: White Pine - Dirty Gum	1658	3633
K7	C8: White Pine - Bulloak	1466	3176
L7	C7: Bulloak - White Pine	802	2450
M7	C8: White Pine - Bulloak	1039	1365
H8	C7: Bulloak - White Pine	531	1874
I8	C8: White Pine - Bulloak	825	1633
E8	C7: Bulloak - White Pine	1052	1072
F10	C7: Bulloak - White Pine	699	3562

Site ID	Vegetation community (Hunter 2010)	Distance from nearest road (m)	Distance from boundary (m)
G8	C7: Bulloak - White Pine	118	2373
J8	C8: White Pine - Bulloak	101	1175
K8	C2: White Pine - Apple	434	718
E9	C7: Bulloak - White Pine	583	1282
F9	C7: Bulloak - White Pine	70	3079
G9	C9: White Pine - Pilliga Box	60	863
E10	C7: Bulloak - White Pine	633	1013
F10	C7: Bulloak - White Pine	259	611
G10	C3: White Pine - Dirty Gum	695	645

Appendix 4. Draft Scorecard for AWC Pilliga project

[attached]