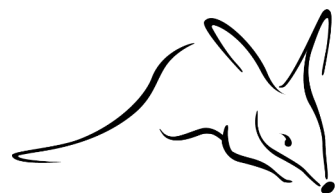


Karakamia Wildlife Sanctuary Ecohealth Report 2021



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Summary

Australian Wildlife Conservancy (AWC) has implemented an Ecological Health Monitoring Program (Ecohealth) across Karakamia Wildlife Sanctuary (Karakamia) to measure the changes in the status and trend of conservation assets, and threats to those assets. Metrics from the program are reported in annual Ecohealth Reports and Scorecards. This is the Ecohealth Report for 2021. Values of metrics derived in this report were based on data collected during surveys carried out in 2021. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In implementing the Ecohealth program, nine surveys are conducted every 1–2 years to report on 26 biodiversity and 6 threat indicators. In 2021, AWC conducted 1036 live trap nights, 3650 camera trap nights and 57 km of spotlighting transects. These surveys targeted the five reintroduced species, Woylie (*Bettongia penicillata*); Quenda (*Isoodon fusciventer*); Tammar Wallaby (*Macropus eugenii*); Western Ringtail Possum (*Pseudocheirus occidentalis*) and Common Brushtail Possum/Koomal (*Trichosurus vulpecula*), as well as feral predators and herbivores. Results are also presented for the Black Cockatoo Survey, an additional survey conducted in 2020 that targets three threatened black cockatoo species.

The Quenda population is currently estimated at 167 individuals and the Woylie population is currently estimated at 213 individuals. Both have been stable since 2015. Tammar Wallabies tend to become overabundant at Karakamia. The Tammar Wallaby population is currently estimated at 178 individuals, well within the management threshold set for this species. Brushtail Possum population estimates were low compared to previous years, but this is more likely to reflect poor visibility during the survey than an actual population decline. No Western Ringtail Possums were detected in 2021. This species, which initially established well after translocations in the late 1990s, has not been observed on Karakamia since 2017. Baudin's Black Cockatoo (*Zanda baudinii*) and Carnaby's Black Cockatoo (*Z. latirostris*), both endangered species, were each detected at 45% of sites. Red-tailed Black Cockatoo (*Calyptorhynchus banksia*) was detected at 91% of sites. There were no detections of feral cats (*Felis catus*), foxes (*Vulpes vulpes*) or rabbits (*Oryctolagus cuniculus*) within the safe haven on Karakamia in 2021.

Overall, the results from the Karakamia Ecohealth monitoring program reflect the positive effect of safe havens on population sizes of threatened mammal species and on reducing the impact of threats including feral predators and rabbits.

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Introduction

Australian Wildlife Conservancy (AWC) currently owns, manages, or works in partnerships across 31 properties in Australia, covering almost 6.5 million hectares, to implement our mission: *the effective conservation of Australian wildlife and their habitats*. AWC relies on information provided by an integrated program of monitoring and research to measure progress in meeting its mission and to improve conservation outcomes.

AWC's Ecohealth Monitoring Program is designed to measure and report on the status and trends of species, ecological processes and threats on each of these properties (Kanowski et al. 2018). Data from the monitoring program are used to address the following broad questions relevant to our mission:

- 'are species persisting on a property?'
- 'are habitats being maintained?'
- 'are threats below ecologically-significant thresholds?'

For threatened and iconic species, including reintroduced species, AWC's monitoring program aims to obtain more detailed information related to their conservation management; for example, data on survival, recruitment, condition, distribution and/or population size.

The structure of the Ecohealth Program is as follows. AWC's Monitoring and Evaluation framework provides guidance on the development of the Ecohealth Monitoring Plans for each property managed by AWC: these plans describe the conservation values and assets of each property, the threats to these assets, and the monitoring program that will be used to track their status and trend, and to evaluate outcomes. Annual survey plans and schedules are developed to implement these plans. The outcomes of these surveys are presented in annual Ecohealth Reports and summary Ecohealth Scorecards.

This document is the second in the series of annual Ecohealth Reports for Karakamia Wildlife Sanctuary (referred to here as Karakamia). The companion Ecohealth Scorecard presents the indicators and their metrics in a summary format.

Karakamia Wildlife Sanctuary

Karakamia ('home of the Red-tailed Black Cockatoo' in Noongar) is within the traditional lands of the Noongar people. Karakamia was AWC's first property and is located in the Perth Hills (Figure 1). It was established in 1991 by AWC's founder Martin Copley. Once a pastoral lease, Martin purchased the land for its ecological diversity, containing all elements of the Jarrah Forest complex, water bodies and riparian zones, all within a relatively small area (268 ha). As a mosaic of Jarrah (*Eucalyptus marginata*) forest, Marri (*Corymbia calophylla*) woodland, Wandoo (*Eucalyptus wandoo*) woodland, riparian zones, and granitic heathlands and shrublands (Figure 2), Karakamia provides habitat for a diverse suite of native wildlife. These systems support 23 mammal (including four reintroduced), 34 reptile, 124 bird, 12 amphibian, and >315 plant species, including 7 threatened fauna and 2 threatened flora species.

The majority of Karakamia (268 ha) is surrounded by a conservation fence and has been free of feral cats (*Felis catus*) and foxes (*Vulpes vulpes*) since 1994. In the absence of these predators, four mammal species have been successfully reintroduced to the property (Woylie, *Bettongia penicillata*; Quenda, *Isodon fusciventer*; Tammar Wallaby, *Macropus eugenii*; and Common Brushtail Possum/Koomal, *Trichosurus vulpecula*). Woylies are listed as endangered nationally, and critically endangered in Western Australia. As a result of this success, all four reintroduced species at Karakamia have been used as a source for reintroductions elsewhere (e.g. Woylie and Common Brushtail Possum to Mt Gibson Sanctuary; and Quenda and Tammar Wallaby to Paruna Sanctuary). The reintroduction of Western Ringtail Possums (*Pseudocheirus occidentalis*) to Karakamia resulted in a population that persisted for close to twenty years, but the species has not been detected since 2017. There have also been small-scale or trial reintroductions of other species, including the Numbat (*Myrmecobius fasciatus*), Quokka (*Setonix brachyurus*) and Rakali (*Hydromys chrysogaster*), which failed to result in established populations.

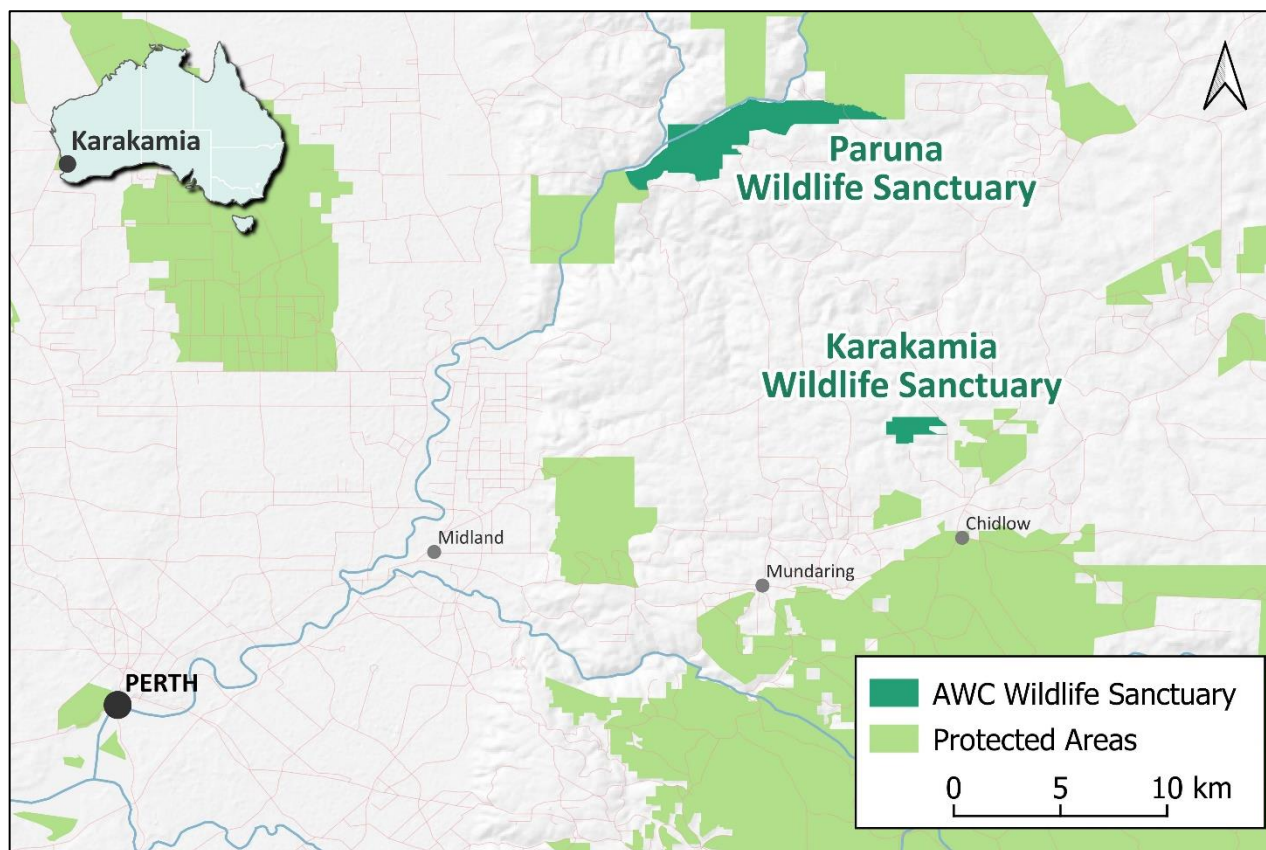


Figure 1. Location and regional context of Karakamia Wildlife Sanctuary and Paruna Wildlife Sanctuary. Inset indicates location within Australia.

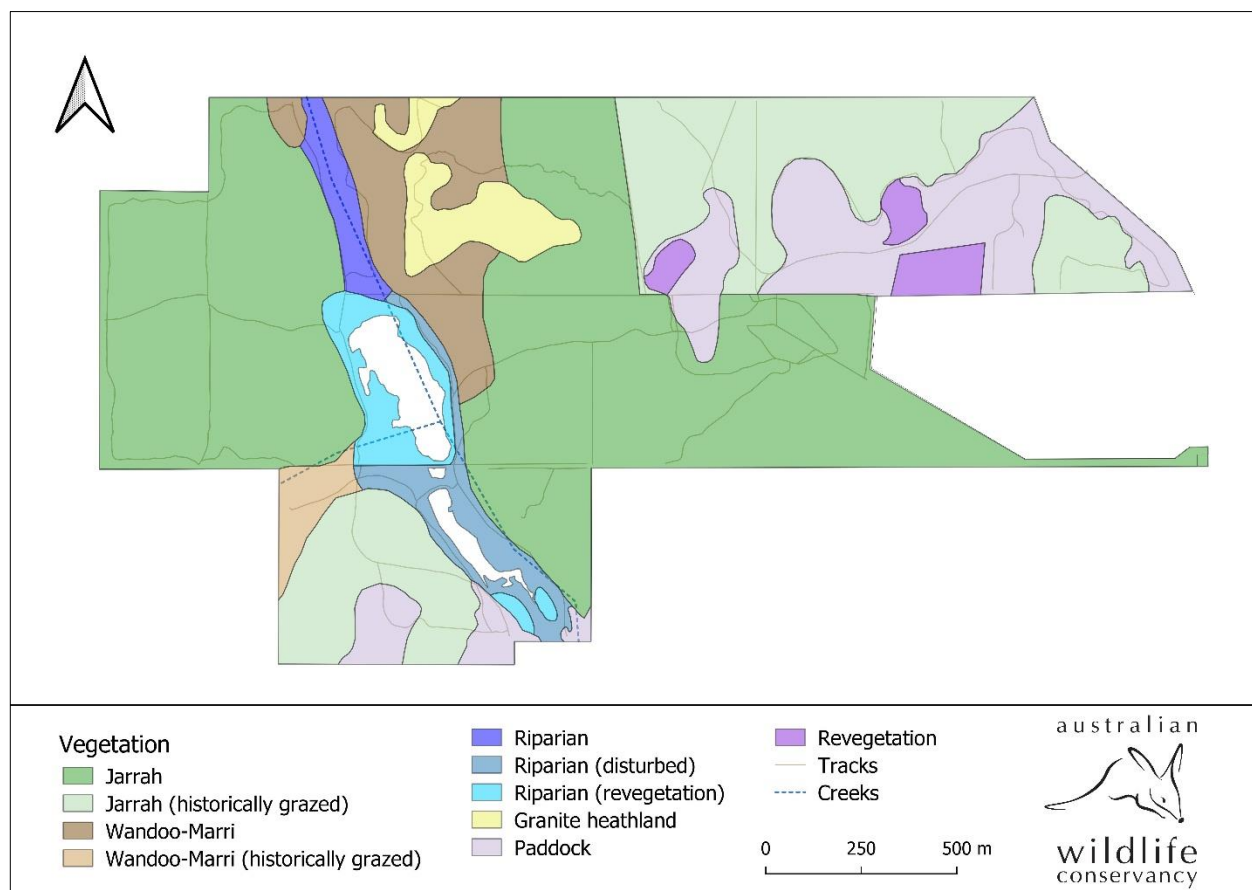


Figure 2. Distribution and extent of broad vegetation groups and water courses at Karakamia Sanctuary.

Climate and weather summary

Karakamia experiences a Mediterranean climate with warm, dry summers and cool, wet winters (Figure 3). Annual average minimum temperatures have been steadily increasing over the past 120 years, with the 2021 average minimum temperature 0.8°C warmer than the preceding long-term (1902-2021) average.

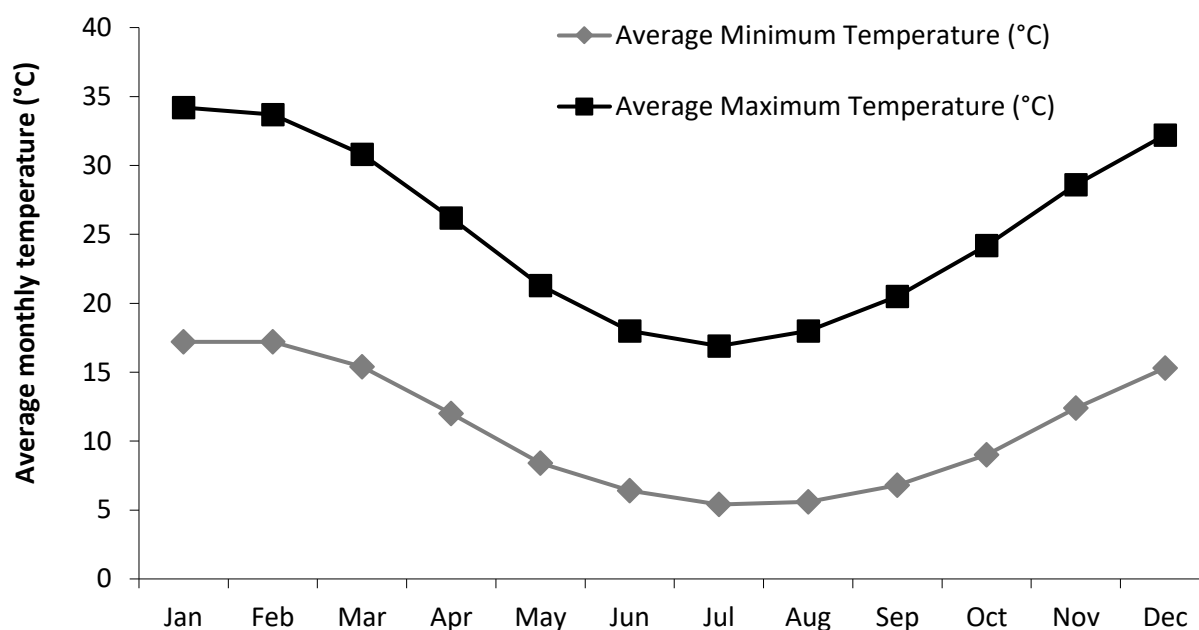


Figure 3. Mean minimum and mean maximum monthly temperature at Northam Monitoring Station, 1902-2021 (BOM Station No. 010111). Source: BOM Climate Data Online.

Total annual rainfall has steadily decreased since 1908 (Figure 4), however in 2021 total annual rainfall (968.3 mm) was well above the long-term average (845.8 mm). Substantial rain in March, July and October was largely responsible for the greater than average yearly total (Figure 5).

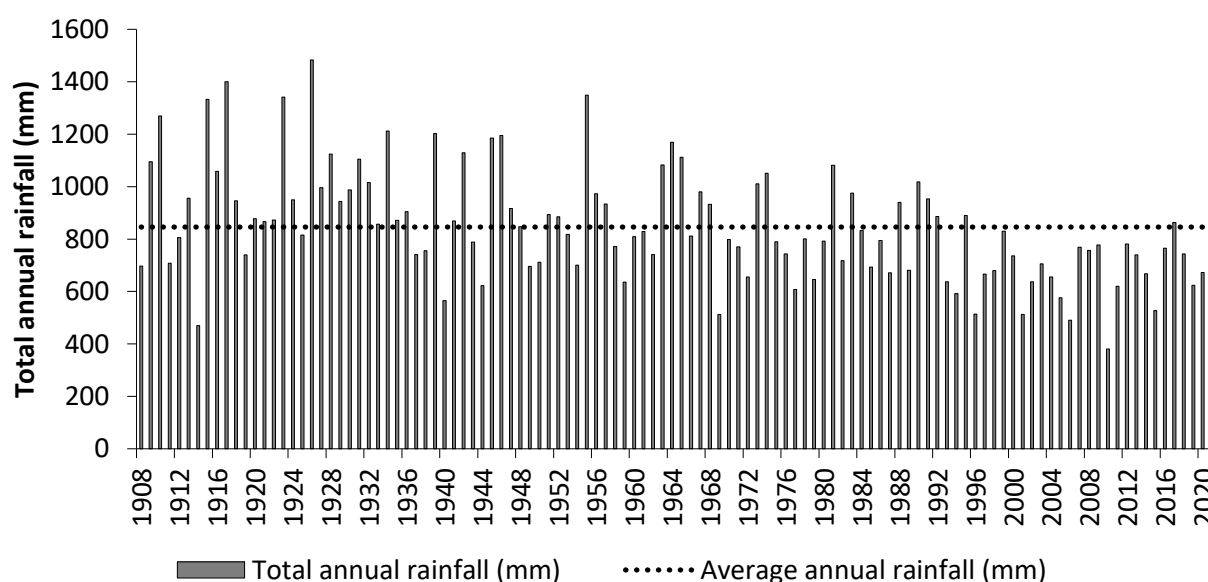


Figure 4. Annual rainfall at Chidlow Monitoring Station 1908-2021, with reference to the annual rainfall long-term average 1908-2020 (BOM Station No. 009007). Source: BOM Climate Data Online.

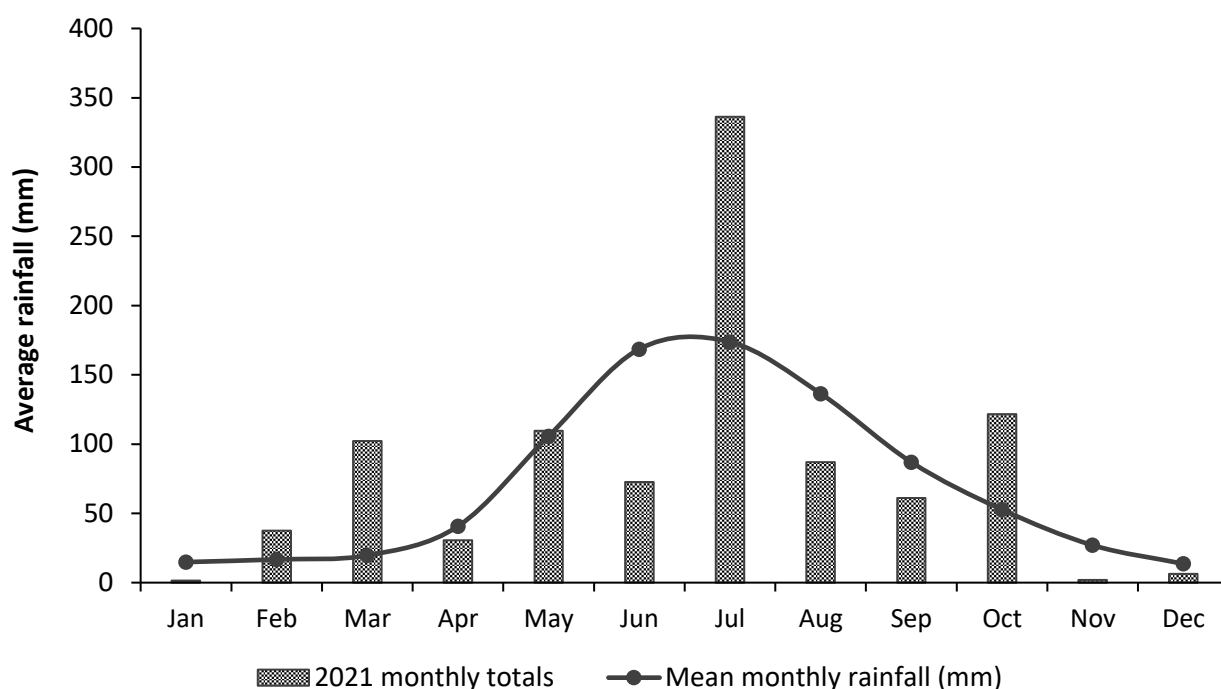


Figure 5. Rainfall in 2021 compared with mean monthly rainfall (1908-2020) at Chidlow Monitoring Station (BOM Station No. 009007). Source: BOM Climate Data Online.

Methods

Monitoring and evaluation framework

Karakamia's Ecohealth Monitoring Program has been designed to measure and report on the status and trends of selected biodiversity and threat indicators on the property, using metrics derived from data collected through a series of purpose-designed surveys. Where possible, outcomes will be evaluated against performance criteria relevant to each species, guild or assemblage.

Reintroduced, key threatened and iconic species

The Ecohealth program is focused on species of high conservation value, including reintroduced species (where present), and key threatened and 'iconic' species (e.g., regional endemics, species with high public profile and other species of conservation importance because of the role they play in an ecosystem, etc).

Monitoring programs for reintroduced species in the establishment phase (i.e., within 5-10 years of establishment) are typically set out in a *Translocation Proposal*, along with success criteria to evaluate outcomes around survival, recruitment, population size, etc.

AWC will develop *Population Management Plans* to underpin management of long-established populations of reintroduced species, to ensure early detection of any serious issues that arise, and to trigger timely responses. These plans will specify a monitoring and evaluation program (e.g., Berry et al. 2021).

AWC will aim to develop *Conservation Plans* for the remaining (extant) threatened and iconic species, with similar objectives to Population Management Plans. These plans will specify metrics to monitor outcomes for target species against nominated performance criteria.

Vertebrate assemblages and surveillance species

AWC's mission involves the conservation of all wildlife, not only threatened or reintroduced species. For this reason, AWC's monitoring program extends to surveillance monitoring of faunal assemblages (mammals, birds, reptiles, frogs). The monitoring program aims to address questions relevant to the conservation of assemblages.

At the most basic level, the program seeks to establish whether all species that are known to occur on the property are persisting on the property (i.e., 'are all species present?').

With increasing information, the monitoring program can address more detailed questions relating to conservation of assemblages, such as 'have species maintained their distributions or abundance?' However, the boom/ bust conditions of most Australian environments can lead to large variations in the numbers of individuals in a population and the habitats or sites occupied by a species – these variations may not necessarily be informative in relation to the conservation of a species at a property over the long term.

AWC is currently working on developing an evaluation framework for surveillance monitoring of faunal assemblages. At present, we will continue to present data on a range of metrics relating to indicator species and guilds.

Indicators and metrics

On Karakamia, 26 biodiversity (species, guilds and assemblages) indicators have been selected for monitoring (Table 1). Twelve of these indicators are reported on in this 2021 report, of which five are reintroduced species.

Threat metrics are selected to monitor the status and trends of introduced weeds, predators and herbivores, and fire regimes). Six threat indicators have been selected for monitoring (Table 2). Four of these threat metrics are reported on in this 2021 report.

Table 1. Biodiversity indicators and metrics for Karakamia.

Reintroduced vertebrates

Indicator	Survey name/methods	Metric	Performance criteria
Quenda (<i>Isoodon fusciventer</i>)	Mammal Trapping Survey	Population size	TBD pending Population Management Plan
Western Ringtail Possum (<i>Pseudocheirus occidentalis</i>)	Possum Spotlight Survey	Occupancy	TBD pending Population Management Plan
Common Brushtail Possum (<i>Trichosurus vulpecula</i>)	Possum Spotlight Survey	Population size	TBD pending Population Management Plan
Woylie (<i>Bettongia penicillata</i>)	Mammal Trapping Survey	Population size	TBD pending Population Management Plan
Tammar Wallaby (<i>Macropus eugenii</i>)	Tammar Spotlight Survey	Population size	Maximum population threshold is 300 individuals. Minimum population threshold TBD pending Population Management Plan

Key threatened and iconic vertebrates

Indicator	Survey name	Survey method	Metric/s
Birds			
Baudin's Black Cockatoo (<i>Zanda baudinii</i>)	Black Cockatoo Survey	Resource use analysis	Occupancy
Carnaby's Black Cockatoo (<i>Zanda latirostris</i>)	Black Cockatoo Survey	Resource use analysis	Occupancy
Red-tailed Black Cockatoo (<i>Calyptorhynchus banksia</i>)	Black Cockatoo Survey	Resource use analysis	Occupancy

Vertebrate assemblages and surveillance species

Indicator	Survey name	Survey method	Metric/s
Mammals			
Assemblage richness	Mammal Trapping Survey, Possum and Tammar Spotlight Surveys, Standard Survey	All mammal survey methods	Number of species
Small-medium sized mammals			

Indicator	Survey name	Survey method	Metric/s
Small-medium sized mammals (guild)	Standard Survey	Camera and pitfall traps	Abundance Richness
Short-beaked Echidna (<i>Tachyglossus aculeatus</i>)	Standard Survey	Camera traps	Occupancy
Mardo (Yellow-footed Antechinus) (<i>Antechinus flavipes</i>)	Standard Survey	Camera traps	Occupancy
Brush-tailed Phascogale (<i>Phascogale tapoatafa</i>)	Standard Survey	Camera traps	Occupancy
Bats			
White-striped Free-tailed Bat (<i>Austronomus australis</i>)	Acoustic Survey	Acoustic recorders	Occupancy
Reptiles			
Assemblage richness	Standard Survey	Pitfall traps, camera traps	Number of species
Buchanan's Snake-eyed Skink (<i>Cryptoblepharus buechananii</i>)	Standard Survey	Pitfall traps	Occupancy
Common Dwarf Skink (<i>Menetia greyii</i>)	Standard Survey	Pitfall traps	Occupancy
South-western Orange-tailed Slider (<i>Lerista distinguenda</i>)	Standard Survey	Pitfall traps	Occupancy
Barking Gecko (<i>Underwoodisaurus milii</i>)	Standard Survey	Pitfall traps	Occupancy
Marbled Gecko (<i>Christinus marmoratus</i>)	Standard Survey	Pitfall traps	Occupancy
Bobtail (<i>Tiliqua rugosa</i>)	Standard Survey	Camera traps	Occupancy
King's Skink (<i>Egernia kingii</i>)	Standard Survey	Camera traps	Occupancy
Birds			
Assemblage richness	Standard Bird Survey; Black Cockatoo Survey	All survey methods listed for birds	Number of species
Diurnal Birds (guild)	Standard Bird Survey	Observational survey	Abundance Richness
Frogs			
Assemblage richness	Acoustic Survey	Acoustic recorders	Number of species
Frogs (guild)	Acoustic Survey	Acoustic recorders	Abundance Richness

Table 2. Threat indicators and metrics for Karakamia in 2021.

Indicator	Survey name/methods	Metric/s	Performance criteria
Pest animals			
Feral cat (<i>Felis catus</i>)	Feral Species Camera Survey	Number of incursions	TBD Pest Animal Strategy
Red fox (<i>Vulpes vulpes</i>)	Feral Species Camera Survey	Number of incursions	TBD Pest Animal Strategy
Rabbit (<i>Oryctolagus cuniculus</i>)	Feral Species Camera Survey	Number of incursions	TBD Pest Animal Strategy
House mouse (<i>Mus musculus</i>)	Standard Survey	Occupancy	TBD Pest Animal Strategy
Black rat (<i>Rattus rattus</i>)	Standard Survey	Occupancy	TBD Pest Animal Strategy
Fire			

Indicator	Survey name/methods	Metric/s	Performance criteria
Extent of planned and unplanned burns	Ground mapping	Area burnt in planned fire (ha) Area burnt in unplanned fire (ha)	Area burned by late season fires.

Survey types and history

To report on the Biodiversity and Threat Indicators, our survey teams conduct a variety of surveys repeated every 1-2 years, as required to obtain timely information on each indicator. These include:

For key threatened and iconic vertebrates, including reintroduced species:

- Mammal Trapping Survey (for Quenda and Woylie)
- Possum Spotlight Survey (for Western Ringtail Possums and Common Brushtail Possum)
- Tammar Wallaby Spotlight Survey
- Black Cockatoo Survey

For monitoring of vertebrate assemblages and surveillance species:

- Standard Survey (pitfall traps and cameras) for small mammals and reptiles
- Standard Bird Survey for diurnal birds
- Acoustic Survey for White-tail Free-tailed Bat (*Austronomus australis*) and frogs – methods under development

To monitor threats:

- Standard Survey (cameras) for monitoring pest rodents
- Feral Species Camera Survey (feral cats, foxes, rabbits)
- Targeted Weed Surveys – methods under development
- Fire Scar Mapping

Four of the ecological surveys were conducted at Karakamia in 2021 (Table 3). Fire Scar Analysis was completed using on-ground mapping. The methodology is described and results of these surveys are reported on in this document.

Table 3. Survey history and effort for Ecohealth surveys on Karakamia for survey results presented in this report.

Survey name	Effort	Description/comment	Previous surveys
Mammal Trapping Survey	1,036 trap nights	66 sites (264 traps) surveyed for three to four nights, recording all captures and processing a subset of individuals.	2015-2020 – 66 sites
Possum Spotlight Survey	24 km of transects	32 track-based fixed transects (250 m length) surveyed using spotlighting and distance sampling on foot for three consecutive nights.	2018 – sites sampled once 2019 – sites sampled twice 2020 – sites sampled thrice 2021 – sites sampled thrice
Tammar Wallaby Spotlight Survey	22 km of transects	8 track-based fixed transects surveyed using spotlighting and distance sampling from a moving vehicle for four consecutive nights.	2016-2019 – 9 sites 2020-2021 – 8 sites
Black Cockatoo Survey	44 surveys	11 sites surveyed in one day, four times per year (seasonally).	2020 – 11 sites
Feral Species Camera Survey	3,650 camera trap nights	10 cameras deployed year-round to detect feral species incursions	2014-2021 – 10 sites

Survey design and methods

Mammal Trapping Survey

Cage trapping is used to monitor the population size of reintroduced Woylies and Quenda, and to obtain demographic, reproductive and health data for Woylies, Quenda and Common Brushtail Possum. Trapping sites ($n = 66$) are located every 200 m along tracks within the sanctuary. The trapping sites are divided into three groups (Figure 6). At each site, there are four cage traps deployed within 5 m of the road. Four sites (KMT1.2, 1.7, 1.8, 2.15 and 2.16) are positioned further from the road as they are located on roads that may be traversed whilst the traps are open. The trap locations cover all major vegetation types within the sanctuary and provide suitable coverage within target species home ranges.

Trapping was conducted over four consecutive nights in January. All traps were opened and lured with universal bait (peanut butter and oats). Traps were opened in the late afternoon and checked before dawn the following morning. Due to the high volume of Woylie captures, minimal animal processing and morphometric data collection was undertaken (i.e. microchip, sex, and reproductive condition), with only 15 male and 15 female adults processed fully (additional morphometric measurements, body weight and pes length) to obtain demographic data. All individual Quenda and Common Brushtail Possum were processed fully.

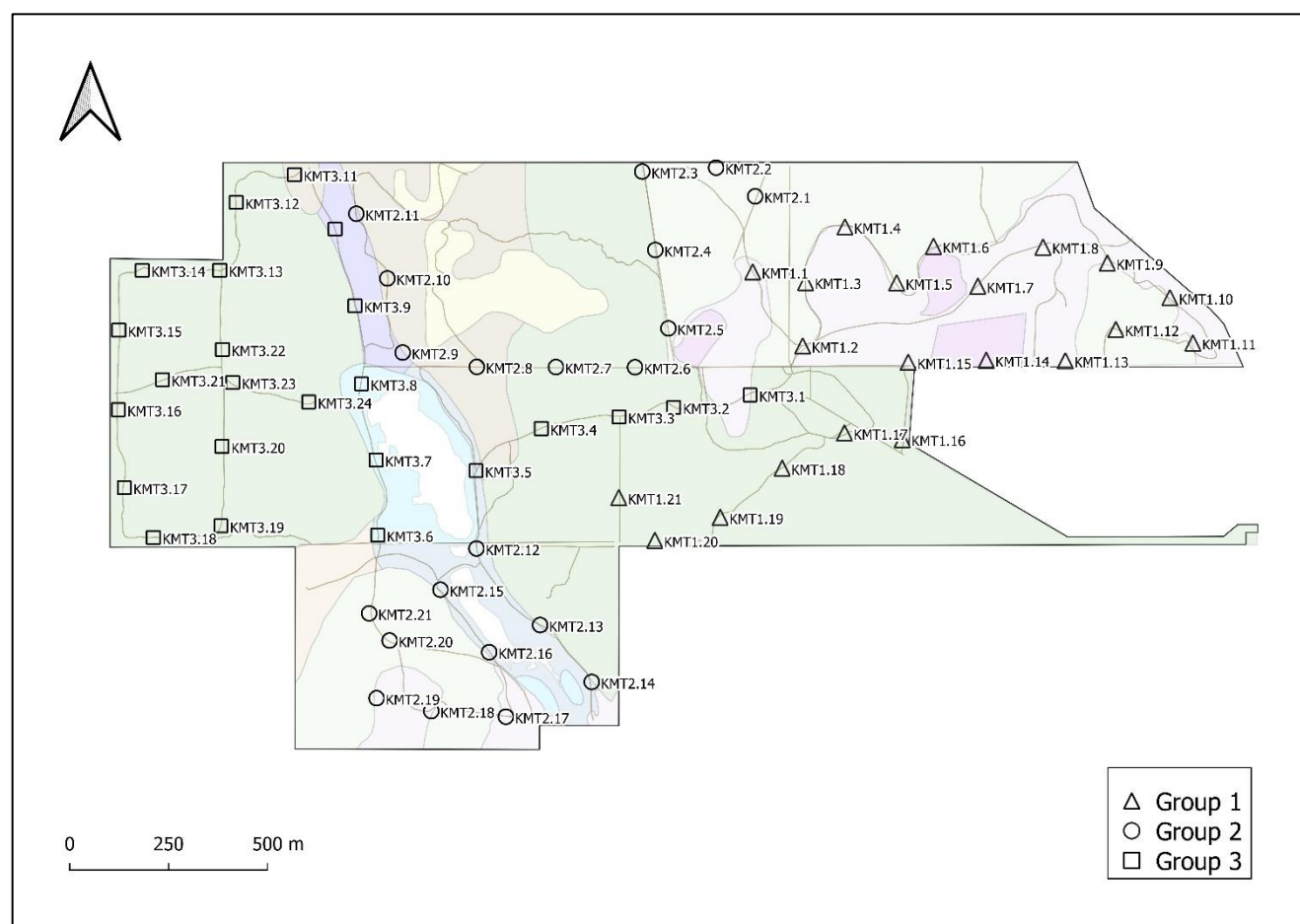


Figure 6. Mammal trapping sites on Karakamia.

Possum Spotlight Survey

Common Brushtail Possum population size and the presence and occupancy of Western Ringtail Possums at Karakamia are monitored via an annual spotlight survey. The survey comprises 32 fixed (250 m) transects, categorised by habitat type: paddock, Jarrah, riparian, or Wandoo-Marri; and transect type: road or bush (Figure 7).

In 2021, spotlighting was conducted over three consecutive nights (i.e., a repeat survey distance sampling survey design; Chandler 2020). The number of repeat surveys has varied in previous years. Commencing one

hour after sunset, transects were walked searching for possums in trees and on the ground. Observers focused on searching for movement and eye shine reflections within trees, with particular attention on the area between 5 m and 12 m high and on the ground. Walking pace was modified depending on canopy density, to ensure a thorough search.

Distance sampling data was collected for each possum sighting. Observer location, distance, and angle from observer were used with transect bearings to calculate each observed animal's perpendicular distance from the transect.

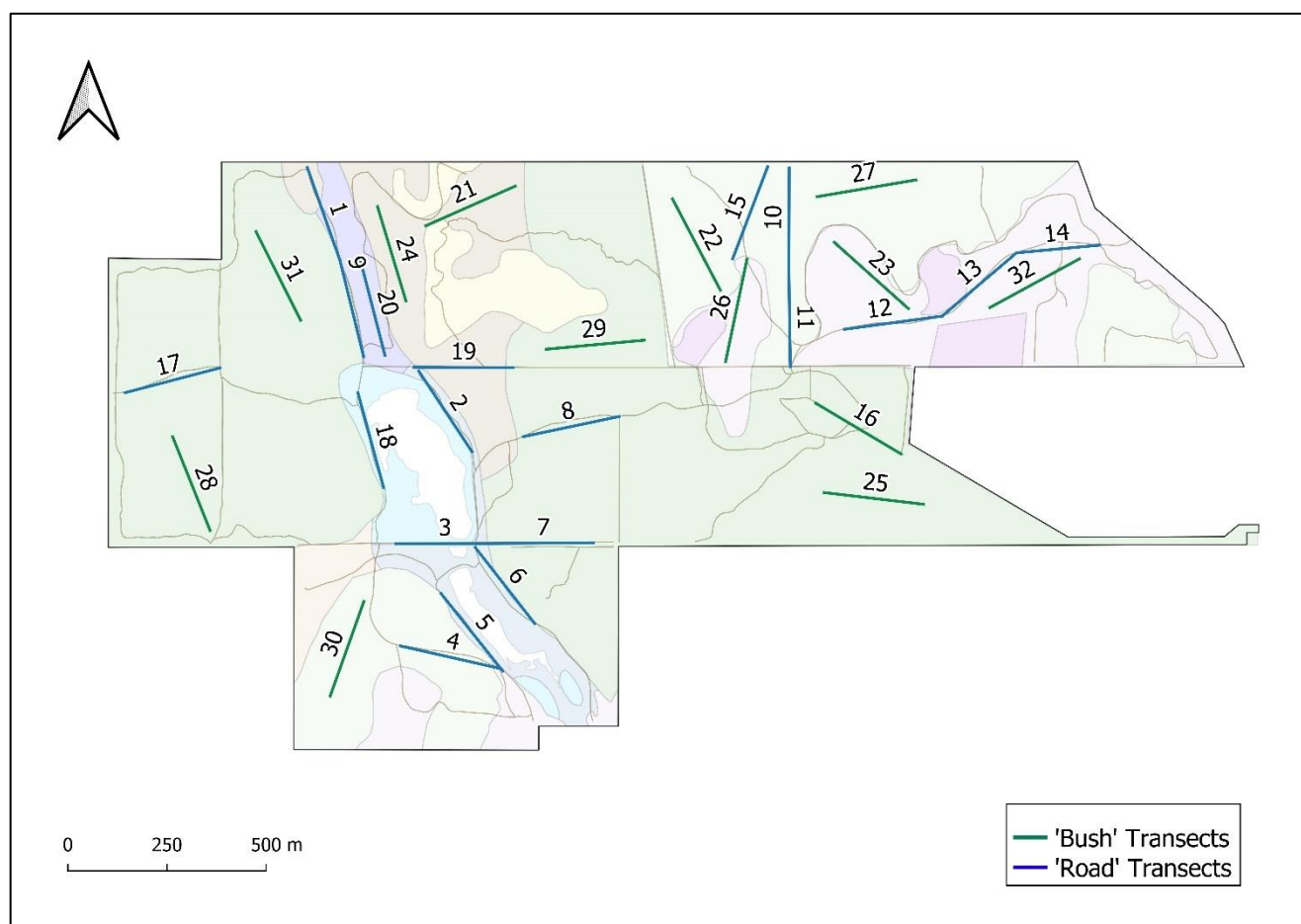


Figure 7. Possum Spotlight Survey monitoring transects on Karakamia. Transects are stratified by transect and habitat type.

Tammar Wallaby Spotlight Survey

Tammar Wallaby populations at Karakamia are monitored with an annual spotlight survey. Surveys are conducted along fixed track-based transects of varying (440 m-960 m) lengths. Historically, two transects were located in the paddocks and seven in other 'bush' (non-paddock) habitats (Figure 8). In 2020, one of the paddock transects (T9) was removed after the area was fenced off for revegetation.

In January 2021, spotlighting was conducted over four nights along eight transects. One hour after sunset, the bush transects (1-7) were driven by vehicle at 5 km/hr. Two observers searched for Tammar Wallabies on one side of the track each. Distance from the road was recorded for each Tammar Wallaby sighted along the bush transects. Animals more than 25 m from the road were excluded from analyses. The 'paddock' transects were surveyed using a 50 m wide strip on one side of the track. All Tammar Wallabies within the marked area were counted independently by both observers. Particular care was taken to ensure individuals were not counted more than once.

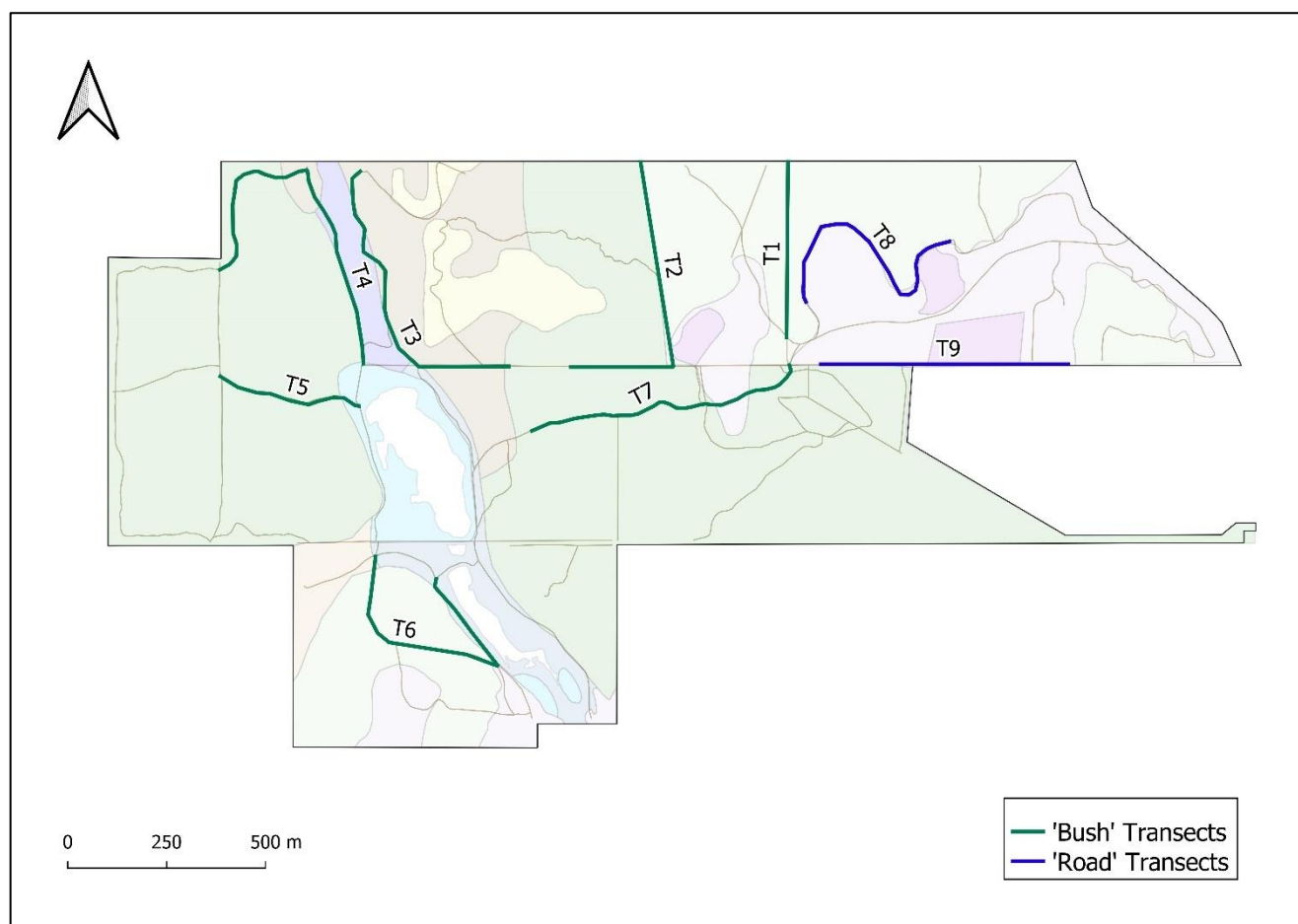


Figure 8. Tammar Wallaby Spotlight Survey transects on Karakamia.

Black Cockatoo Survey

The objective of this survey is to confirm the occupancy of, and habitat use by, threatened black cockatoo species by searching for Marri nuts with distinctive feeding signs. Three threatened species rely on Marri nuts as an important food source: Red-tailed Black Cockatoo (*Calyptorhynchus banksia*), Baudin's Black Cockatoo (*Zanda baudinii*) and Carnaby's Black Cockatoo (*Z. latirostris*). In 2020, searches for feeding signs were conducted at 11 sites four times within the year (once per season; Figure 9). Sites were associated with creek lines, dams and granite outcrops also utilised for amphibian surveys. A search was undertaken for Marri nuts on the ground in an area within approximately 50 m. Differences in mandible size between the species produce noticeably different feeding marks, which were examined to determine a species' presence (Fleming 2018). Searches were conducted by a single staff member and concentrated on ground under Marri trees where possible. All species identified from feeding signs were recorded, as was the freshness of the nuts (green, red/brown, brown/grey).

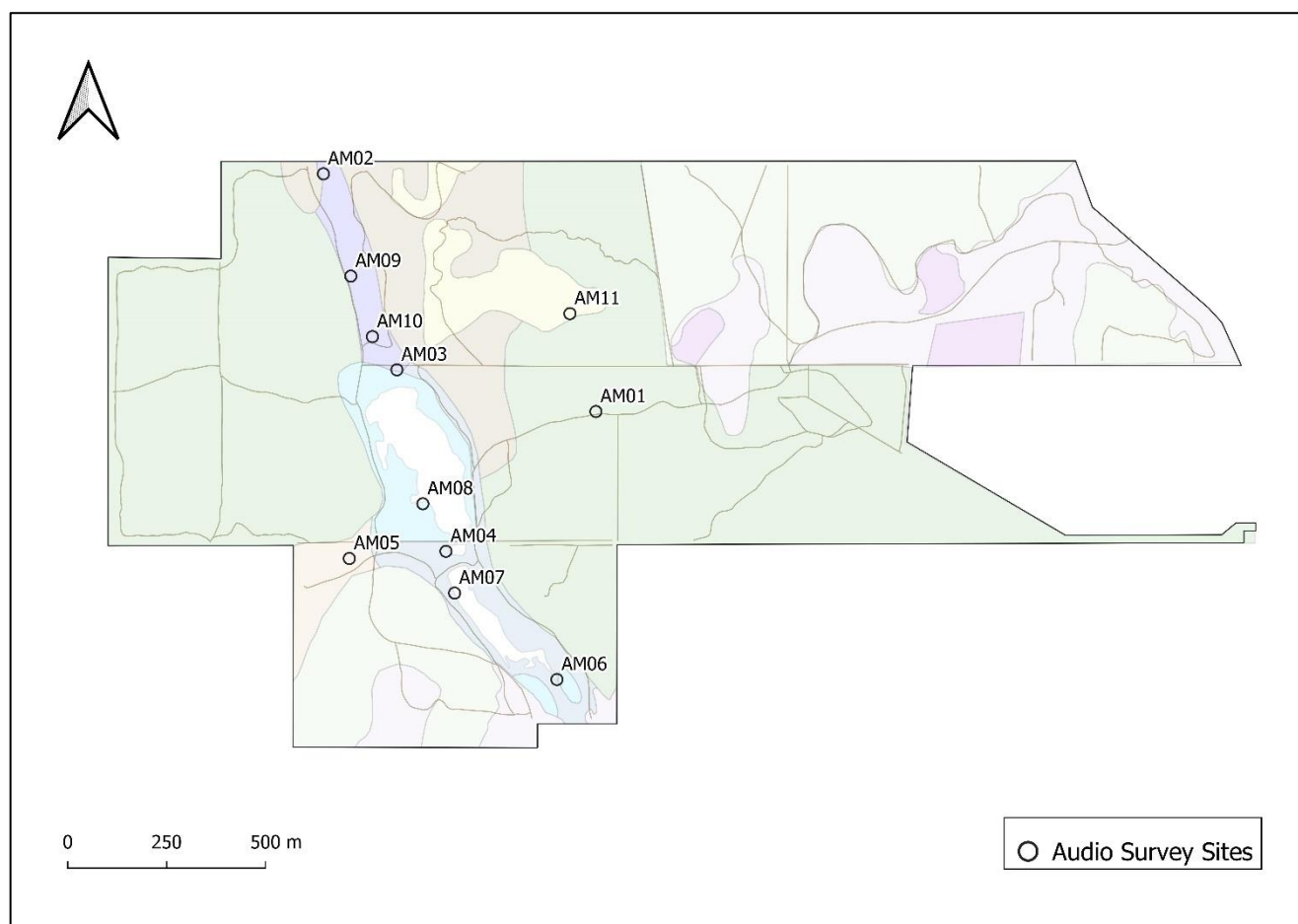


Figure 9. Black Cockatoo Survey sites at Karakamia.

Feral Species Camera Survey

Feral incursion monitoring sites ($n = 10$) are situated on internal fence line tracks. A single camera is deployed permanently at each monitoring site. Cameras are maintained once per week, with batteries refreshed and images from SD cards downloaded. Images were reviewed for evidence of any incursion by cats, foxes or rabbits.

Analysis methods

Unless noted otherwise, the metrics are calculated as set out in Table 4.

Table 4. Metrics and associated calculations for Karakamia for results presented in this report.

Indicator	Metric	Survey data sources	Description	Analysis summary/calculation
Assemblage richness	Number of species	All surveys and incidental records	A measure of intactness for the whole sanctuary	The number of species detected on the sanctuary within the last 1-5 years is compared to the number of species listed as 'confirmed', 'very likely' or 'likely' on the sanctuary species list.
Quenda, Woylie	Population Estimate	Mammal Trapping Survey	Estimate of total number of individuals in the population based on live trapping	Population estimates were generated using Spatially Explicit Capture-Recapture methods (Efford and Fewster 2013). Package OSCR (Sutherland et al. 2019) run within R software (R Core Team 2013) was used (Australian Wildlife Conservancy 2021).

Indicator	Metric	Survey data sources	Description	Analysis summary/calculation
				Mark-recapture was used to estimate total population size of Quenda based on cage trapping surveys. This approach is used when counting all individuals in a population is not practical. In mark-recapture analyses, a portion of the population is captured and marked, prior to release. During subsequent sampling event(s), another portion is captured, and the number of previously marked animals is counted. Assuming the number of previously marked animals is proportional to the total number of marked animals in the population, an equation is used to estimate total population size.
Tammar Wallaby	Population Estimate	Tammar Spotlight Survey	Estimate of total number of individuals in the population based on distance sampling	Population size is estimated by employing N-mixture models using the temporally replicated count data collected during spotlight surveys. Models are run within R software (R Core Team 2013) with the R2WinBUGS Package and WinBUGS (version 1.4.3; Lunn et al. 2009) using code provided by Kéry and Royle 2010). Animal counts were modelled as a function of the transect length and whether the transect was in a paddock or not. Detection was modelled as a function of whether the transect was in a paddock or not.
Western Ringtail Possum	Occupancy	Possum Spotlight Survey	A measure of distribution; the proportion of sites where the species was recorded using a particular technique.	Number of sites at which the species was recorded/number of sites surveyed x 100
Red-tailed Black Cockatoo, Baudin's Black Cockatoo, Carnaby's Black Cockatoo	Occupancy	Black Cockatoo Survey	A measure of distribution; the proportion of sites where the species was recorded using a particular technique	Number of sites at which the species was recorded/number of sites surveyed x 100
Cat, fox, rabbit	Number of incursions	Feral Species Camera Survey	Detection of the species in a camera trap image.	Number of occasions the species was detected.

Fire Scar Analysis

Fire scars were measured by walking the perimeter of the burned area using a handheld GPS unit with tracking function. The area of the scar in hectares was calculated using ArcMap 10 with Spatial Analyst (Environmental System Research Institute Inc., Redlands, CA, USA).

Results

Reintroduced species

Quenda

The number of Quenda at Karakamia has been stable since 2015 (Figure 10). In 2021, the total population was estimated at 167 individuals.

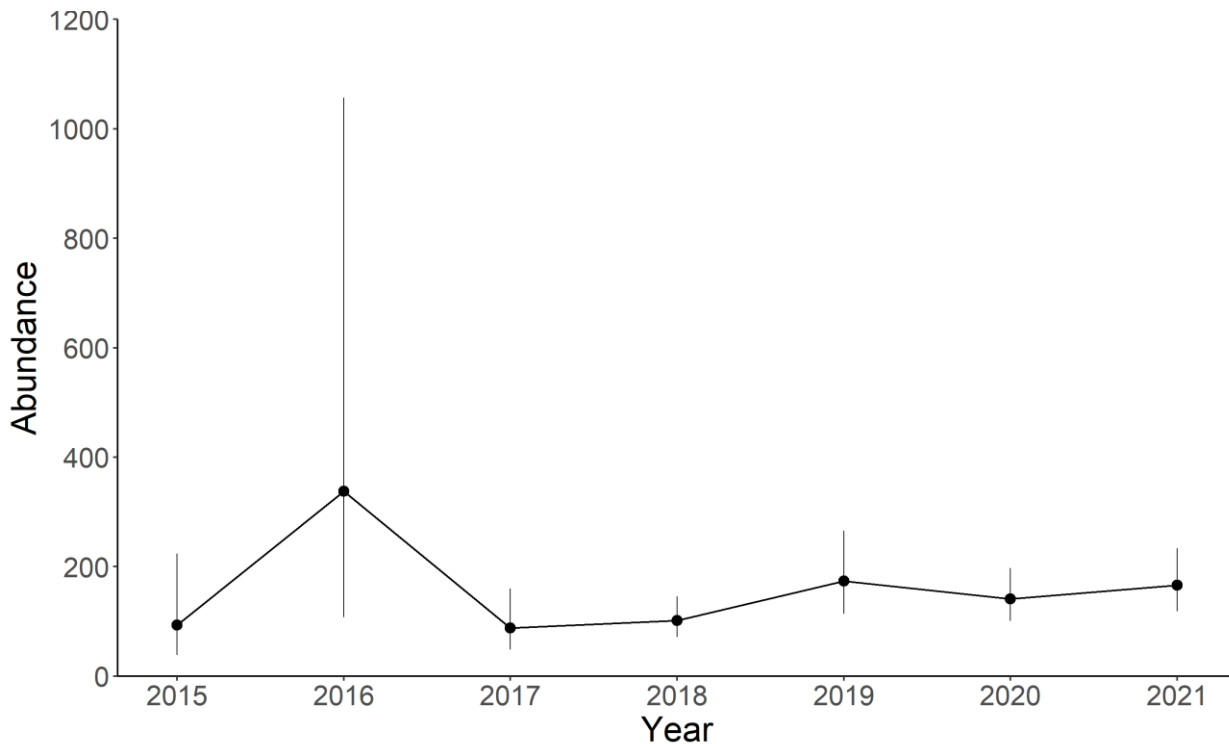


Figure 10. Population size of Quenda at Karakamia from 2015-2021. Error bars represent 95% confidence intervals.

Western Ringtail Possum

No Western Ringtail Possums were detected in 2021. The last confirmed sighting of the species was in 2017 during a targeted camera trapping survey. Based on these results, we consider it likely that the species is no longer present on Karakamia.

Common Brushtail Possum

In 2021, the total population of Common Brushtail Possum was estimated at 86 individuals, a substantial decline compared to estimates for previous years (170-233 individuals; Figure 11). Visibility during the 2021 survey was hampered by poor conditions (rain and fog) and the number of Common Brushtail Possum observations was less than half that recorded in 2020. Additionally, 17 Common Brushtail Possum were translocated out of Karakamia (to Mount Gibson) a month prior to the 2021 survey. Preliminary results from a survey conducted in early 2022 in more favourable conditions indicate that the population is stable, and the 2021 result is most likely an underestimate due to adverse survey conditions. Rescheduling surveys affected by adverse weather conditions should prevent similar issues recurring.

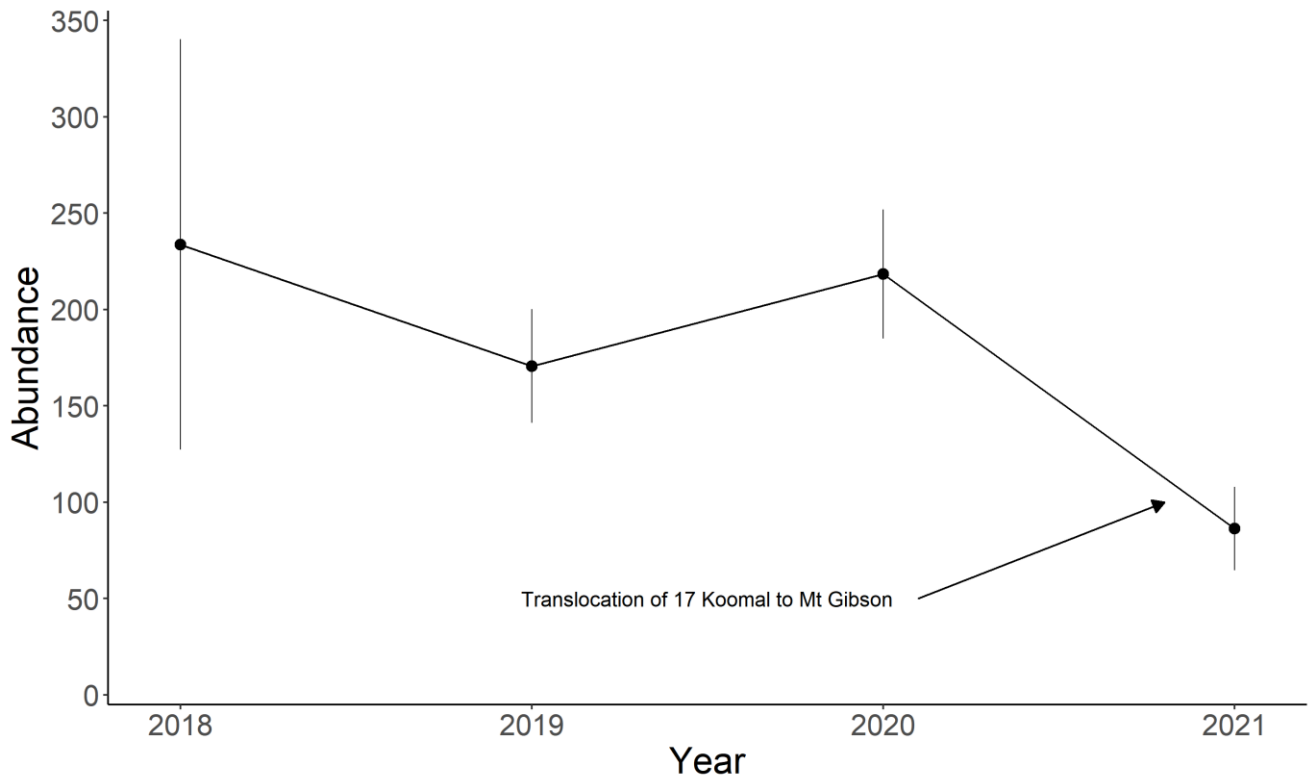


Figure 11. Population size of Common Brushtail Possum (Koomal) at Karakamia 2018-2021. Error bars represent standard error and the timing of a significant translocation event is illustrated by the arrow.

Woylie

The Woylie population has remained relatively stable since 2016, after a decline from initial estimates in 2015 (Figure 12). Refinement of the survey method between 2015 and 2017 has led to better population estimates in later years. The total population size in 2021 was estimated at 213 individuals.

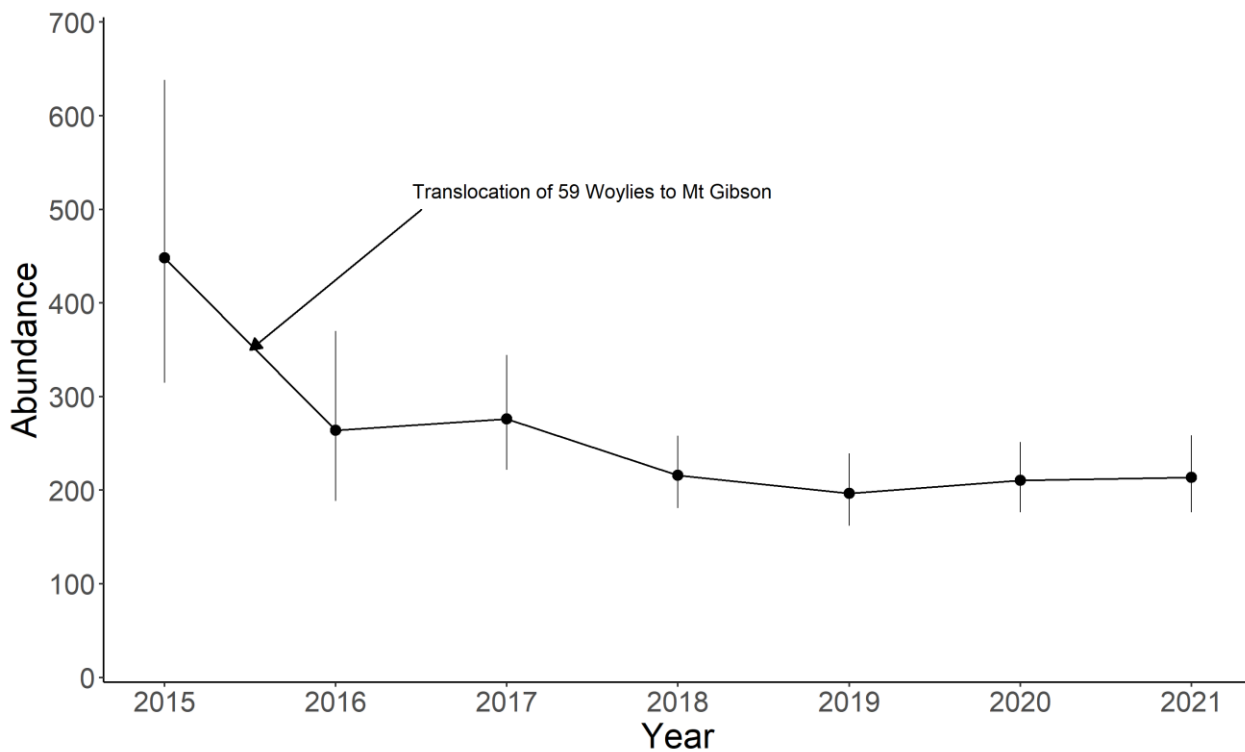


Figure 12. Population size of Woylie at Karakamia 2015-2021. Error bars represent 95% confidence intervals, and the timing of a significant translocation event is illustrated by the arrow.

Tammar Wallaby

The Tammar Wallaby population has decreased substantially since 2016 (2021 population estimate = 178; Figure 13), following targeted management actions by AWC to address overabundance. The current population size is not considered of concern. Refinement of the survey method, such as replacing transects that have been affected by fencing for rehabilitation works, may be required for future surveys.

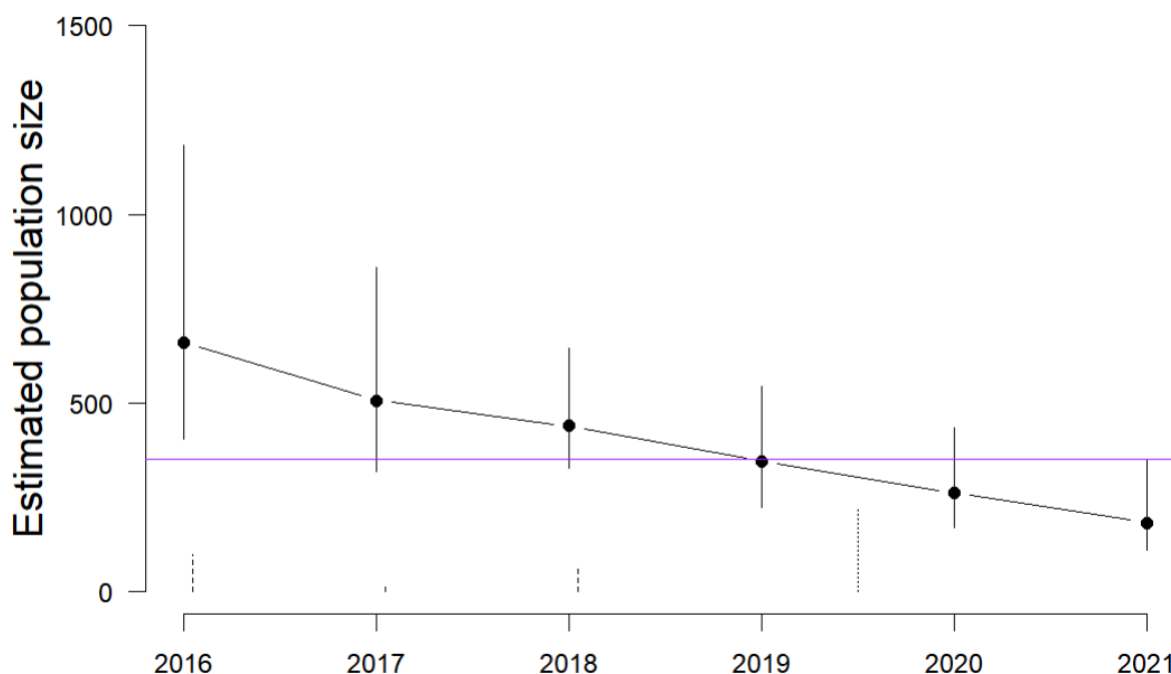


Figure 13. Population size of Tammar Wallabies at Karakamia 2016-2021. Purple line = management threshold ($n = 300$). Dashed vertical lines = number of animals removed from property.

Key threatened and iconic vertebrates

Black cockatoos

This survey was not conducted in 2021, so results from 2020 are reported here. Evidence of feeding upon Marri nuts was detected for all three black cockatoo species. Red-tailed Black Cockatoos were detected at 91% of sites. Baudin's and Carnaby's Black Cockatoos were each detected at 45% of sites.

Vertebrate assemblages and surveillance species

Mammals

A total of 9 mammal species were recorded in 2020-2021, from 23 known or likely to occur. Missing species are mostly bats (8 species) which were not surveyed in this period. They also include species that occur at low densities such as Western Brush Wallaby (*Macropus irma*) and Western Pygmy Possum (*Cercartetus concinnus*) and two species that are now believed to be absent (Rakali and Western Ringtail Possum).

Reptiles

A total of 9 reptile species were recorded in 2020-2021, from 34 known or likely to occur. Missing species include species that occur in low densities (large elapids). Surveys targeting reptiles were not conducted in 2021.

Birds

A total of 50 species in this guild recorded from 2020-2021, from 125 known or likely to occur. Missing species are largely those that occur in low densities and/or are nomadic or migratory.

Frogs

A total of 5 frog species were recorded on Karakamia in 2020-2021 from 12 species known to occur. Surveys targeting frogs were not conducted in 2021. Targeted surveys for this taxon are under development.

Threat indicators

Feral animals

There were no detections of feral cats, foxes or rabbits inside the fenced area in 2021 (Table 5).

Table 5. Pest animal metrics for Karakamia for 2021.

Indicator	Metric	Current value	Year	Performance/comments
Pest animals				
Feral cat	Number of incursions	0%	2021	↔ Results similar to most previous years
Fox	Number of incursions	0%	2021	↔ Results similar to most previous years
Rabbit	Number of incursions	0%	2021	↔ Results similar to most previous years

Fire

No unplanned fires occurred at Karakamia in 2021. Fourteen hectares, in three separate blocks, were burnt in prescribed fires (Table 6). These burns were primarily conducted to protect assets and infrastructure.

Table 6. Fire metrics for Karakamia for 2021. Note: A long-term Fire Management Strategy is currently being developed to address the complexity of fire control at Karakamia.

Indicator	Metric	Current value	Year	Performance/comments
Fire				
Extent of planned and unplanned burns (ha)	Area burnt in planned fire (ha)	14	2021	↔ Results similar to most previous years
	Area burnt in unplanned fire (ha)	0	2021	↔ Results similar to most previous years

Discussion

In 2021, the Karakamia Ecohealth monitoring program focused primarily on reintroduced species, feral predators, rabbits and fire. The remainder of the Ecohealth indicators are not monitored on an annual basis and, consequently, a number of Ecohealth surveys were not carried out in 2021.

Our survey programs indicate that the population sizes of Quenda and Woylies have remained stable and within an acceptable range. The population size of Common Brushtail Possum is also thought to be stable, despite a substantially lower population estimate in 2021 compared to previous years. The 2021 Possum Spotlighting Survey was impacted by poor weather conditions which affected detectability. Preliminary results from a survey conducted in early 2022, in more favourable conditions, indicate that the 2021 survey results were likely to be misleading and the population is stable. The population size of Tammar Wallabies has continued to decline since 2016 in response to management actions designed to address overabundance of the species. The current population size is not considered of concern.

As in previous years, the 2021 survey program failed to detect Western Ringtail Possums. The species was last recorded on Karakamia in 2017, and it is highly likely that it is no longer present on the sanctuary. The decline of Western Ringtail Possums at Karakamia may have been driven by the effects of climate change. The species is highly susceptible to extreme temperatures and to reduced nutritional quality of their preferred foliage caused by rainfall declines (Molloy et al 2014). The northern Jarrah forests are predicted to become unsuitable for Western Ringtail Possums under multiple climate scenarios (Molloy et al. 2014) and the

reintroduced population on Karakamia was the most northerly population of this species. A targeted survey is planned for 2022 to confirm the absence of Western Ringtail Possums on Karakamia.

The Black Cockatoo Survey conducted in 2020 confirmed the presence of the three threatened target species across 45% to 91% of survey sites. This survey was conducted as a trial in 2020, and the results will be used to develop a comprehensive survey, planned to commence in 2022.

The status of threat indicators monitored in 2021 was in line with management expectations. No cats, foxes or rabbits were detected, and no unplanned fires occurred. Overall, the results from the Karakamia Ecohealth monitoring program continue to reflect the positive effect of safe havens on population sizes of threatened mammal species and on reducing the impact of threats including feral predators and rabbits.

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