Karakamia Wildlife Sanctuary

Ecohealth Report 2020

australian wildlife conservancy

Summary

Australian Wildlife Conservancy (AWC) has implemented an Ecological Health Monitoring Program to measure changes in the status and trend of conservation assets, and threats to those assets, across Karakamia Wildlife Sanctuary (Karakamia). Metrics from the program are reported in annual Ecohealth Reports and Scorecards.

This is the Ecohealth Report for 2020. Metrics scores in this report were calculated from data collected during surveys carried out throughout 2020. The metrics are summarised in the accompanying Ecohealth Scorecard. This report provides a summary of the methodology and results of surveys pertaining to the Ecohealth Monitoring conducted at Karakamia.

Seven surveys designed to monitor extant and reintroduced species were conducted in this reporting period. Standard trapping surveys continue to provide robust data, allowing AWC to monitor ecological health. Results indicate that the status of key biodiversity indicators continues to improve or remain stable. Targeted surveys of reintroduced mammal species: Woylie (*Bettongia penicillata*); Quenda (*Isoodon fusciventer*); Tammar Wallaby (*Macropus eugenii*); and Koomal/ Common Brushtail Possum (*Trichosurus vulpecula*), indicate that population trajectories are within acceptable ranges and in line with expectations. In contrast, the Western Ringtail Possum was last recorded on Karakamia in 2017. This species has generally been declining from the north of its range, in response to hotter and drier conditions.

This period has seen the development and implementation of two new surveys; a comprehensive diurnal bird species survey, and a resource-use targeted Black Cockatoo species survey. Site occupancy of three black cockatoo species was reported: Red-tailed Black Cockatoo (*Calyptorhynchus banksia*), Carnaby's Black Cockatoo (*Zanda latirostris*), and Baudin's Black Cockatoo (*Z. baudinii*), all of which are listed as threatened under State (*Western Australian Biodiversity Conservation Act 2016*) and/or Federal (*Environment Protection and Biodiversity Conservation Act 1999*) environmental legislation. The diurnal bird survey recorded 48 terrestrial bird species.

There were no detections of feral cats, foxes or rabbits on Karakamia in 2020.

Contents

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Cover photographs: Photos from Karakamia Wildlife Sanctuary (clockwise from left): Carpet Python (*Morelia spilota*) (R Audcent/AWC), Field Ecologist Phoebe Dickens in action (M Smith/AWC), White-tailed Black Cockatoo (*Zanda sp.*) (M Smith/AWC), scene of Karakamia dam (C Jackson/AWC).

Introduction

Australian Wildlife Conservancy (AWC) owns, manages, or works in partnerships across 30 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 management. AWC's Ecohealth Monitoring Program has been 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). The program focuses on selected 'indicator' species, guilds, processes and threats, using metrics that are derived from data collected through a series of purpose-designed surveys.

The structure of the Ecohealth Program on each AWC property is as follows. Based on the guidance provided by AWC's over-arching program framework, above, Ecohealth Monitoring Plans are developed, describing the conservation values or assets of each property, and threats to these assets; and setting out the monitoring program that will be used to track the status and trend of selected indicators of these conservation assets and threats. 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, the Karakamia Ecohealth Report 2020, draws on surveys conducted during 2020 to calculate values for metrics that track the status and trend of the Ecohealth indicators. The companion Karakamia Ecohealth Scorecard 2020 presents these metrics in a summary format.

Karakamia Wildlife Sanctuary

Karakamia is within the traditional lands of the Noongar people. Karakamia (Noongar: 'home of the Red-tailed Black Cockatoo') was AWC's first property, 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, plus water bodies and riparian zones, all within a relatively small area (275 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.

The majority of Karakamia (250 ha) is surrounded by a conservation fence and has been free of cats and foxes since 1994. In the absence of cats and foxes, four mammal species have been successfully reintroduced to the property (Woylie or Bush-tailed Bettong, *Bettongia penicillata*; Quenda or Southern Brown Bandicoot, *Isoodon fusciventer*; Tammar Wallaby, *Macropus eugenii*; and Koomal or Common Brushtail Possum, *Trichosurus vulpecula*). Woylies are listed as Endangered nationally and Critically Endangered in Western Australia. As a result of this success three of these species have been used as source populations for reintroductions elsewhere (Woylie and Koomal to Mt Gibson Sanctuary; and Tammar Wallaby to Paruna Sanctuary). There have been small-scale or trial reintroductions of other species, including the Western Ringtail Possum, Numbat, Quokka and Water-rat. Of these, only the Western Ringtail Possum established a population on Karakamia, although high quality habitat for the species is limited in extent on the property.

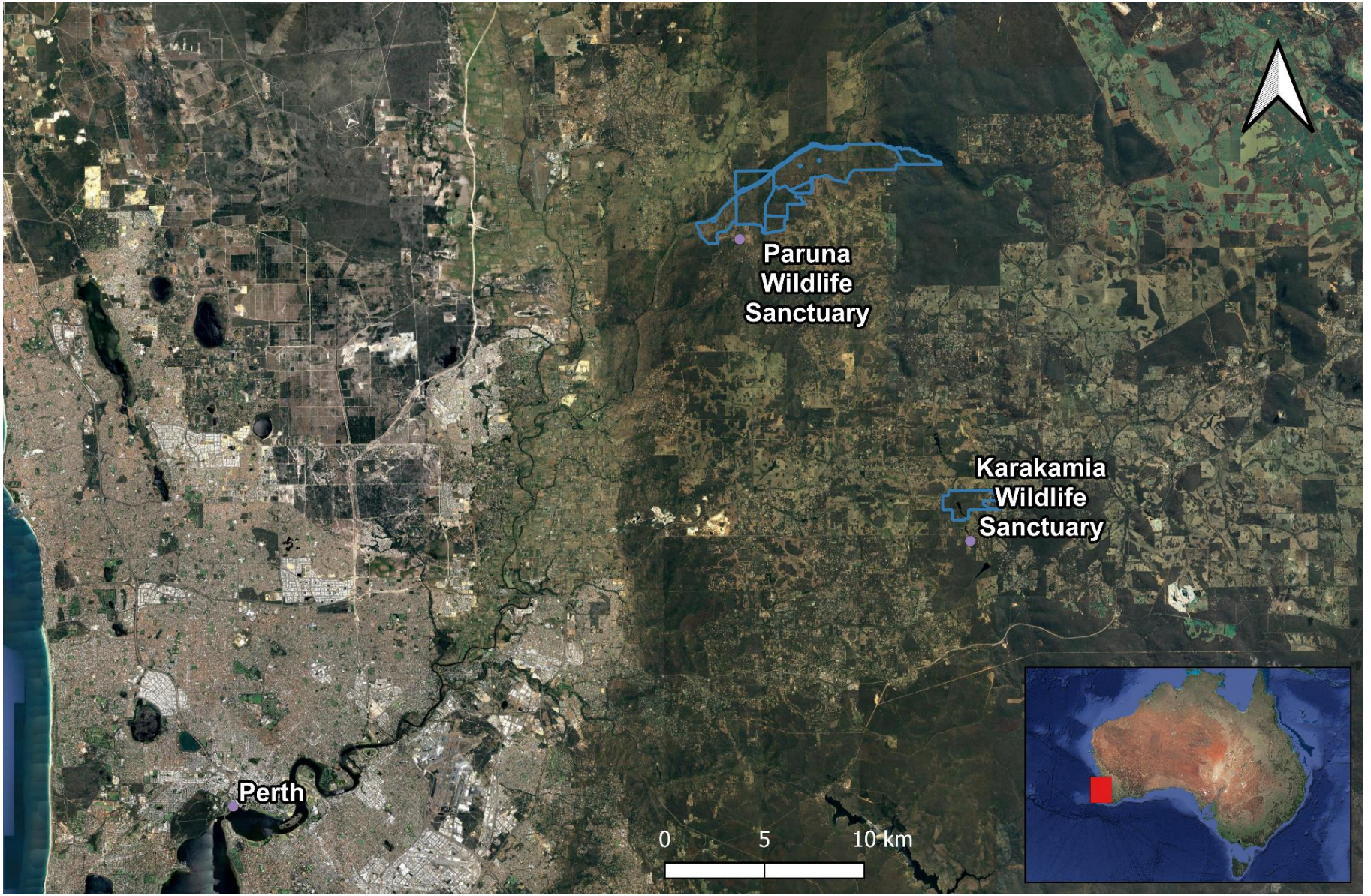

Figure 1. Location and regional context of Karakamia Sanctuary and Paruna Sanctuary. Inset indicates location within Australia.

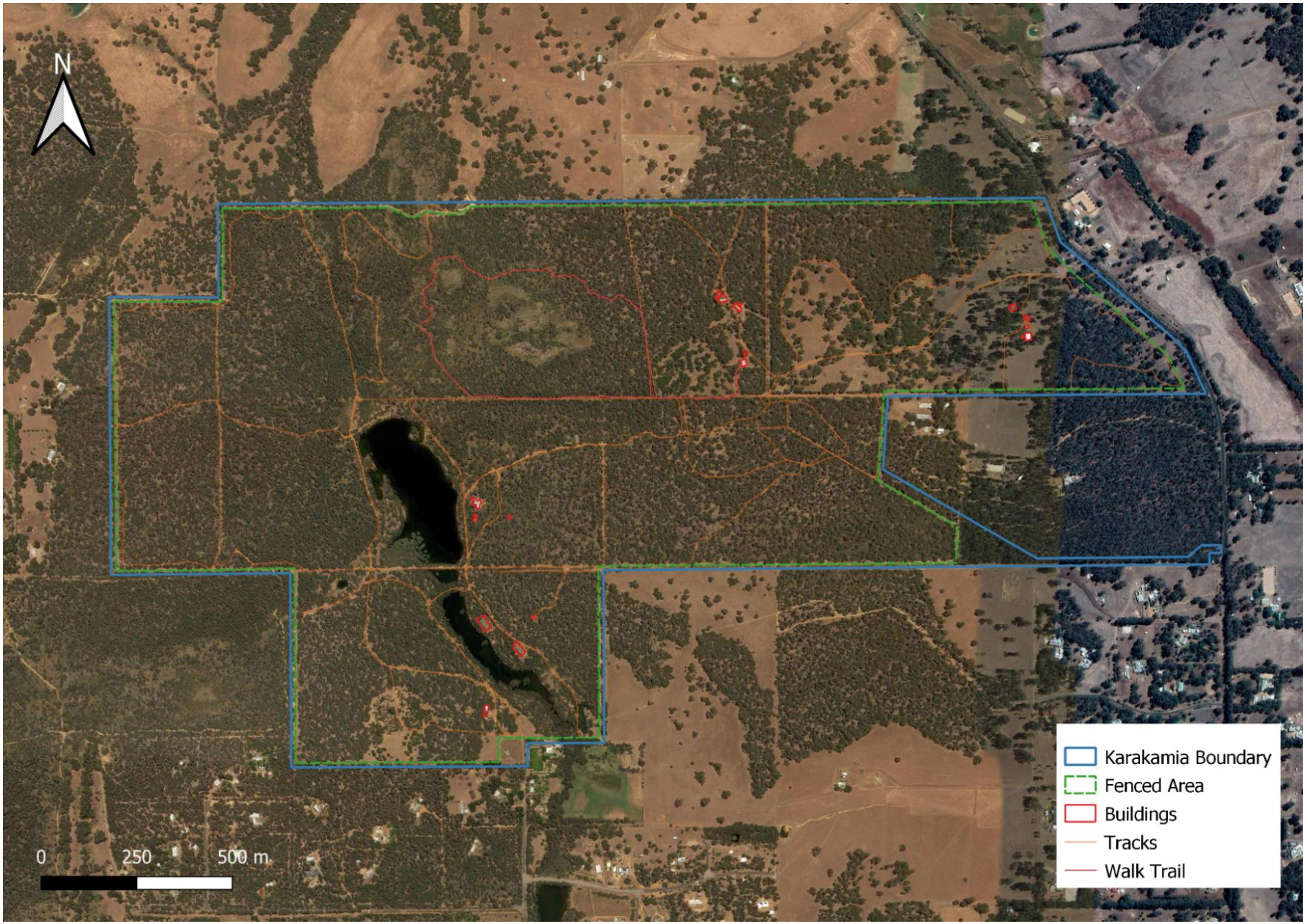

Figure 2. Aerial photo of Karakamia Sanctuary including major assets and infrastructure.

Climate and weather summary

Karakamia experiences a Mediterranean climate with warm, dry summers and cool, wet winters (Figure 3; Figure 4; Figure 5; Figure 6). Annual average maximum temperatures have been steadily increasing since 1902 (Figure 4), with the 2020 average maximum temperature (26.4°C) 1.0°C warmer than the preceding long-term average (25.4°C, 1900-2019).

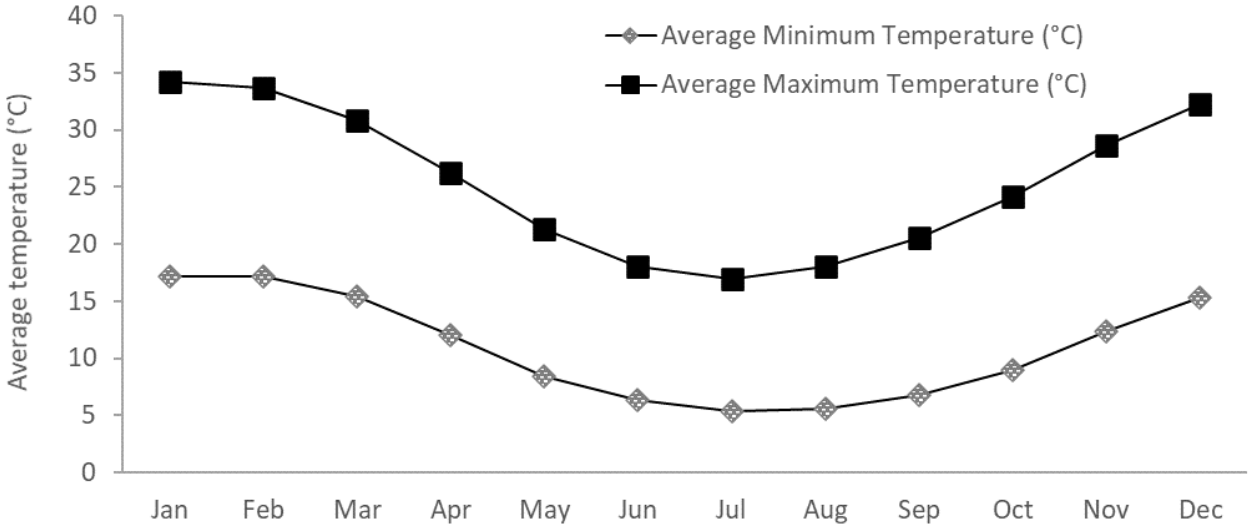

Figure 3. Mean minimum and mean maximum monthly temperature at Northam Monitoring Station (1902-2020) (BOM Station No. 010111). Source: BOM Climate Data Online.

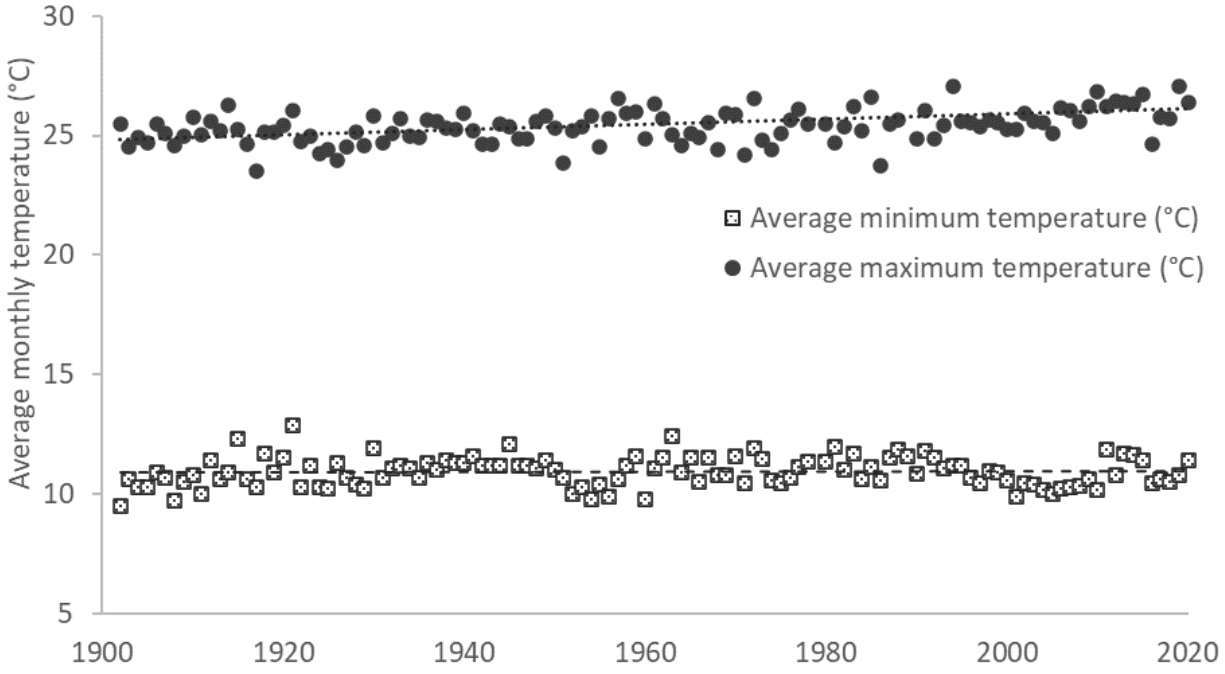

Figure 4. Mean minimum and mean maximum annual temperature at Northam Monitoring Station (1902-2020) with reference to long-term temporal trends in both metrics (dotted; mean maximum, dashed; mean minimum) (BOM Station No. 010111). Source: BOM Climate Data Online.

Total annual rainfall has steadily decreased since 1908 (Figure 5), and total monthly rainfall in 2020 was predominantly below average, particularly in winter months (Figure 6). In 2020, total annual rainfall (674 mm) was well below the preceding long-term average (797 mm, 1908-2019).

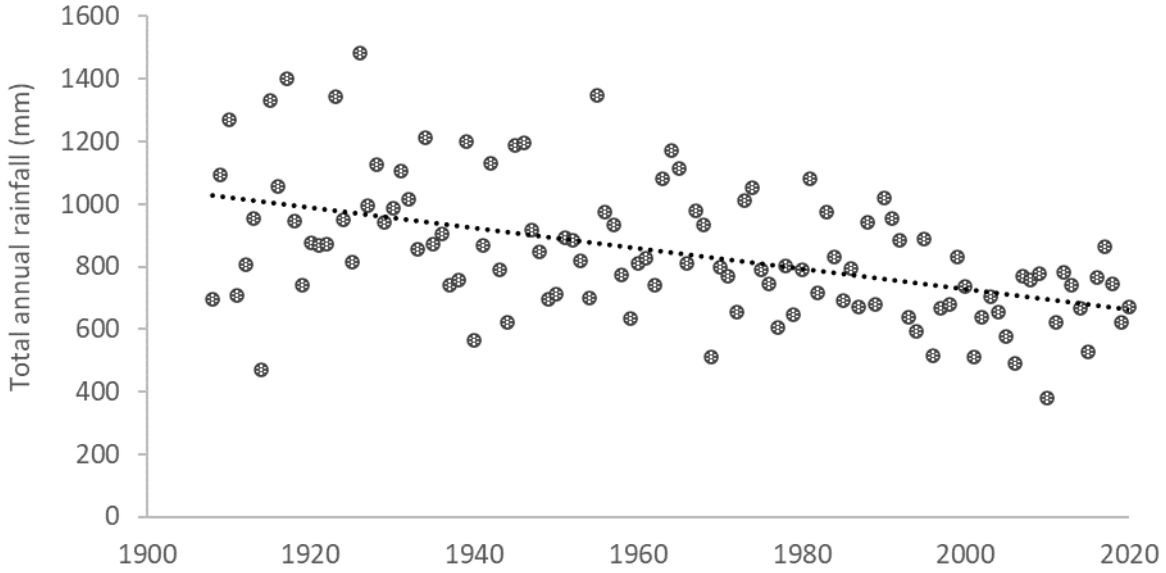

Figure 5. Total annual rainfall at Chidlow Monitoring Station (1908-2020) (BOM Station 009007). The dashed line indicates the long-term temporal trend of decreasing total annual rainfall. Source: BOM Climate Data Online.

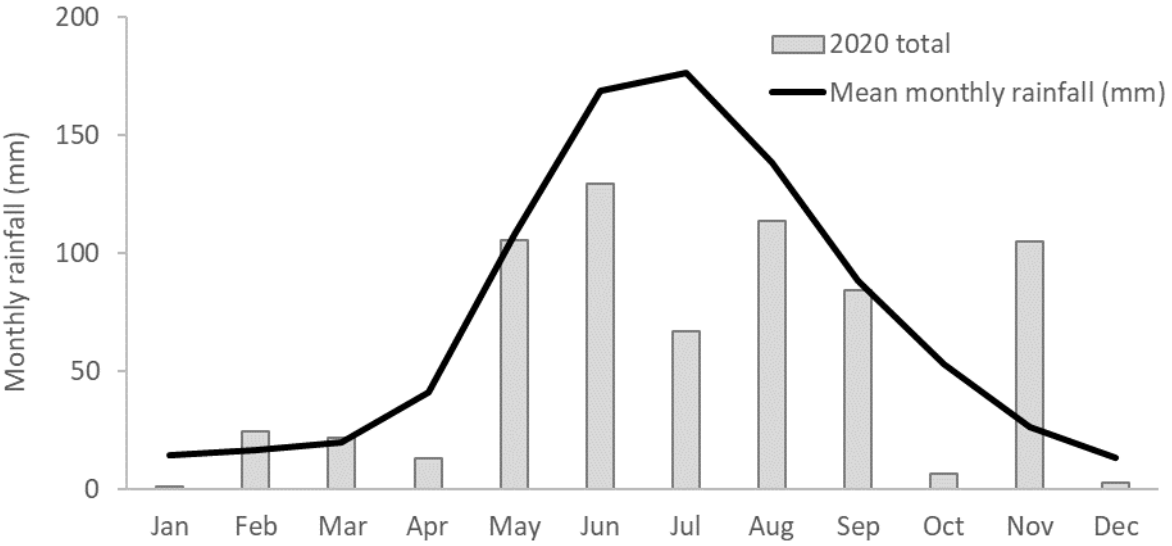

Figure 6. Mean monthly rainfall at Chidlow Monitoring Station (1908-2020) (BOM Station 009007) compared to total monthly rainfall in 2020. Source: BOM Climate Data Online.

Methods

Indicators and metrics

Karakamia's Ecohealth Monitoring Program has been designed to measure and report on the status and trends of species, ecological processes and threats on the sanctuary. The program focuses on selected biodiversity and threat indicators, using metrics derived from data collected through a series of purpose-designed surveys. A selection of species or guilds were chosen as biodiversity indicators which fit into one or more of the following categories: (1) declining and/or threatened species or guilds, (2) strong drivers of ecosystem function, or (3) are a member of the full range of taxa (to enable ongoing surveillance monitoring of a range of taxonomic groups to provide early warning of any unexpected declines).

There are 20 biodiversity indicators (species and guilds), of which 19 are reported on in 2020; the rationale for their selection is recorded in Table 1. Threat metrics are selected to ensure monitoring the status and trends of introduced predators and herbivores, and weeds. In 2020, 7 threat metrics are reported on (Table 2).

Table 1. Biodiversity indicators for the Ecohealth Monitoring Framework for Karakamia Wildlife Sanctuary. Rationale for selection: T = threatened, declining, vulnerable, or rare; D = strong driver of ecosystem function; S = surveillance monitoring. Metric definitions: population size = estimate of number of individuals in project area; occupancy = the proportion of sites where species detected; richness = number of species detected at each site.

Indicator	Rationale			Survey method	Metric/s
	T	D	S		
Mammals					
Reintroduced mammals					
Woylie (Brush-tailed Bettong) (*Bettongia penicillata*)	*	*		Cage traps (Mammal Survey)	Population size
Tammar Wallaby (*Macropus eugenii*)		*	*	Vehicle-based spotlighting transects (Tamar Wallaby Spotlighting Survey)	Population size
Common Brushtail Possum (Koomal) (*Trichosurus vulpecula*)		*	*	Walking spotlight survey (Koomal Spotlighting Survey)	Population size
Southern Brown Bandicoot (Quenda) (*Isoodon fusciventer*)		*	*	Cage traps (Mammal Survey)	Population size
Western Ringtail Possum (*Pseudocheirus occidentalis*)	*		*	Camera monitoring, walking spotlight survey (Western Ringtail Possum Camera Survey)	Occupancy
Small-medium mammals					
Short-beaked Echidna (*Tachyglossus aculeatus*)		*	*	Camera monitoring (Standard Trapping Survey)	Occupancy
Yellow-footed Antechinus (Mardo) (*Antechinus flavipes*)		*	*	Camera monitoring (Standard Trapping Survey)	Occupancy
Brush-tailed Phascogale (*Phascogale tapoatafa*)		*	*	Camera monitoring (Standard Trapping Survey)	Occupancy
Bats					

Indicator	Rationale			Survey method	Metric/s
	T	D	S		
White-striped Free-tailed Bat (*Austronomus australis*)		*	*	Acoustic recording (AudioMoth) (Methods under development)	Occupancy. Data under analysis
Reptiles					
Small-medium sized reptiles					
Buchanan's Snake-eyed Skink (*Cryptoblepharus buchananii*)		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Occupancy
South-western Orange-tailed Slider (*Lerista distinguenda*)		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Occupancy
Common Dwarf Skink *(Menetia greyii)*		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Occupancy
Marbled Gecko (*Christinus marmoratus*)		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Occupancy
Barking Gecko (*Underwoodisaurus milii*)		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Occupancy
Other reptiles					
King's Skink (*Egernia kingii*)		*	*	Camera monitoring (Standard Trapping Survey)	Occupancy
Bobtail (*Tiliqua rugosa*)		*	*	Camera monitoring (Standard Trapping Survey)	Occupancy
Birds					
Black-cockatoos					
Red-tailed Black Cockatoo (*Calyptorhynchus banksia*)	*	*		Seed survey (Black Cockatoo Survey)	Occupancy
Carnaby's Black Cockatoo (*Zanda latirostris)*	*	*		Seed survey (Black Cockatoo Survey)	Occupancy
Baudin's Black Cockatoo (*Zanda baudinii)*	*	*		Seed survey (Black Cockatoo Survey)	Occupancy
Other					
Terrestrial birds		*	*	Diurnal Bird Survey	Richness

Table 2. Threat indicators for Ecohealth Monitoring Framework for Karakamia Wildlife Sanctuary. Metric definitions: population size = estimate of number of individuals in project area; occupancy = proportion of sites where species detected.

Indicator	Rationale	Survey method	Metric/s
Introduced predators			
Feral cat (*Felis catus*)	Predation by cats is a major threatening process for many wildlife assets. Cats have been removed from Karakamia but monitoring for incursions is ongoing.	Camera monitoring (Feral Species Camera Survey)	Occupancy
Fox (*Vulpes vulpes*)	Predation by foxes is a major threatening process many wildlife assets. Foxes have been removed from Karakamia but monitoring for incursions is ongoing.	Camera monitoring (Feral Species Camera Survey)	Occupancy
Introduced omnivores			
Black rat (*Rattus rattus*)	Major threat to wildlife.	Camera monitoring (Standard Trapping Survey)	Occupancy
House mouse (*Mus musculus*)	Potential competition with native species, sustains populations of predators.	Camera monitoring; Pitfall traps; Funnel traps (Standard Trapping Survey)	Occupancy
Introduced herbivores			
Rabbit (*Oryctolagus cuniculus*)	Rabbits have been removed from Karakamia but monitoring for incursions is ongoing.	Camera monitoring (Feral Species Camera Survey)	Occupancy
Native herbivores			
Tammar Wallaby	When in high densities (population size > 300 individuals), grazing by Tammar Wallabies may constitute a major threatening process for wildlife assets (flora directly and fauna indirectly).	Spotlight survey (Tammar Wallaby Spotlighting Survey)	Population size
Fire			
Fire occurrence	Fire regimes are a key driver of vegetation composition, structure, and succession, and subsequently wildlife assets (food availability, nesting habitat).	Ground and/ or aerial mapping	Extent, by season • prescribed, late autumn- spring • wildfire (late spring-early autumn)

Survey type and history

To report on the Biodiversity and Threat Indicators, our survey teams conduct a variety of surveys over a period of 1-5 years. AWC established the Feral Predators Survey in 2014, shortly followed by the Standard Trapping Survey and Mammal Survey in 2015. Other components of the Karakamia Ecohealth monitoring program have been added in subsequent years. The following surveys were undertaken in 2020:

- Standard Trapping Survey;
- Diurnal Bird Survey;
- Mammal Survey;
- Tammar Wallaby Spotlighting Survey;
- Koomal Spotlighting Survey;
- Western Ringtail Possum Camera Survey;
- Black Cockatoo Survey; and
- Feral Species Camera Survey.

The surveys conducted in 2020 and associated effort and history are outlined in Table 3. The methodology is described, and results of these surveys are reported on in this document.

Table 3. Survey effort for Ecohealth Monitoring Program surveys on Karakamia Wildlife Sanctuary in 2020

Survey name	2020 Effort	Description/comment	Survey history
Standard Trapping Survey	1,144 trap nights (live-trapping) 1,120 trap nights (camera trapping)	8 trapping sites surveyed for four consecutive days with 8 pitfall, and 12 funnel traps (excluding one night in which pitfall traps were closed due to rain; and occasional pit closures due to ants etc); and 40 camera traps deployed across 10 sites over 28 consecutive days (4 cameras per site). Stratified to cover a range of geography and major vegetation types.	2015, 16, 17 – 9 sites 2018 – 11 sites 2020 – 8 sites (live trapping), 10 sites (camera)
Diurnal Bird Survey	48 surveys	11 standard trapping sites (+1 additional dam site) surveyed for four consecutive days, 20 minute 2-ha surveys around dawn.	2020 = 11 sites
Reintroduced Mammal Survey (Woylie, Quenda)	1,036 trap nights	66 sites (264 traps) surveyed for three - four nights, recording all captures and processing a subset of individuals.	2015-20, annually – 66 sites
Tammar Wallaby Spotlighting Survey	36 surveys	8* track-based fixed transects surveyed for four consecutive nights, spotlighting from a moving vehicle.	2016, 17, 18, 19 – 9 sites 2020 – 8 sites
Koomal (Brushtail Possum) Spotlighting Survey	128 surveys	32 track-based fixed transects surveyed for four consecutive nights, spotlighting on foot.	2018, 19, 20 – 32 sites
Western Ringtail Possum camera survey	531 trap nights	98 camera traps deployed in a grid network across the sanctuary. Cameras active for 13-14 days (site-dependent).	2020 = 98 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	10 cameras deployed all year.	2014-20, annually – 10 sites

Survey design and methods

Following the completion of the reintroduction programs, survey efforts have targeted monitoring the size of each reintroduced population. Additional surveys conducted as part of the Ecohealth Monitoring program include a Standard Trapping Survey program and bird surveys (e.g., seed chew-mark monitoring, and 2-ha searches).

Mammals

Reintroduced Mammal Trapping Survey (Woylie, Quenda and Koomal)

Mammal cage trapping is used to monitor population size of reintroduced Woylies, Quendas and Koomal.

Trapping sites (n = 66) are located every 200 m along tracks within the sanctuary. The trapping sites are divided into three transects (Figure 7). 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 summer. At each site, four cage traps (placed approximately 5 m apart) were positioned under/next to sheltering vegetation. A hessian sack was placed over each trap. All traps were opened and lured with universal bait (peanut and oats). Traps were opened in the late afternoon and checked before dawn the following morning. Due to the high volume of captures, minimal animal processing and morphometric data collection was undertaken (i.e. microchip, sex, and reproductive condition), with only a subset of each species (15 male and 15 female adults) processed fully (additional morphometric measurements, body weight and pes length) to obtain demographic data.

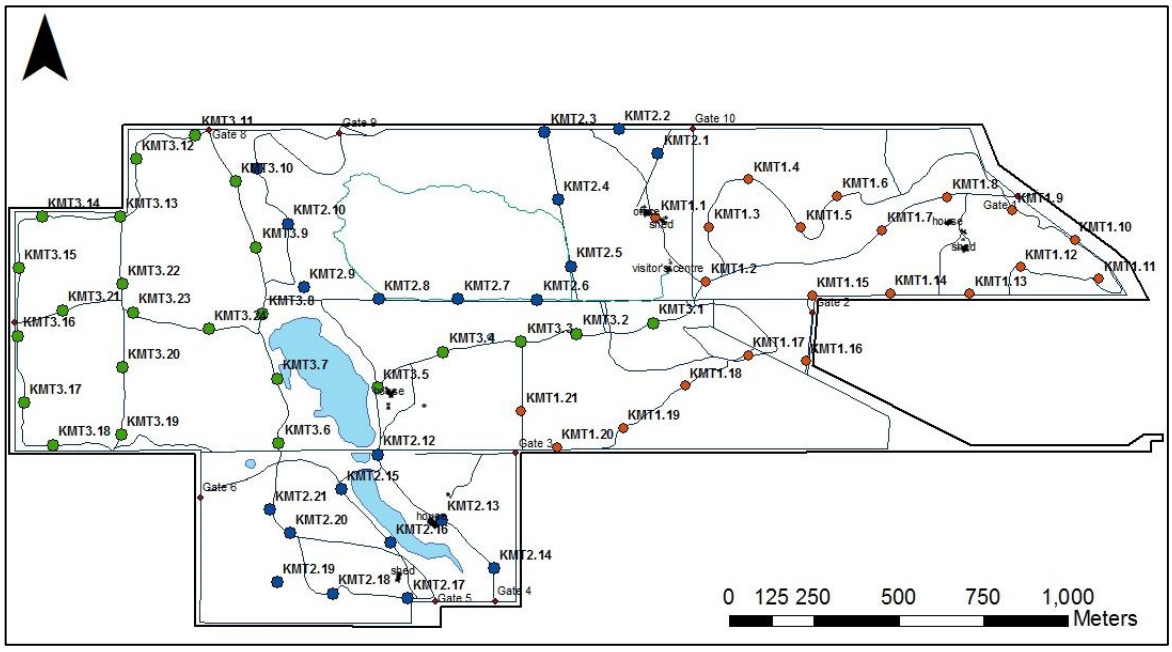

Figure 7.Reintroduced mammal trapping sites on Karakamia. Coloured circles denote trapping sites, and each colour denotes a trapping transect.

Tammar Wallaby Spotlighting Survey

Tammar Wallaby populations at Karakamia are monitored with an annual spotlight survey. Surveys are conducted along nine fixed transects of varying lengths; two transects are located in the paddocks and seven in other 'bush' (non-paddock) habitats (Figure 8).

In January 2020, spotlighting was conducted over four nights at the nine track-based transects. One hour after sunset, the bush transects (1 – 7) were driven by vehicle at 5 – 10 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 are excluded from analyses.

The 'paddock' transect was 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 spot-lighters. Particular care was taken to ensure individuals are not counted more than once. The distance of the Tammar Wallabies from the track is not collected on the paddock transects.

The Tammar Wallaby spotlighting survey generates population estimates that inform management of the wallaby population. The lack of predation and periodically high availability of food can enable Tammar Wallabies to become abundant on Karakamia, which may result in overgrazing, with potential impacts on vegetation and Woylies, and with animal welfare issues for the wallabies (Smith et al. 2020).

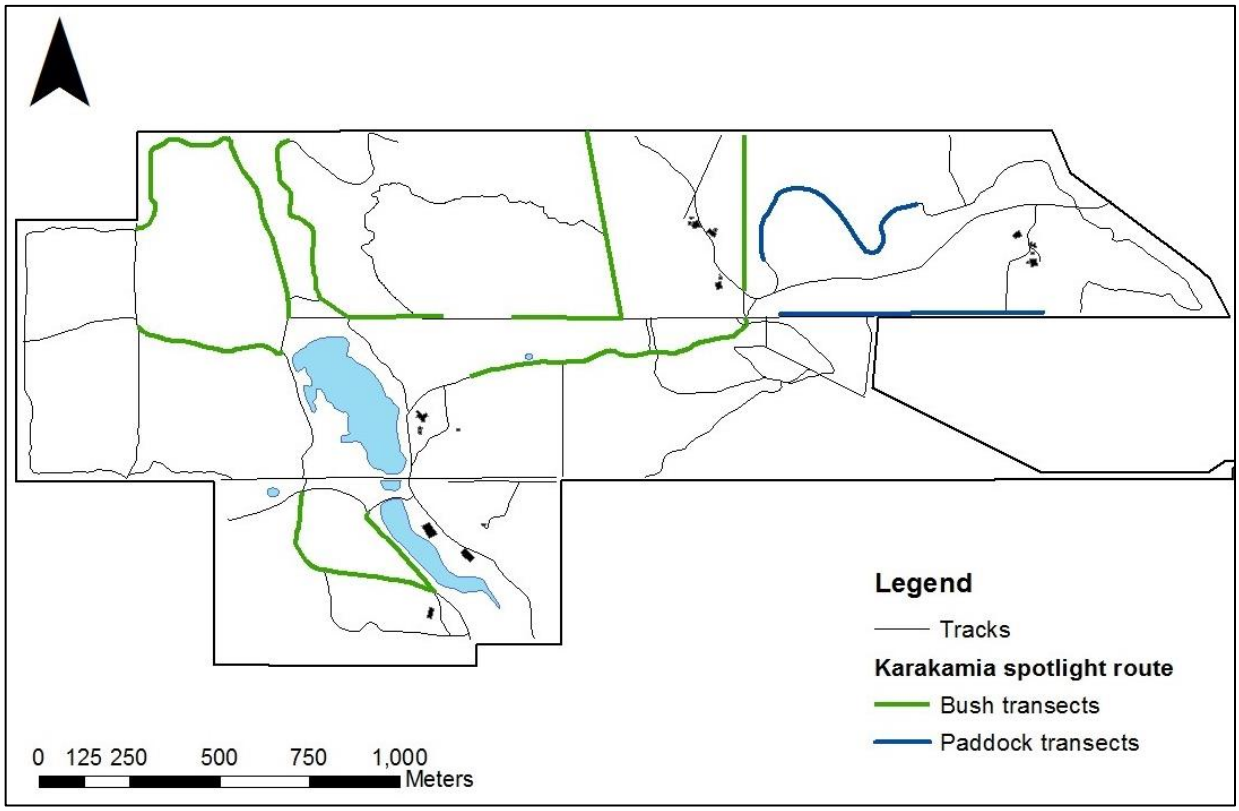

Figure 8. Tammar Wallaby spotlight survey transects on Karakamia. Green lines denote 'bush' transects' and blue lines, 'paddock' transects.

Koomal Spotlighting Survey

Koomal populations at Karakamia are primarily monitored via an annual spotlight survey. The survey comprises 32 track – based fixed transects, categorised by habitat type: paddock, Jarrah, riparian, or Wandoo-Marri; and transect type: road or 'off road' (Figure 9).

Spotlighting was conducted over four consecutive nights (i.e., a repeat survey distance sampling survey design; Chandler 2020). 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 between 5 m and 12 m in height and on the ground. Walking pace was modified depending on canopy density, to ensure a thorough search.

Distance sampling data was collected upon each possum sighting. Observer location, distance, and angle from observer were used with transect coordinates to calculate each observed animal's perpendicular distance from the transect. Each transect was categorised as: road or bush; and paddock or other vegetation type (Jarrah Forest, Marri-Wandoo woodland and riparian).

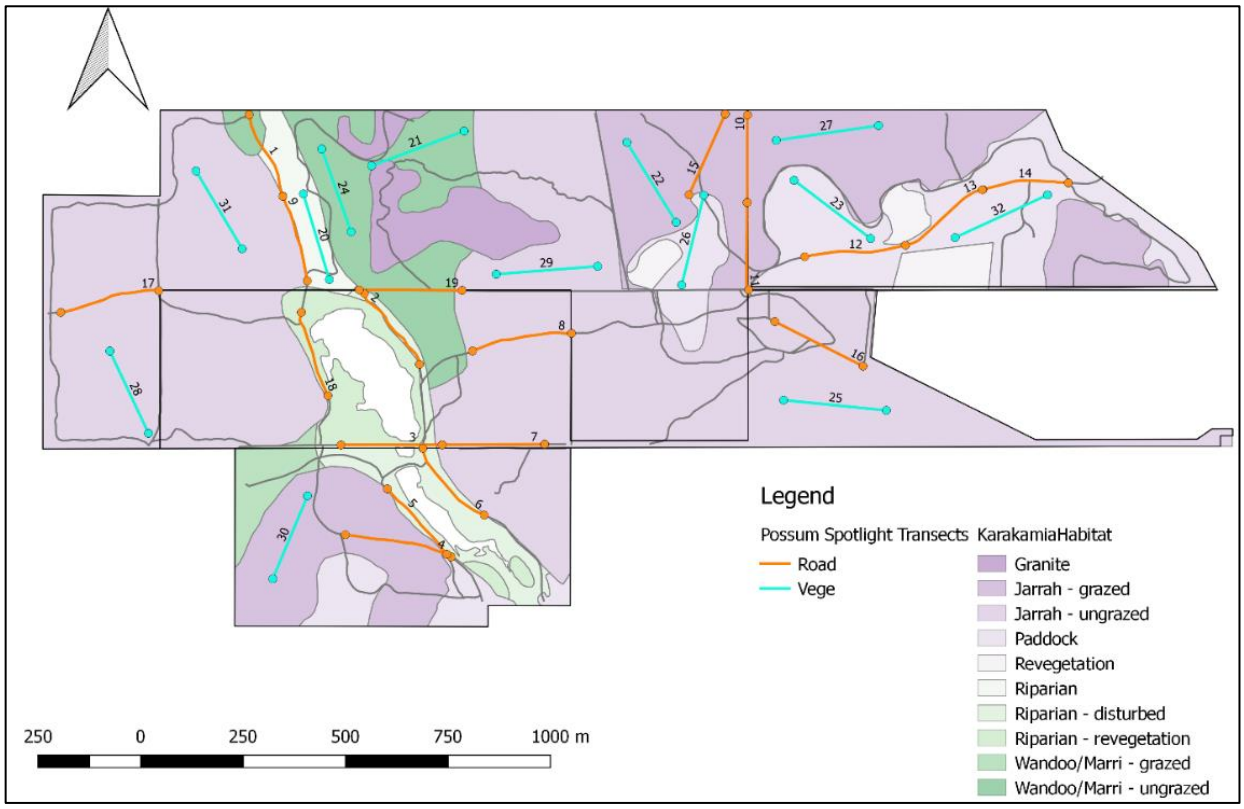

Figure 9. Koomal (Brushtail Possum) monitoring transects on Karakamia. Transects are stratified by road (orange)/vegetation (blue), and habitat type.

Western Ringtail Possum Camera Survey

Western Ringtail Possum persistence at Karakamia Sanctuary was monitored in 2020 with a comprehensive camera trapping survey. Camera traps (n=98) were deployed across Karakamia Sanctuary in November 2020 and remained in-situ for two weeks. These included sites within riparian and Wandoo-Marri vegetation types, and the remaining 64 sites were distributed as a grid throughout the Jarrah woodland and revegetation (Figure 10). Paddock areas were excluded.

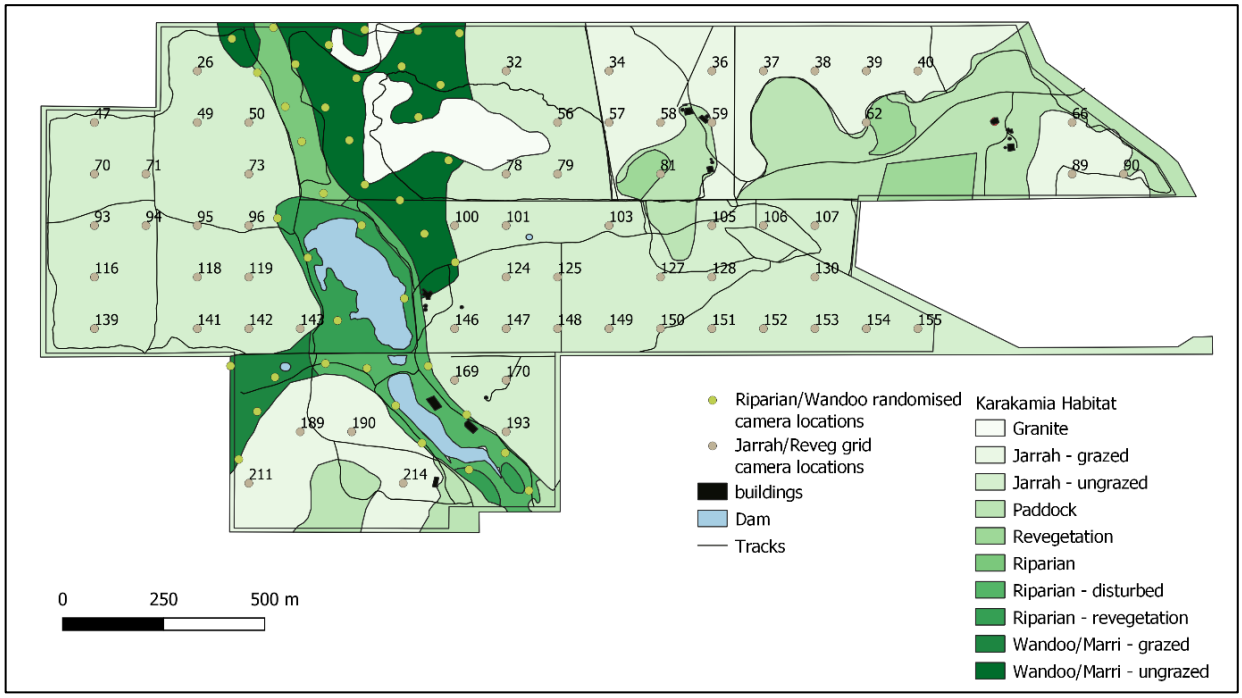

Figure 10. Western Ringtail Possum camera monitoring sites on Karakamia.

Camera traps were deployed in trees, or on raised fallen logs/branches and faced out along a horizontal branch/log. Cameras were lured with a cannister containing a rag soaked with rose-geranium and

peppermint-eucalyptus oils. Cannisters were secured to a horizontal branch 1 – 1.5 m from the camera. Cameras are programmed to take 3 images per trigger with no quiet period between triggers.

Small Mammals and Reptiles

Standard Trapping Survey

The Standard Trapping Survey for small mammals and reptiles occurs biennially on Karakamia. A stratified (by vegetation type) sampling design was used to establish 11 sites (Figure 11), situated across five major vegetation types: Granite heath (n = 1), Jarrah woodland (n = 5), Wandoo-Marri woodland (n = 1), paddock (n = 3), and Riparian vegetation (n = 1). Sites are separated by a minimum of 250 m. Two sites (sites 10 and 11), in granite heath and riparian vegetation, respectively, are not suitable for pitfall trapping. At these sites, field work is constrained to camera trap surveys.

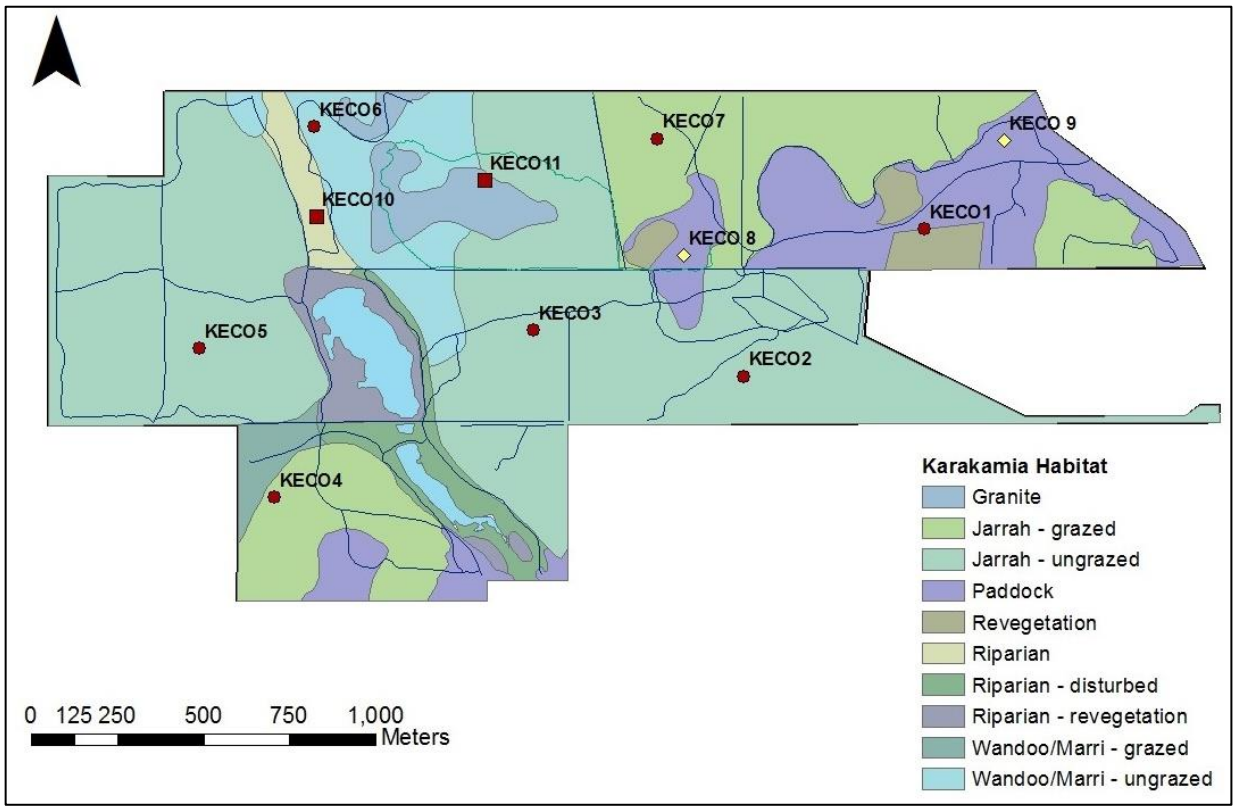

Figure 11. Location of 11 Standard Trapping Survey sites on Karakamia. Sites denoted by yellow diamonds were established in 2018; Red squares indicate sites with camera surveys only.

Each survey site constituted a 1-ha area (100 m x 100 m). Sites 1 to 9 consisted of two trapping arrays, each with four pitfall traps, six funnel traps, and two camera traps (Figure 12). Cameras were also deployed at the two sites (10 and 11) not suitable for pitfalls. At these sites, four lured, horizontal cameras were deployed at 50 m intervals (Figure 13). Cameras are programmed to take 3 images per trigger with no quiet period between triggers and remain in-situ for three weeks.

Trapping arrays contained 30 m of drift fence in a T – shape. All pitfall and funnel traps were open throughout the night and following day during the four-day survey period.

After four nights of live trapping, all traps were closed, and sites were set up for camera trapping as follows: a small gap is created in the drift fence at the centre of both 'T's. A cork tile is placed into the gap and a camera is placed 'horizontally' above the cork tile (Figure 14). A second, lured (sardines) 'vertical' camera is placed within each 'T'.

Inclement weather was experienced during the 2020 survey and pitfall traps were closed for one night. Site 5 was not opened due to rain and the risk of spreading dieback from this infected area.

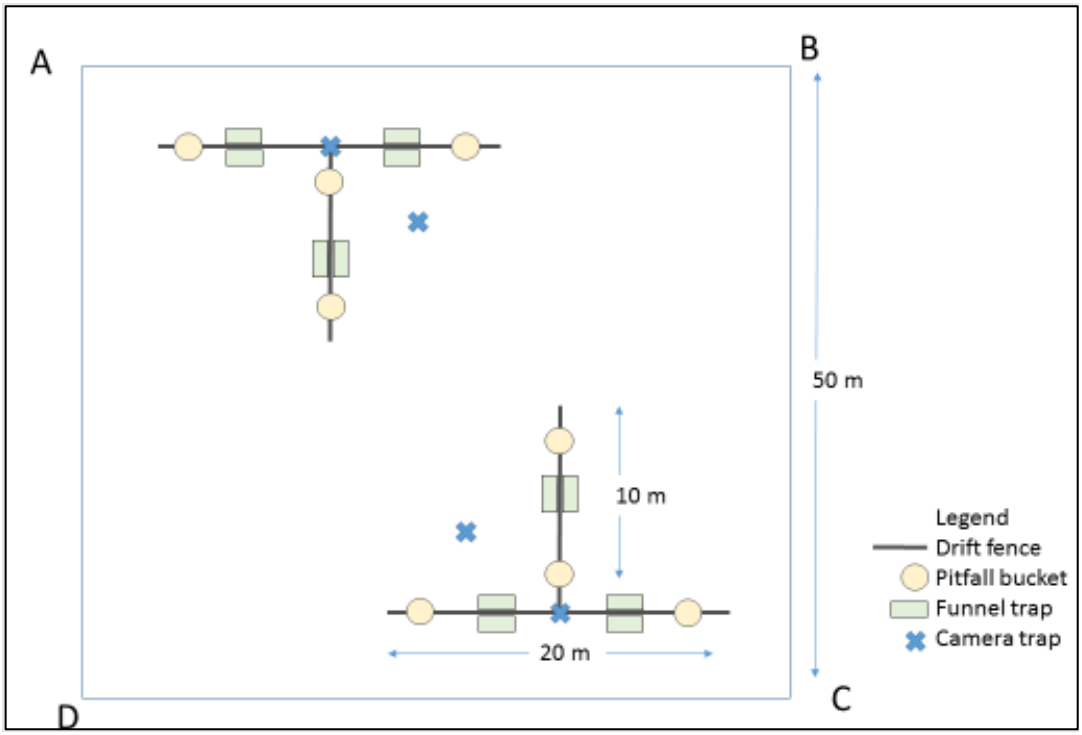

Figure 12. Design of Standard Trapping Surveys for Ecohealth monitoring on Karakamia

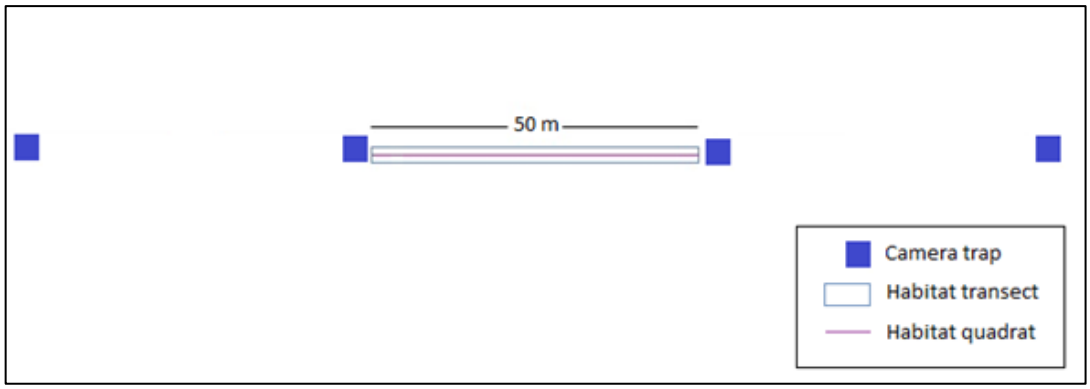

Figure 13. Design of Camera Trap surveys on two sites unsuitable for pitfall trapping on Karakamia

Figure 14. Positioning of the camera trap and cork tile placed at the centre point of the pitfall trapping arrays. The drift fence has been pulled back from the centre point to allow the placement of the cork tile.

Birds

Diurnal Bird Survey

Diurnal Bird Surveys were conducted at the 11 survey sites described above, with an additional site at a dam to survey water birds (Figure 15). Bird surveys are conducted biennially, in September/October, and are repeated over four days.

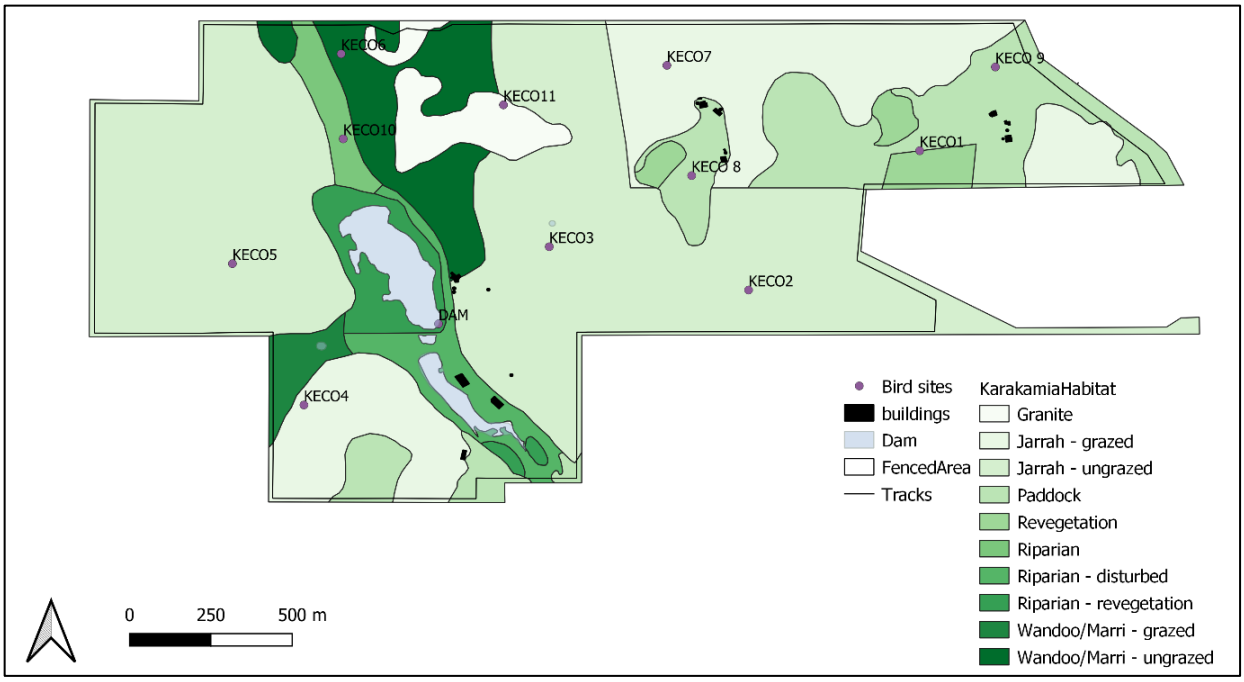

Figure 15. Location of bird monitoring sites on Karakamia

Bird surveys followed the 2-ha 20-minute search standard (Loyn 1986) consistent with BirdLife Atlas survey methods using a circular area with a radius of 80 m (Figure 16). Observers spent 20 minutes meandering throughout the site, always remaining within 80 m of the centre point. All bird species observed during the 20 minutes were recorded along with the method of observation (seen, heard or flyover).

The survey was conducted over four days by three teams, consisting of at least one AWC ecologist. Surveys commenced at dawn. The primary surveyor changed sites each day to minimise observer bias. The 11 sites were surveyed each day in a prescribed order, with the order of sites reversed every second day to minimise possible time-of-day or temperature bias.

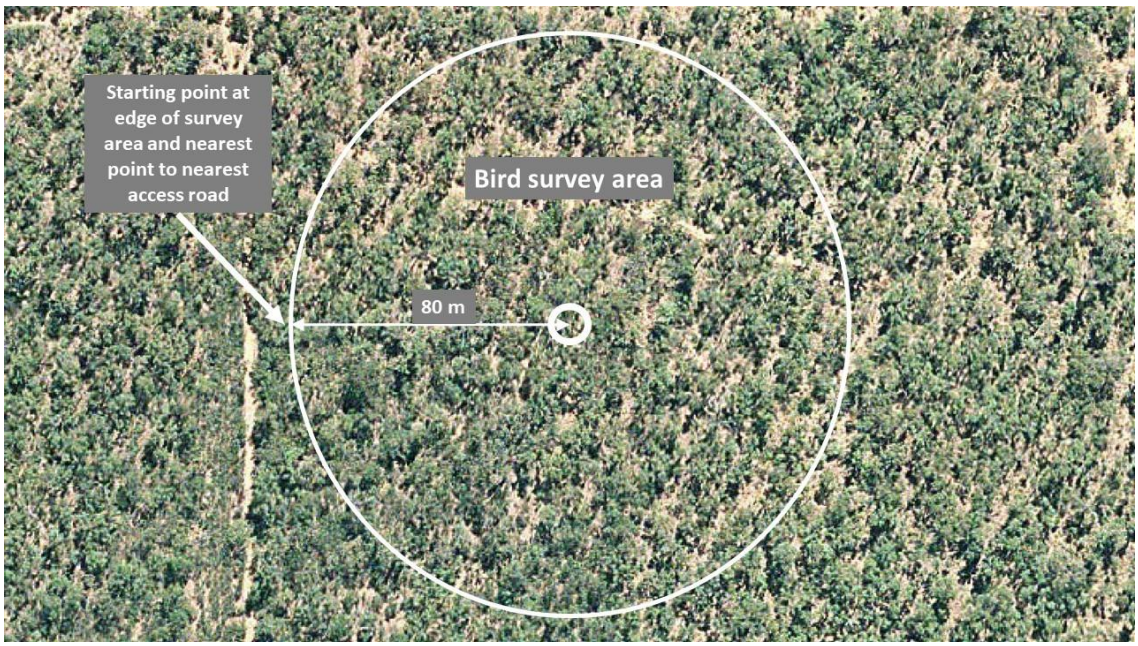

Figure 16. The standardised 2-ha Diurnal Bird Survey site layout

Black Cockatoo Survey

Eleven survey sites situated near water bodies and potential seeps throughout Karakamia were surveyed for black cockatoos, based on feeding sign (Figure 17). Black cockatoo surveys occur four times within a year (once per season), every second year. Acoustic surveys were also conducted at these sites, however analysis of acoustic are still under development and results are not presented in this report.

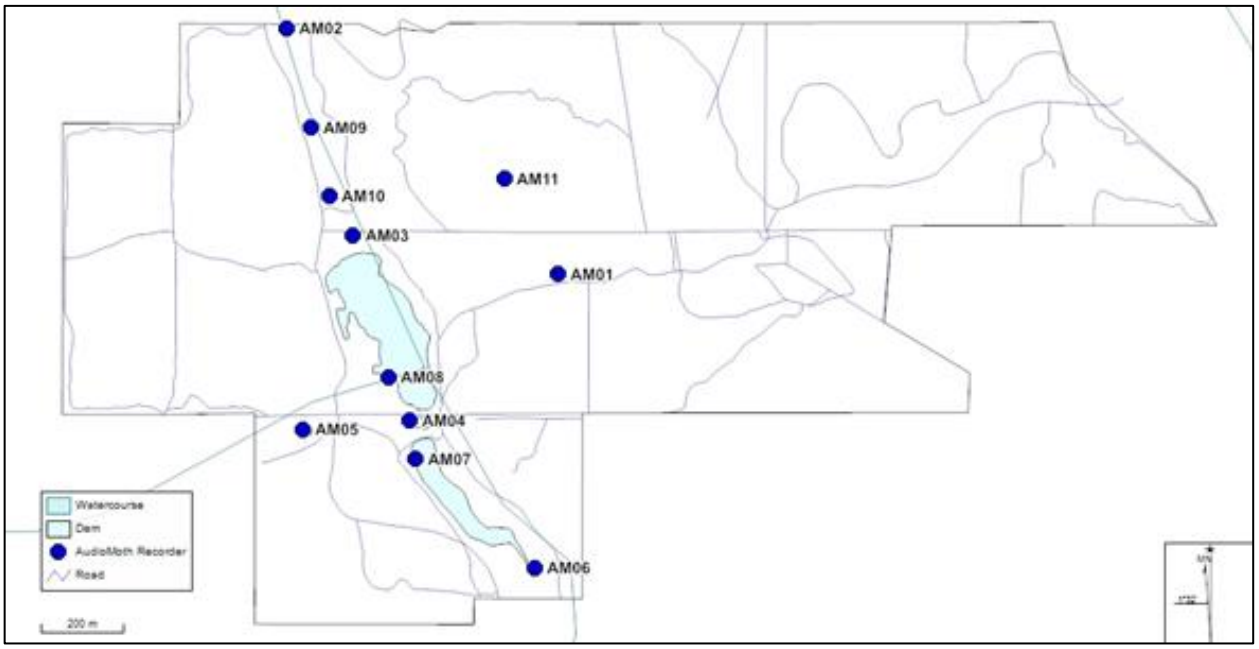

Figure 17. Black cockatoo monitoring sites

The objective of this survey is to confirm the occupancy of, and habitat use by, threatened black cockatoos (Forest Red-tailed Black Cockatoo, Baudin's Black Cockatoo and Carnaby's Black Cockatoo) at sites by searching for Marri nuts with distinctive feeding signs.

A search was undertaken for Marri nuts on the ground in an area within about 50 m of the frog and bat acoustic monitoring site and examined for signs of feeding by black cockatoos. Differences in mandible size between the species produce noticeably different feeding marks, which were examined to determine a species' presence (Figure 18; 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 are recorded, as was the freshness of the nuts (green, red/brown, brown/grey).

Feral Species Camera Survey

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

Fire

Karakamia Sanctuary has been subdivided into 24 fire management units. An annual burn plan was developed for 2020 with prescribed burning for asset and infrastructure protection and biodiversity conservation.

Figure 18. Marri nuts with distinctive feeding markings present.

Analysis methods

Reintroduced Mammal Survey (Woylie and Quenda)

Population size estimates were generated from Mammal Survey data 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). A Binomial encounter model was used with density, detection, and space use modelled for the different sexes. Detection was also modelled with a covariate to account for 'trap happiness' (Sutherland et al. 2019).

Standard Trapping Survey (live-trapping and camera monitoring)

Live trapping data and camera detections were used to calculate occupancy as the proportion of sites at which each species was detected.

Diurnal Bird Survey

Data from terrestrial bird surveys (2 ha plots) was used to calculate the richness, the average number of species detected at each site and across all sites during the four-day survey period.

Tammar Wallaby Spotlighting Survey

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.

Koomal Spotlighting Survey

Population size was estimated from the Koomal Spotlighting Survey data with temporally replicated distance sampling (Chandler 2020). Models with different combinations of abundance and detection sub models were run and compared (using AIC) within R software (R Core Team 2013) using package Unmarked (Fiske and Chandler 2011). A negative binomial mixture function for abundance and an exponential detection function was the most supported model formulation; however, this method produced population estimates with exceptionally large confidence bounds, and a revised methodology may be used in future.

Western Ringtail Possum Camera Survey

Prior to 2017 Western Ringtail Possums were detected during targeted camera trap surveys and were observed during targeted spotlighting surveys. Following several years of nil detections or observations (targeted sanctuary-wide camera trap survey in 2018 and grid surveys around potential sighting locations in 2018 and 2019), the 2020 sanctuary-wide camera trap survey attempted to determine current occupancy (proportion of sites detected).

Black Cockatoo Survey

Occupancy for black cockatoos was calculated as the proportion of sites where feeding signs were detected for each species.

Fire

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

Biodiversity indicators

Reintroduced mammals

Woylie

The Woylie population has remained relatively stable over the period 2016 to 2020, after a slight decrease in between 2017 and 2018 (Figure 19). The 2020 total population estimate was 199 individuals.

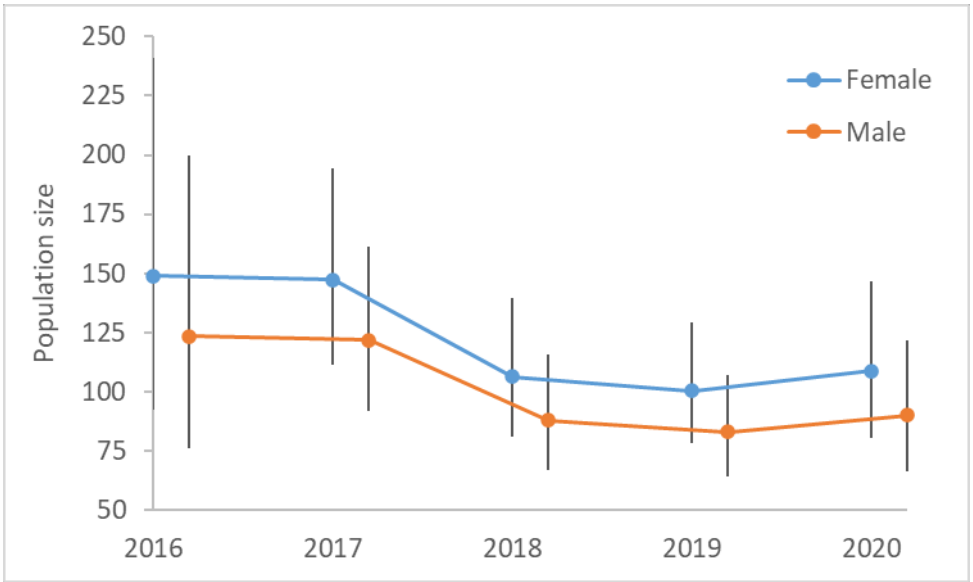

Figure 19. Population estimates of Woylies at Karakamia, 2016-2020.

Quenda

The number of Quenda has gradually increased since 2016 (Figure 20). In 2020, the total population was estimated to be 162 individuals.

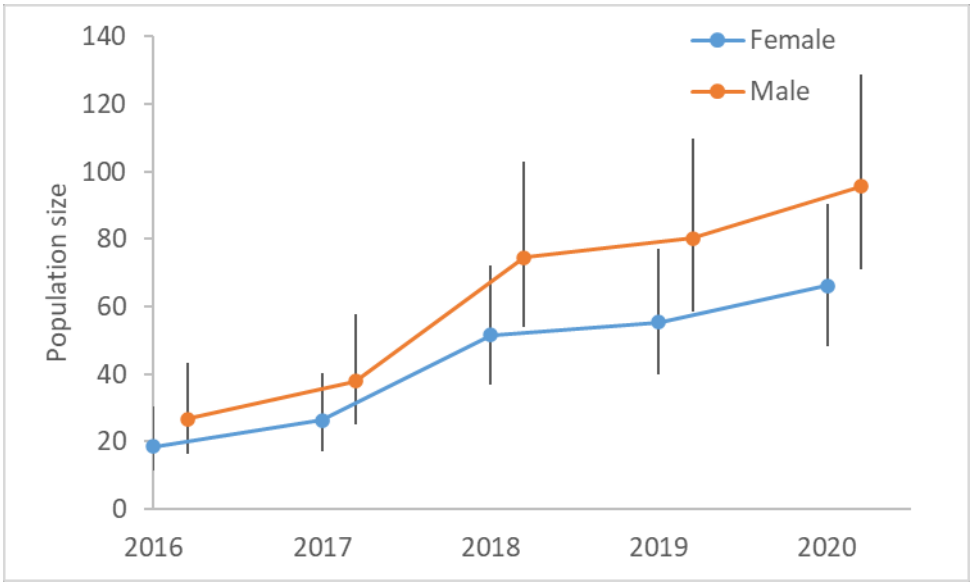

Figure 20. Population estimates of Quenda at Karakamia, 2016-2020

Koomal

In 2020, a population estimate of 247 was derived based upon spotlighting survey data. This estimate has large confidence bounds (52 to 1,318) indicating that the estimate currently lacks interpretive power. To derive more robust population estimates in future, we may increase number of replicate surveys, and/ or use a different method of analysis less affected by modelled detectability (e.g., strip transects).

Tammar Wallaby

The Tammar Wallaby population has decreased substantially since 2016 (2020 population estimate = 259, Figure 21), following targeted management actions by AWC. The current population size is below the threshold of 300 individuals which would trigger a management response (Smith et al. 2020).

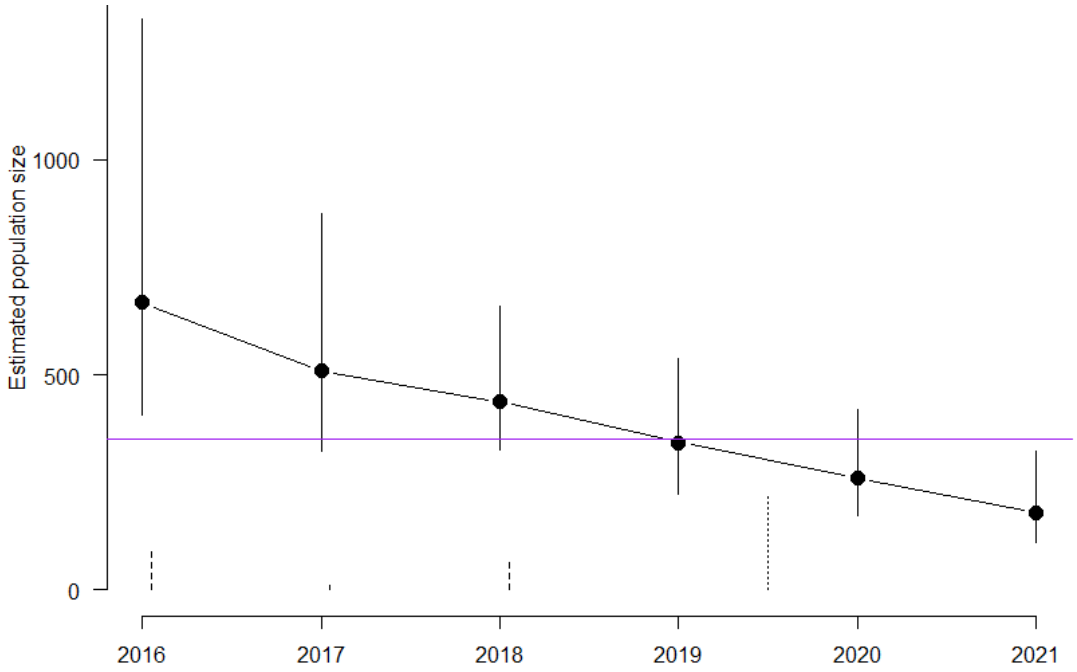

Figure 21. Population trend of Tammar Wallabies at Karakamia from 2016-2021. Purple line = management threshold (n = 300). Dashed vertical lines = number of animals removed from property.

Western Ringtail Possums

Despite extensive camera surveys, no Western Ringtail Possums were detected in 2020. Between 1995 and 2012, 55 Western Ringtail Possums were reintroduced to Karakamia Sanctuary. Detections of the possums have declined in recent years, with the last confirmed sighting in 2017 during a targeted camera trapping survey. Based on these results, the species may be locally extinct on Karakamia, or at least is at very low abundance. AWC will continue to conduct surveys for the species, using a variety of methods.

Extant small-medium Mammals

Camera trap results indicate that the occupancies of the Ecohealth indicator species Echidna and Mardo (Yellow-footed Antechinus) have remained reasonably stable over the period 2016 to 2020 (Figure 22). Brush-tailed Phascogales have experienced an increasing trend in occupancy since 2016.

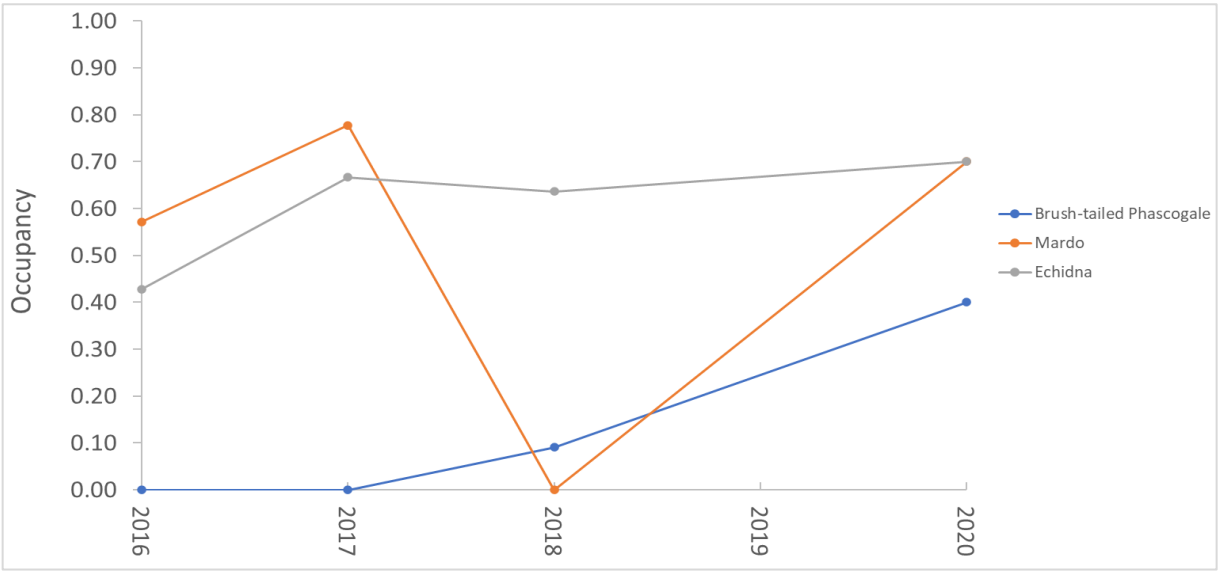

Figure 22. Proportion of sites where Echidna, Mardo and Brush-tailed Phascogale were detected, 2016-2020

Reptiles

The proportion of sites detected by camera traps (occupancy) for select reptile indicator species (Bobtail and King's Skinks) is presented in Table 4. Despite low captures in 2020 due to inclement weather, pitfall trap results for small reptiles (diurnal and nocturnal) indicate that site occupancy for most common reptile species has remained largely stable over the period 2015 to 2020 (Figure 23). Occupancy of two indicator species: Buchanan's Snake-eyed Skink and South-western Orange-tailed Slider, remain relatively high and stable. Occupancy of the Common Dwarf Skink displays oscillations for the period 2015 - 2020 but is overall stable and relatively high. The nocturnal small reptile indicator species, Marbled Gecko and Barking Gecko, were not trapped during the 2020 survey, likely due to the unfavourable weather conditions.

Table 4. 2020 Ecohealth reptile metrics

Indicator	Occupancy
Small Reptiles (diurnal)	
Buchanan's snake-eyed skink	0.38
South-western Orange-tailed Slider	0.63
Common Dwarf Skink	0.25
Small reptiles (nocturnal)	
Marbled Gecko	0.00
Barking Gecko	0.00
Large Reptiles (diurnal)	
King's Skink	0.09
Bobtail	0.27

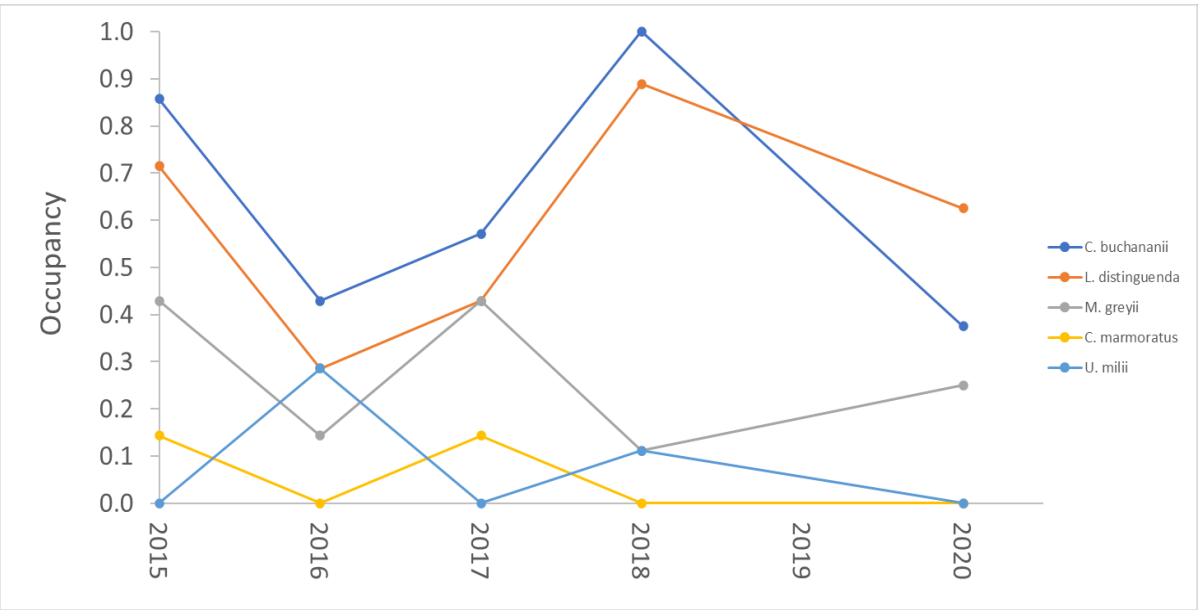

Figure 23. Proportion of sites detected (occupancy) for five Ecohealth indicator species in pitfall surveys, 2015-2020. Data presented for Buchanan's snake-eyed Skink, South-western Orange-tailed Slider, Common Dwarf Skink, Marbled Gecko and Barking Gecko

Birds

Terrestrial Diurnal Birds

A total of 48 bird species were detected during diurnal bird survey (Appendix 1, Table 6). An average of 7.27 species were detected across the 12 sites over four days. Most commonly detected species were predominantly the small passerine birds within the Families Acanthizidae (warblers, gerygones, thornbills), Meliphagidae (honeyeaters), Pachycephalidae (whistlers), Pardalotidae (pardalotes), Rhipiduridae (fantails) and Zosteropidae (white-eyes). Larger psittacine birds were similarly detectable, including species from the Families Psittaculidae (Australian Ringneck) and Cacatuidae (Black Cockatoo spp., Galahs).

Black Cockatoos

Evidence of feeding upon Marri nuts was detected for all three Black Cockatoo species. Forest Red-tailed Black Cockatoos were the most abundant and detected at 91% of sites (Table 5).

Table 5. Proportion of 11 sites where Black Cockatoos were detected from feeding sign.

Species	Proportion of sites detected
Forest Red-tailed Black Cockatoo	0.91
Carnaby's Black Cockatoo	0.45
Baudin's Black Cockatoo	0.45

Threat indicators

Cats and foxes

No incursions of feral cats or foxes were detected from camera surveys in 2020.

Introduced herbivores

There were no detections or known incursions of feral herbivores (rabbits) in 2020.

Other pest species

Occupancy estimates, derived from Standard Trapping Survey camera data, indicate that other pest species, the black rat and house mouse have remained stable over the survey period 2016 to 2020 (Figure 24). Black rats were most frequently detected in riparian habitats. House mice were observed most frequently in granite heathland.

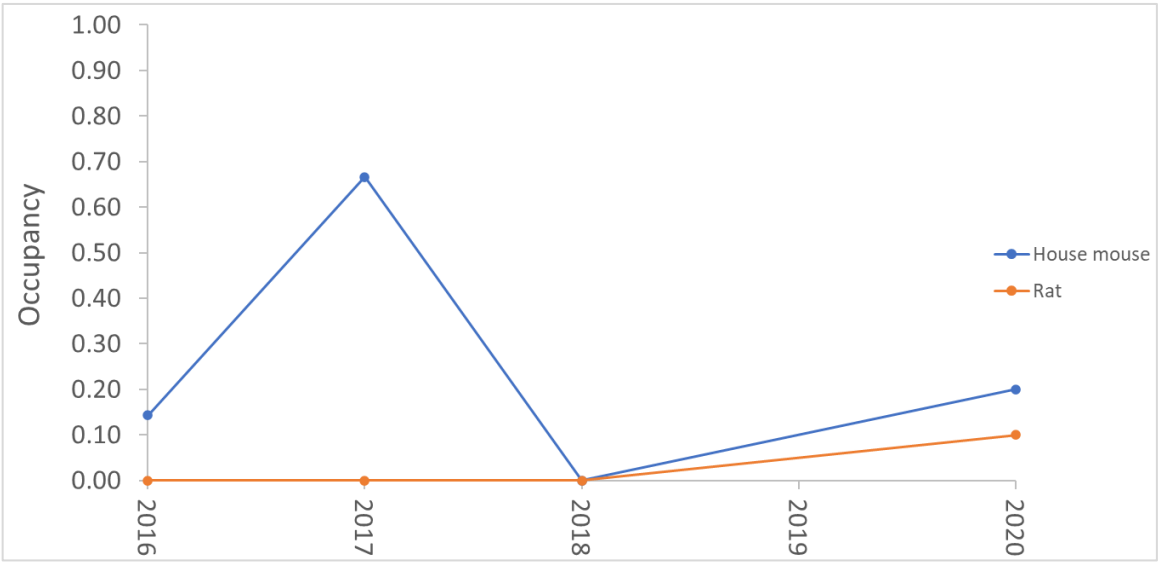

Figure 24. Occupancy (proportion of sites detected) for two Ecohealth indicator pest mammals over the period 2016 to 2020

Fire

There were no prescribed burns on Karakamia in 2020. A small area (5 ha) of habitat within the fenced area was burnt due to a prescribed burn on an adjacent property (conducted by external contractors, not within AWC property) that escaped containment.

Discussion

Karakamia's Ecohealth monitoring program now has most elements in full operation and providing robust data. Two new surveys were conducted in 2020: diurnal birds and targeted Black Cockatoo species monitoring. The first bird surveys were conducted to monitor bird species occupancy and richness. A total of 48 species were recorded. The targeted Black Cockatoo survey was also a success, confirming the presence of three threatened species on the Sanctuary and giving our first estimates of site occupancy. As surveys progress in future, trends in these findings may be used to assess the impacts of threatening processes, such as overgrazing and the efficacy of land management practices such as weed control and fire management.

Other survey programs indicate most of the key biodiversity indicators were within an acceptable range; population abundance and/or occupancy estimates remain stable for most mammal indicator species, except for the Western Ringtail Possum, which was last recorded on Karakamia in 2017. The status of the threat indicators was also in line with management expectations, with no cats, foxes or rabbits detected in 2020. Recent declines in population estimates for the Tammar Wallaby can be attributed to AWC management to avoid overpopulation. Small- to medium-sized mammals and small reptiles appear stable over time.

The data are consistent with an interpretation of a positive effect of the safe haven on species population sizes, with the exception of the Western Ringtail Possum. This species has been declining from the north of its range, with the decline attributed to climate change: specifically, hotter and drier conditions.

Acknowledgements

This work was conducted on Noongar Country. AWC acknowledges the traditional owners of this land and pays respect to Noongar Elders; past, present and emerging. AWC's Ecohealth Program is only possible because of the generosity of AWC's supporters. Thank-you to the entire South-West Science and Operations teams for their hard work at Karakamia that has made the running and collection of data from all our surveys possible. Thank you to our dedicated and passionate guides who facilitate our educational walks.

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Appendix 1

Table 6. Mean modelled site occupancy (and upper and lower confidence bounds) of 48 bird species detected at Karakamia Sanctuary

Species	Mean occupancy	95%. Lower	95%. Upper
Acanthiza apicalis	0.79	0.34	1.00
Acanthiza chrysorrhoa	0.28	0.07	0.75
Acanthiza inornata	0.71	0.21	1.00
Acanthorhynchus superciliosus	0.78	0.25	1.00
Anthochaera lunulata	0.49	0.11	1.00
Artamus cinereus	0.48	0.11	1.00
Barnardius zonarius	0.95	0.75	1.00
Biziura lobata	0.11	0.01	0.33
Cacatua pastinator	0.59	0.04	1.00
Cacomantis flabelliformis	0.82	0.35	1.00
Calyptorhynchus banksii naso	0.80	0.56	1.00
Chrysococcyx lucidus	0.65	0.14	1.00
Colluricincla harmonica	0.88	0.55	1.00
Coracina novaehollandiae	0.82	0.33	1.00
Corvus coronoides	0.81	0.57	1.00
Dacelo novaeguineae	0.65	0.13	1.00
Eolophus roseicapilla	0.79	0.54	1.00
Eopsaltria griseogularis	0.63	0.24	1.00
Falco cenchroides	0.68	0.15	1.00
Falco peregrinus	0.49	0.10	1.00
Fulica atra	0.11	0.01	0.29
Gavicalis virescens	0.38	0.03	1.00
Gerygone fusca	0.92	0.78	1.00
Gymnorhina tibicen	0.88	0.59	1.00
Hirundo neoxena	0.37	0.03	1.00
Lichenostomus leucotis	0.64	0.13	1.00
Lichmera indistincta	0.98	0.89	1.00
Malurus splendens	0.84	0.52	1.00
Melithreptus chloropsis	0.96	0.79	1.00
Microeca fascinans	0.81	0.32	1.00
Pachycephala occidentalis	0.98	0.88	1.00
Pachycephala rufiventris	0.83	0.37	1.00
Pardalotus punctatus	0.67	0.14	1.00
Pardalotus striatus	0.90	0.56	1.00
Petroica boodang	0.71	0.26	1.00
Phalacrocorax sulcirostris	0.37	0.03	1.00
Phalacrocorax varius	0.37	0.03	1.00
Phaps chalcoptera	0.82	0.37	1.00
Phylidonyris niger	0.11	0.01	0.33
Phylidonyris novaehollandiae	0.90	0.67	1.00
Purpureicephalus spurius	0.55	0.29	0.95

Species	Mean occupancy	95%. Lower	95%. Upper
Quoyornis georgianus	0.93	0.78	1.00
Rhipidura albiscapa	0.93	0.03	1.00
Rhipidura leucophrys	0.60	0.03	1.00
Sericornis maculatus	0.38	0.69	1.00
Smicrornis brevirostris	0.86	0.03	1.00
Tachybaptus novaehollandiae	0.39	0.13	0.93
Zosterops lateralis	0.35	0.65	0.99