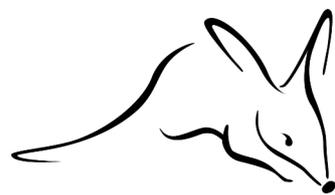


Paruna Wildlife Sanctuary Ecohealth Report 2021



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Summary

Australian Wildlife Conservancy (AWC) has implemented an Ecological Health Monitoring Program (Ecohealth) across Paruna Wildlife Sanctuary (Paruna) 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 between 2020 and 2021. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In implementing the Ecohealth program at Paruna in 2021, AWC conducted 2,459 camera trap nights that detected 11 native mammals (including 5 reintroduced and threatened species), 9 birds and 4 introduced vertebrates (feral cat, *Felis catus*; red fox, *Vulpes vulpes*; feral goat, *Capra hircus*; and house mouse, *Mus musculus*). This report also includes results from two surveys conducted in 2020: the Rock-Wallaby Trapping Survey and Black Cockatoo Survey. At Paruna, six surveys are conducted on a schedule of 1-5 years to report on 30 biodiversity and 10 threat indicators.

The Sanctuary-wide Camera Survey has been conducted annually since 2016 to target a suite of native mammals, including several reintroduced and threatened species, and introduced animals. Occupancy of Quenda (*Isoodon fusciventer*) remained relatively stable since 2018 while occupancy of Common Brushtail Possum/Koomal (*Trichosurus vulpecula*), Chuditch (*Dasyurus geoffroii*) and Black-gloved Wallaby (*Macropus irma*) increased slightly after recent declines. Occupancy of Short-beaked Echidna (*Tachyglossus aculeatus*) and Western Grey Kangaroo (*Macropus fuliginosus*) remained high and stable across the sanctuary. Although Tamar Wallabies (*Macropus eugenii*) have successfully established at Paruna, the Sanctuary-wide Camera Survey has shown a slow decline in the occupancy of the reintroduced population since 2017. The survey results also showed that the occurrence of feral predators and herbivores on the property remains low.

Live trapping for Black-flanked Rock Wallabies (*Petrogale lateralis lateralis*) suggested an increase in estimated population size from 10 in 2019 to 17 in 2020; however, there were large confidence intervals around these figures. The Black-cockatoo Survey conducted in 2020 resulted in Red-tailed Black Cockatoos (*Calyptorhynchus banksii naso*) being detected at 65% of sites while Baudin's Black Cockatoos (*Zanda baudinii*) and Carnaby's Black Cockatoos (*Z. latirostris*) were each detected at 45% of sites.

Overall, the results from the Paruna Ecohealth monitoring program reflect the positive effect of control efforts by the Paruna operations staff on reducing the impact of threats including feral predators and herbivores.

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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 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). 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 Paruna Wildlife Sanctuary (referred to here as Paruna). The companion Ecohealth Scorecard presents the indicators and their metrics in a summary format.

Paruna Wildlife Sanctuary

Paruna Wildlife Sanctuary is a 1,912 ha property in the Avon Valley approximately 60 km north east of Perth. Paruna is within the traditional lands of the Noongar people. It is bordered by two regionally significant national parks – Walyunga National Park to the west and Avon Valley National Park to the east. The Avon-Swan River forms much of the property's northern boundary (Figure 1).

Paruna features nine broad vegetation types (Figure 2) with the property dominated by woodlands of Wandoo (*Eucalyptus wandoo*), Jarrah (*E. marginata*), Marri (*Corymbia callophylla*) and Powderbark Wandoo (*E. accendens*) interspersed with large areas of shrublands and heathlands. There are 353 confirmed plant species on the property, with additional flora cataloguing planned for the near future.

Around 21 native mammal, 43 reptile, 124 bird, and 12 frog and species are confirmed or considered likely to occur at Paruna. Extensive control efforts for feral cats (*Felis catus*), red foxes (*Vulpes vulpes*), feral pigs (*Sus scrofa*), feral goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*) have allowed for the reintroduction of the nationally endangered Black-flanked Rock-wallaby (*Petrogale lateralis lateralis*), as well as populations of the Tamar Wallaby (*Macropus eugenii*), Quenda (*Isodon fusciventer*) and Common Brushtail Possum/Koomal (*Trichosurus vulpecula*). A total of 27 translocations of 5 mammal species to Paruna occurred between 2000 and 2018 (Table 1). The sanctuary also supports extant populations of other threatened species including Chuditch (Western Quoll, *Dasyurus geoffroii*; nationally vulnerable), Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*; nationally vulnerable), Baudin's Black Cockatoo (*Zanda baudinii*; nationally vulnerable) and Carnaby's Black Cockatoo (*Z. latirostris*; nationally endangered), as well as iconic small mammals such as the Western Pygmy Possum (*Cercartetus concinnus*) and Honey Possum (*Tarsipes rostratus*).

Table 1. Summary of mammal translocations to Paruna 2000-18.

Year	Species	Number translocated
2000	Quenda	66
2000	Woylie	107
2001	Black-flanked Rock-wallaby	10
2001	Tammar Wallaby	34
2001	Woylie	78
2002	Quenda	1
2002	Woylie	55
2002	Black-flanked Rock-wallaby	11
2002	Tammar Wallaby	28
2002	Common Brushtail Possum	21
2003	Black-flanked Rock-wallaby	21
2003	Common Brushtail Possum	14
2004	Quenda	39
2004	Woylie	63
2004	Common Brushtail Possum	34
2005	Quenda	5
2005	Black-flanked Rock-wallaby	15
2006	Quenda	47
2006	Woylie	133
2006	Common Brushtail Possum	1
2007	Black-flanked Rock-wallaby	19
2009	Tammar Wallaby	18
2011	Tammar Wallaby	46
2011	Common Brushtail Possum	53
2015	Tammar Wallaby	5
2016	Tammar Wallaby	123
2017	Tammar Wallaby	15
2018	Tammar Wallaby	84

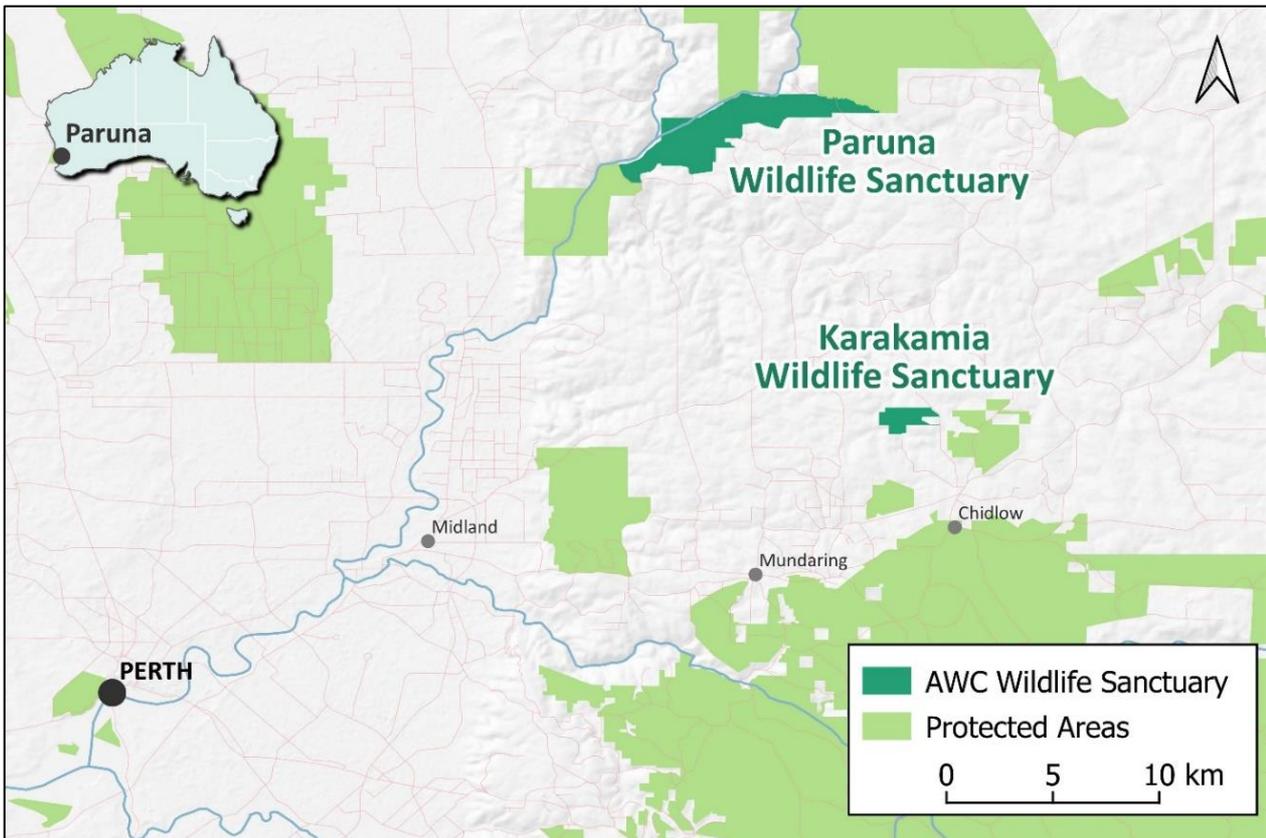


Figure 1. Location and regional context of Paruna Wildlife Sanctuary and Karakamia Wildlife Sanctuary. Inset indicates location within Australia.

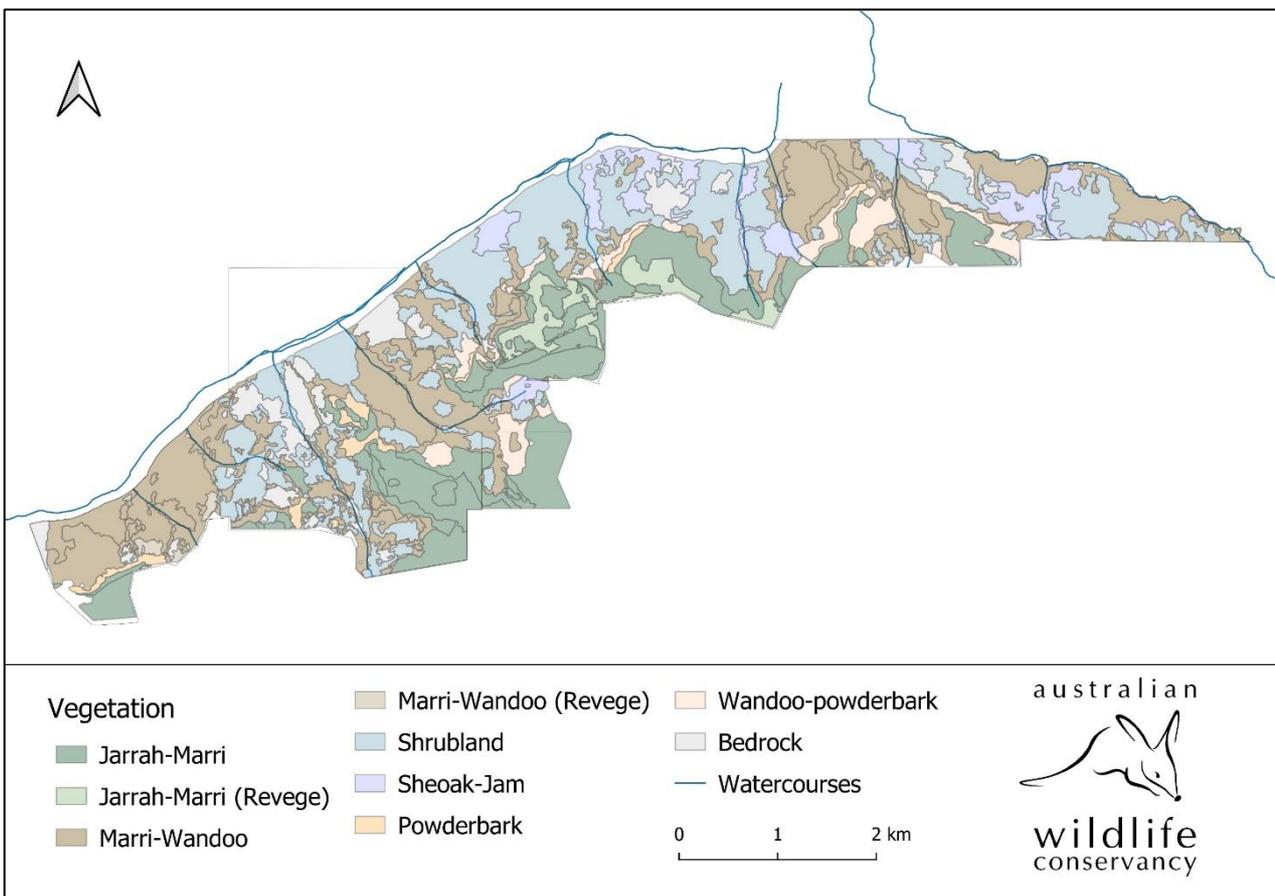


Figure 2. Distribution and extent of broad vegetation groups and water courses at Paruna Sanctuary.

Climate and weather summary

Paruna has 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 (1900-2021) average.

The average total annual rainfall has steadily decreased since 1908 (Figure 4), however, in 2021 total annual rainfall (968 mm) was well above the long-term average (846 mm). Substantial rain in March, July and October was largely responsible for the greater than average 2021 total (Figure 5).

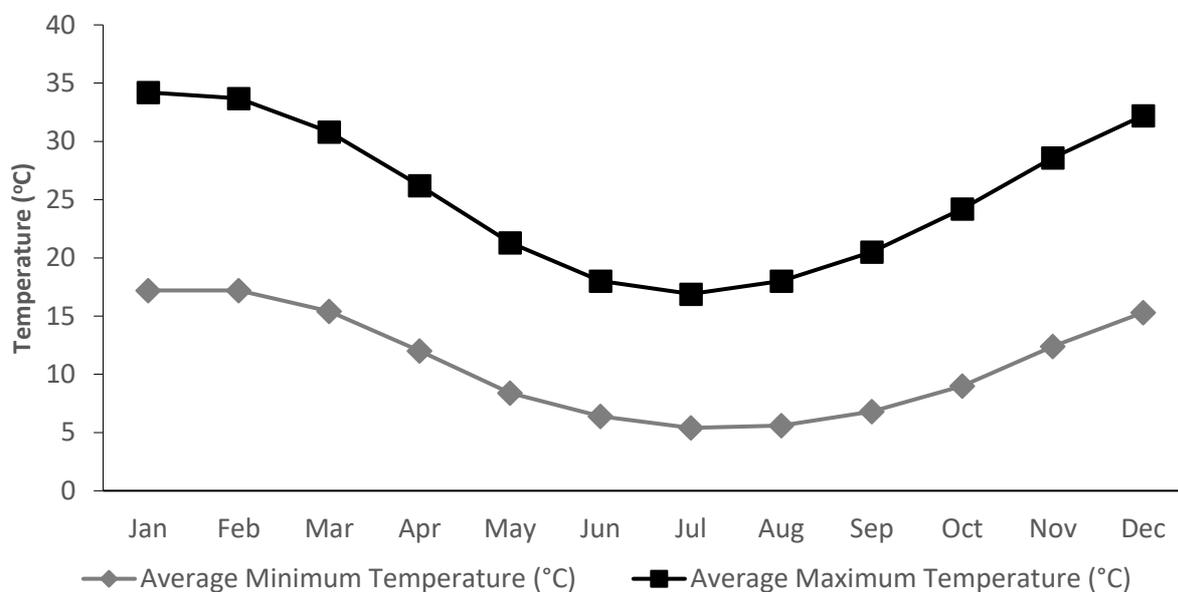


Figure 3. Mean minimum and mean maximum monthly temperature at Northam Monitoring Station, 1902-2021 (BOM Station No. 010111). Source: BOM Climate Data Online.

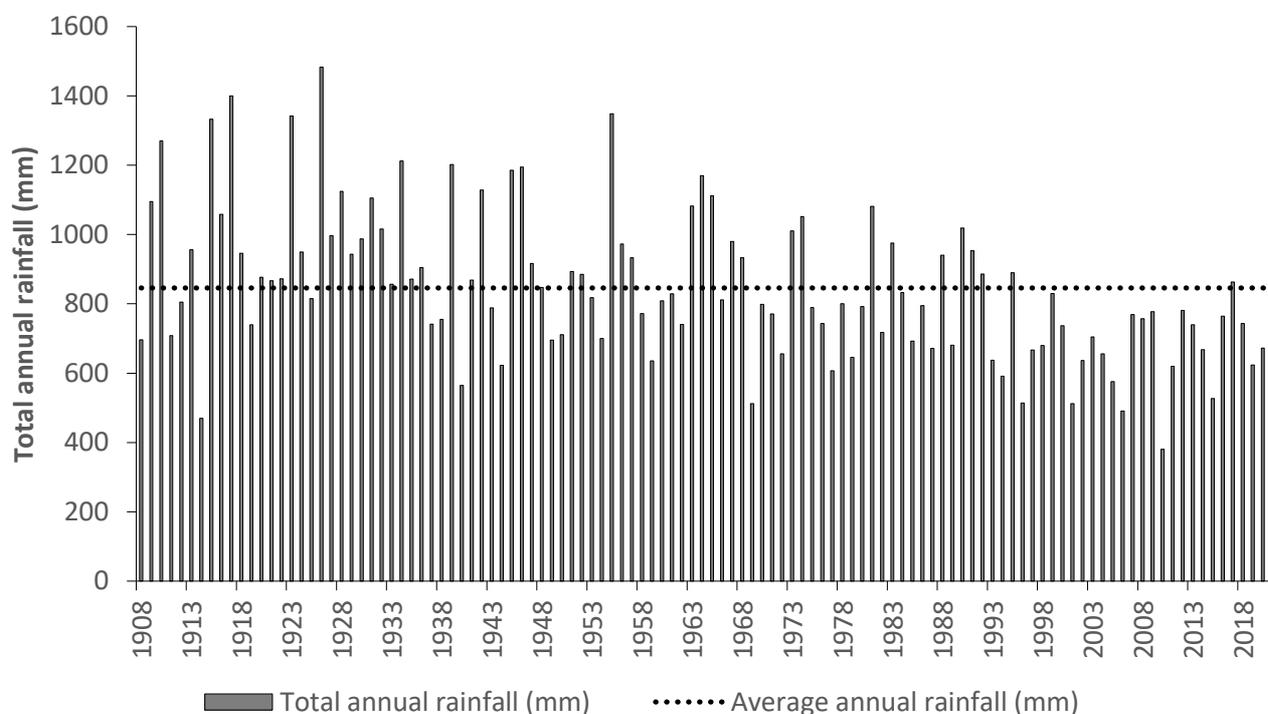


Figure 4. Annual rainfall at Chidlow Monitoring Station 1908-2021, with reference to the annual rainfall long-term average 1908-2020 (BOM Station No. 009007). Source: BOM Climate Data Online.

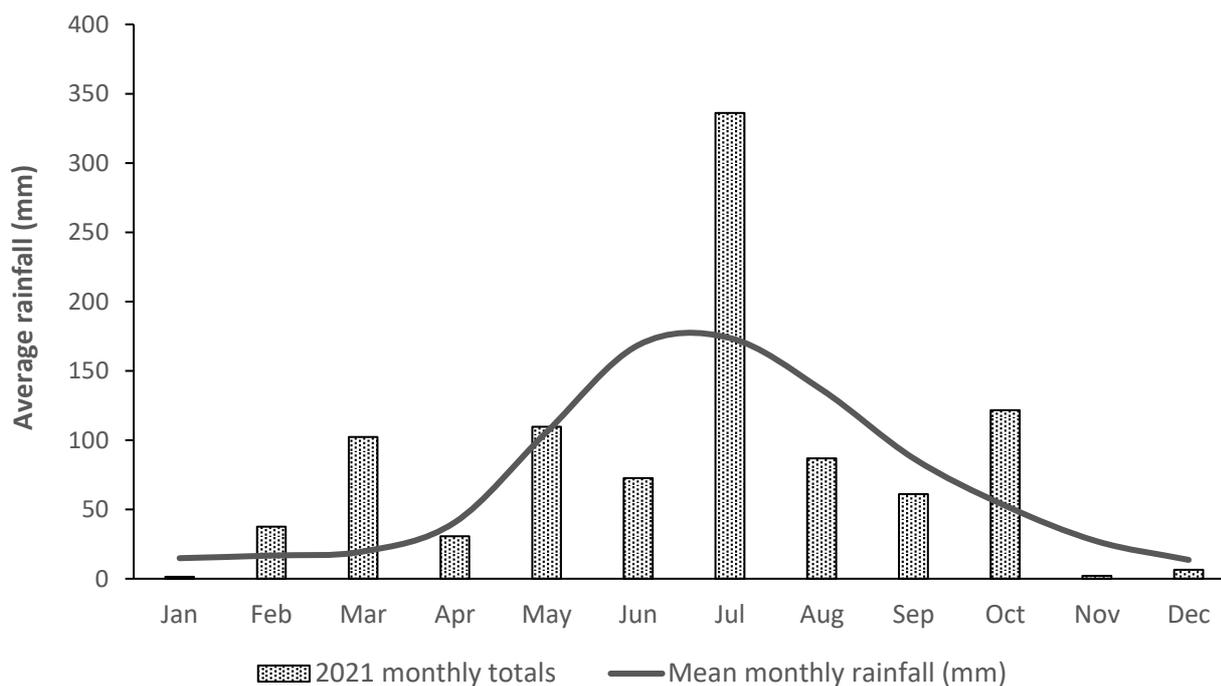


Figure 5. Rainfall in 2021 compared with mean monthly rainfall (1908-2020) at Chidlow Monitoring Station (BOM Station No. 009007). Source: BOM Climate Data Online.

Methods

Monitoring and evaluation framework

Paruna'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, threatened and iconic vertebrates

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) and key species. The monitoring program aims to address questions relevant to the conservation of assemblages and key species.

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 and key species. At present, we will continue to present data on a range of metrics relating to indicator species and guilds.

Indicators and metrics

On Paruna, 30 biodiversity (species, guilds and assemblages) indicators have been selected for monitoring (Table 2). Eleven of these indicators were reported on in 2021, including 8 related to threatened and iconic species (of which, 4 are reintroduced species) and the remainder to surveillance monitoring of faunal assemblages and key species.

Threat metrics are selected to monitor the status and trends of weeds, introduced predators and herbivores, and inappropriate fire regimes. Ten threat indicators have been selected for monitoring at Paruna (Table 3). Nine of these threat metrics were reported on in 2021.

Table 2. Biodiversity indicators and metrics for Paruna.

Reintroduced vertebrates

Indicator	Survey name/methods	Metric	Performance criteria
Quenda (<i>Isoodon fusciventer</i>)	Sanctuary-wide Camera Survey/camera traps	Occupancy	TBD pending Population Management Plan
Common Brushtail Possum/Koomal (<i>Trichosurus vulpecula</i>)	Sanctuary-wide Camera Survey/camera traps	Occupancy	TBD pending Population Management Plan
Tammar Wallaby (<i>Macropus eugenii</i>)	Sanctuary-wide Camera Survey/camera traps	Occupancy	TBD pending Population Management Plan
Black-flanked Rock-wallaby (<i>Petrogale lateralis lateralis</i>)	Rock-wallaby Trapping Survey - Thomas (soft cage) traps	Population size	TBD pending Population Management Plan

Key threatened and iconic vertebrates

Indicator	Survey name	Survey method	Metric/s
Mammals			
Chuditch (<i>Dasyurus geoffroii</i>)	Sanctuary-wide Camera Survey	Camera traps	Occupancy
Birds			
Red-tailed Black Cockatoo (<i>Calyptorhynchus banksia</i>)	Black Cockatoo Survey	Resource use analysis	Occupancy
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

Vertebrate assemblages and surveillance species

Indicator	Survey name	Survey method	Metric/s
Mammals			

Indicator	Survey name	Survey method	Metric/s
Assemblage richness	Sanctuary-wide Camera Survey, Standard Trapping Survey, Acoustic Survey, Rock-wallaby Trapping Survey	All mammal survey methods	Number of species
Small-medium sized mammals			
Assemblage richness	Sanctuary-wide Camera Survey, Standard Trapping Survey	Camera traps, pitfall traps, Elliot traps	Number of species
Short-beaked Echidna (<i>Tachyglossus aculeatus</i>)	Sanctuary-wide Camera Survey	Camera traps	Occupancy
Sooty Dunnart (<i>Sminthopsis fuliginosis</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Arboreal mammals			
Assemblage richness	Standard Trapping Survey	Pitfall traps	Number of species
Western Pygmy Possum (<i>Cercartetus concinnus</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Honey Possum (<i>Tarsipes rostratus</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Large mammals			
Assemblage richness	Sanctuary-wide Camera Survey	Camera traps	Number of species
Western Grey Kangaroo (<i>Macropus fuliginosus</i>)	Sanctuary-wide Camera Survey	Camera traps	Occupancy
Black-gloved Wallaby (<i>Macropus irma</i>)	Sanctuary-wide Camera Survey	Camera traps	Occupancy
Reptiles			
Assemblage richness	Standard Trapping Survey	Pitfall traps	Number of species
Small reptiles			
Assemblage richness	Standard Trapping Survey	Pitfall traps	Number of species
Small reptiles (guild)	Standard Trapping Survey	Pitfall traps	Richness
Buchanan's Snake-eyed Skink (<i>Cryptoblepharus buchananii</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
South-western Orange-tailed Slider (<i>Lerista distinguenda</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Common Dwarf Skink (<i>Menetia greyii</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Marbled Gecko (<i>Christinus marmoratus</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Barking Gecko (<i>Underwoodisaurus milii</i>)	Standard Trapping Survey	Pitfall traps	Occupancy
Medium reptiles			
Assemblage richness	Standard Trapping Survey	Camera traps	Number of species
Bobtail (<i>Tiliqua rugosa</i>)	Standard Trapping Survey	Camera traps	Occupancy
Birds			
Assemblage richness	Standard Bird Survey	Observational	Number of species
Diurnal birds (guild)	Standard Bird Survey	Observational	Richness Abundance

Table 3. Threat indicators and metrics for Paruna.

Indicator	Survey name/methods	Metric/s	Performance criteria
Pest animals			
Feral cat (<i>Felis catus</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
Red fox (<i>Vulpes vulpes</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
Rabbit (<i>Oryctolagus cuniculus</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
Feral goat (<i>Capra hircus</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
Feral pig (<i>Sus scrofa</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
Feral sheep (<i>Ovis aries</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
Fallow deer (<i>Dama dama</i>)	Sanctuary-wide Camera Survey	Occupancy	TBD Pest Animal Strategy
House mouse (<i>Mus musculus</i>)	Standard Trapping Survey	Occupancy	TBD Pest Animal Strategy
Weeds			
Weeds	TBD	TBD	TBD Weed Strategy
Fire			
Extent of planned and unplanned burns	Ground mapping	Area burnt in planned fire (ha) Area burnt in unplanned fire (ha)	<ol style="list-style-type: none"> 1. Reduce the threat of widespread wildfire by reducing high fuel loads 2. Create and maintain an internal, burnt buffer of mixed age vegetation inside the southern fence 3. Create a mosaic of fire histories across the sanctuary

Survey types and history

To report on the Biodiversity and Threat Indicators, our survey teams conduct a variety of surveys repeated on a schedule of 1-5 years, as required to obtain timely information on each indicator. These include:

For threatened and iconic species, including reintroduced species:

- Sanctuary-wide Camera Survey for Quenda, Common Brushtail Possum, Tammar Wallaby and Chuditch
- Rock-wallaby Trapping Survey for Black-flanked Rock-wallaby
- Black Cockatoo Survey for Red-tailed Black Cockatoo, Baudin's Black Cockatoo and Carnaby's Black Cockatoo

For surveillance monitoring of assemblages:

- Sanctuary-wide Camera Survey for some small-medium mammals and macropods
- Standard Trapping Survey for some small terrestrial and arboreal mammals, and reptiles
- Standard Bird Survey for bird species assemblages

To monitor threats:

- Sanctuary-wide Camera Survey for feral species

The Sanctuary-wide Camera Survey was the only ecological survey conducted at Paruna in 2021 (Table 4). Fire Scar Analysis was completed using on-ground mapping. The methodology is described and results of these surveys and computations are reported on in this document.

Table 4. Survey history and effort for Ecohealth surveys on Paruna reported on in 2021. Note: 2016 Sanctuary-wide Camera Survey results excluded from analyses due to significant site discrepancy.

Survey name	Effort	Description/comment	Previous surveys
Sanctuary-wide Camera Survey	2,459 trap nights	177 sites surveyed with lured camera traps (1 camera per site, 2 bait cannisters per site)	2016 – 72 sites 2017 – 172 sites 2018 – 164 sites 2019 – 176 sites 2020 – 175 sites
Not conducted (but reported on) in 2021			
Black-flanked Rock-wallaby Survey	160 trap nights (2020)	4 nights trapping at 3 outcrop locations with a total of 40 Thomas traps	2010-2014 – 20 traps 2015-2020 – 40 traps
Black Cockatoo Survey	54 surveys (2020)	Up to 20 sites surveyed seasonally <ul style="list-style-type: none"> - 8 sites (summer) - 12 sites (autumn) - 20 sites (winter) - 14 sites (spring) 	

Survey design and methods

Sanctuary-wide Camera Survey

The Sanctuary-wide Camera Survey is used to monitor the occupancy of Quenda, Common Brushtail Possum, Tammar Wallaby, Chuditch, Short-beaked Echidna (*Tachyglossus aculeatus*), Western Grey Kangaroo (*Macropus fuliginosus*) and Black-gloved Wallaby (*Macropus irma*). The survey is also used to monitor introduced predators and herbivores including feral cats, red foxes, rabbits, feral goats, feral pigs, feral sheep (*Ovis aries*) and fallow deer (*Dama dama*). The camera array consisted of 177 locations stratified by major habitat type and burn management areas (Figure 6; Figure 7). Cameras were deployed in a roughly equal pattern with one camera per 10 ha.

The Sanctuary-wide Camera Survey is conducted annually. Annual deviations in the number of sites surveyed are a result of trial phase (2016) or due to inaccessibility due to vegetation growth patterns (2016-2021). Cameras were deployed at each site for 12-14 days, between May and July, divided into three rounds. Up to 60 cameras were deployed per round. Each camera trapping site consisted of a single Reconyx white-flash camera (PC850 Hyperfire Pro White Flash) affixed to a fence dropper or tree at a height of 50 cm. The camera faced two lured canisters, one with cooked chicken, the other with apple and dairy crave. The cannisters were attached to a short fence dropper approximately 2 m from the camera. Cameras were programmed to take 3 images per trigger with no quiet period between triggers.

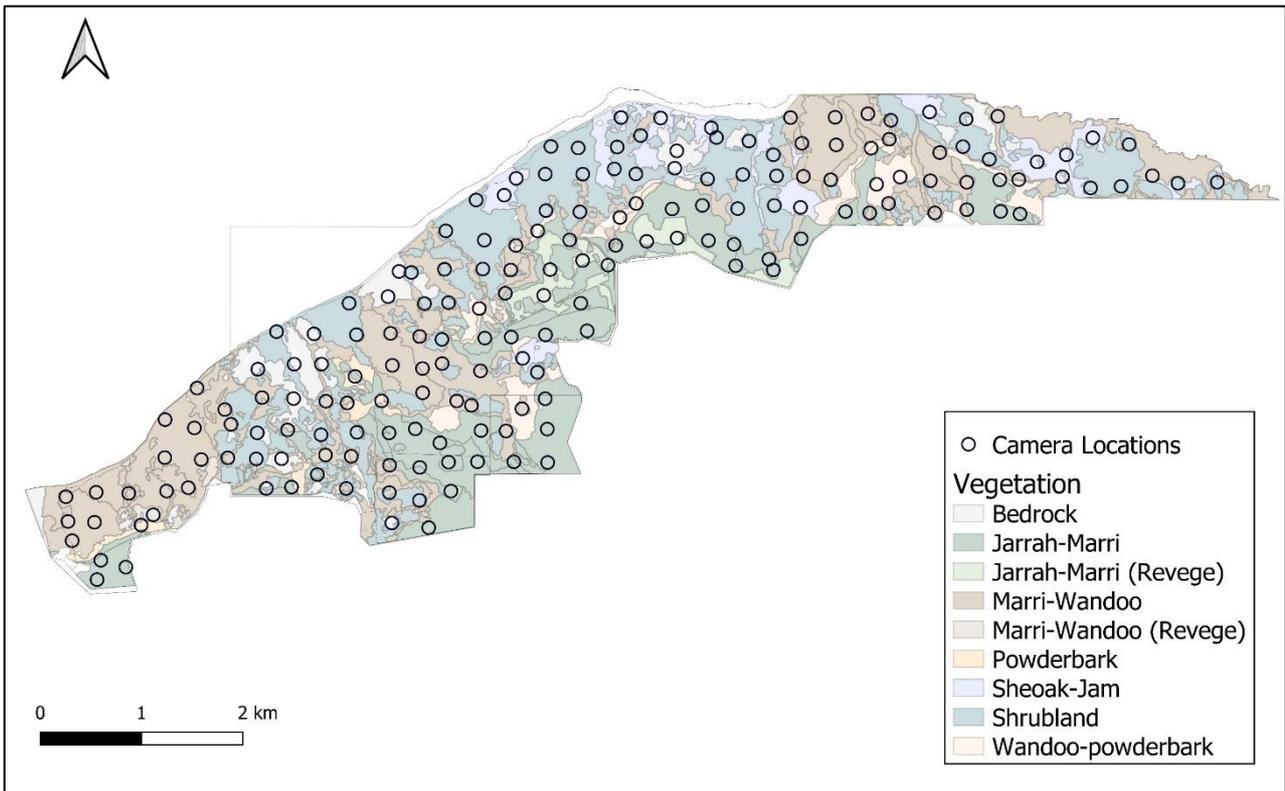


Figure 6. Sanctuary-wide Camera Survey camera trap locations (circles) in relation to major habitat types on Paruna.

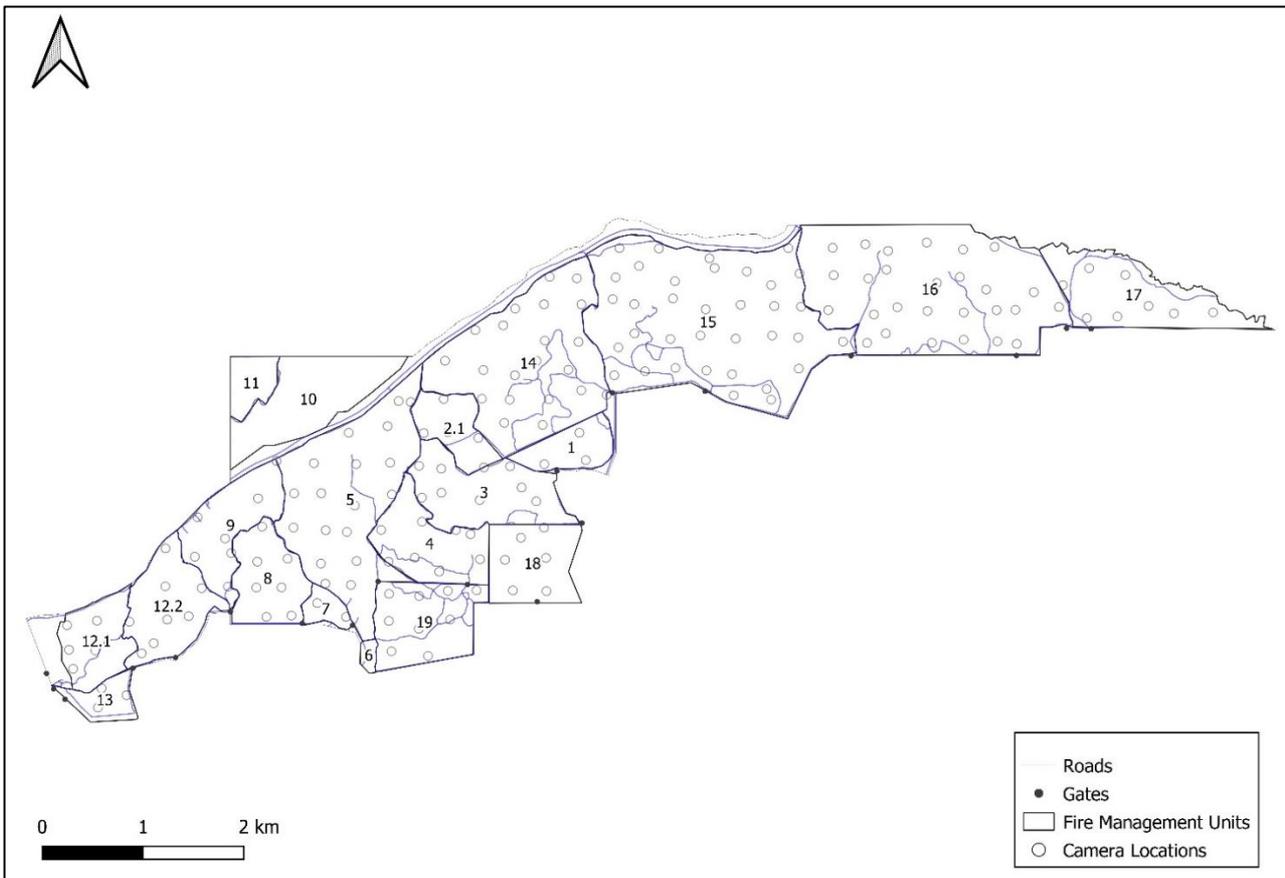


Figure 7. Sanctuary-wide Camera Survey camera trap locations (circles) in relation to burn management areas on Paruna.

Rock-wallaby Trapping Survey

The Rock-wallaby Trapping Survey monitors the size and health of the Black-flanked Rock-wallaby population. Specifically, the survey generates abundance estimates which allow trend analyses, and monitors the populations' demographic (age, sex ratio) and physiological (reproductive health, body condition) details. The survey has been conducted annually since 2010, except 2021. Trapping sites ($n = 40$) are restricted to three granite outcrops at which the species has been detected (Figure 8): the main outcrop (which was the original translocation release) site, a second outcrop 1.5 km to the east and a more recently (2019) established trapping site within a gorge between the two outcrops.

In 2020, a total of 40 Thomas traps were deployed across the three locations (Figure 9). The main outcrop contained 20 traps, the second outcrop contained 10 traps, and the gorge contained 10 traps. Traps were positioned at stable points along outcrops, were wired to remain open (dormant), and were pre-baited with chaff, apple, and Dairy Krave for two weeks prior to conducting trapping. Following two weeks of pre-baiting the wiring was removed and the traps were set (active). The live trapping occurred over three consecutive nights, wherein traps were cleared and closed at first light, and were reopened in the late afternoon.

Captured individuals were processed and the following data were recorded: microchip, weight, sex, age, pouch condition/reproductive status, pes length, body condition, and any additional identifiers (ear-tags, notable physiology). New individuals were recorded and microchipped. Individuals recaptured within a survey session were not processed again.

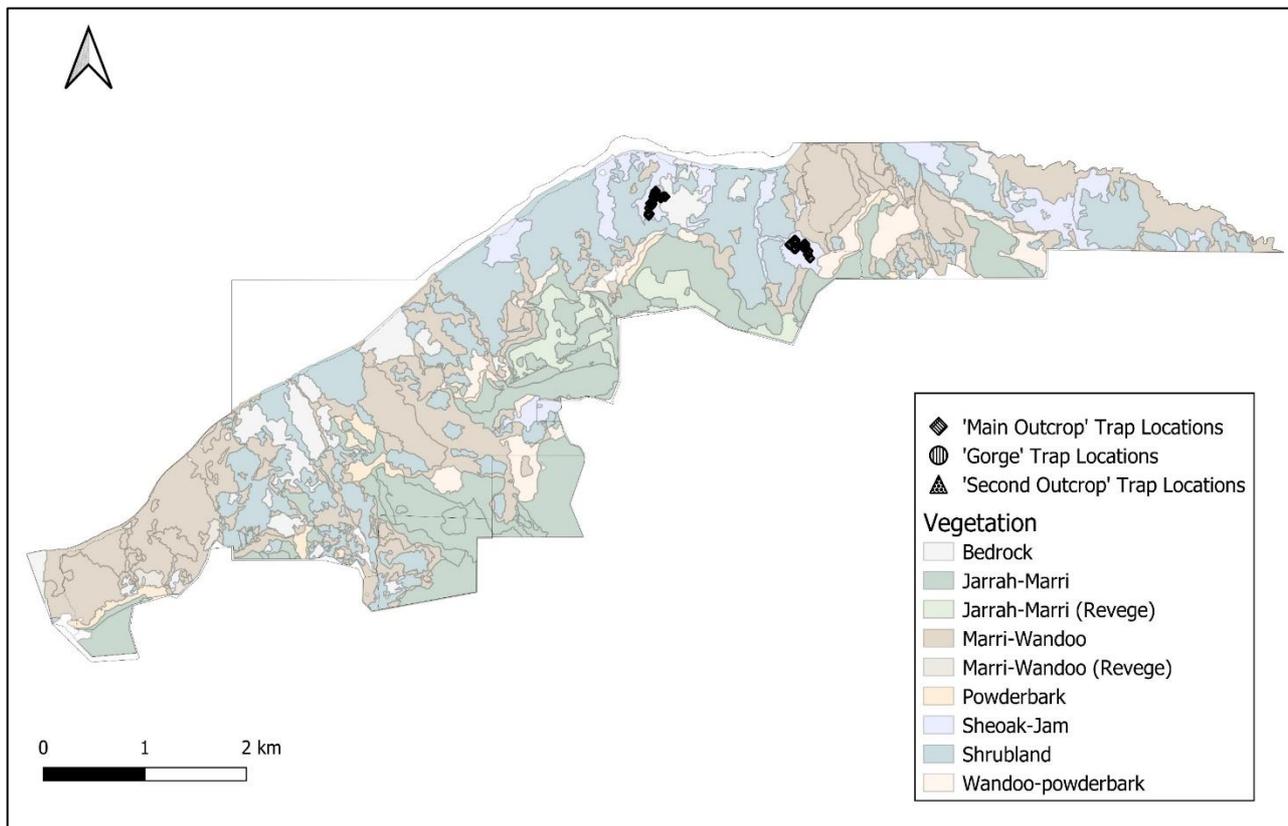


Figure 8. Location of Black-flanked Rock-wallaby traps at Paruna Sanctuary.

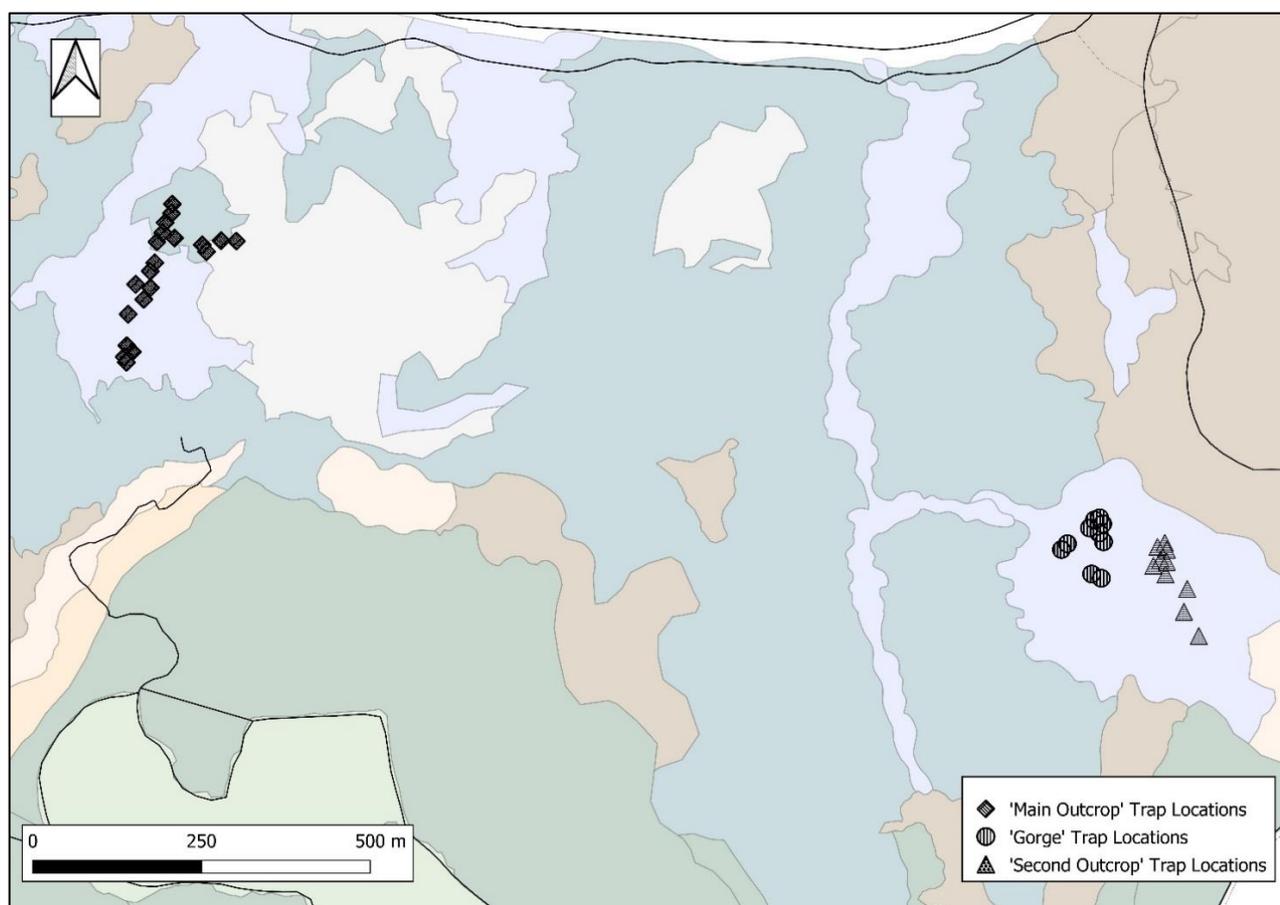


Figure 9. Regional context of the three clusters of Black-flanked Rock-wallaby traps at Paruna Sanctuary.

Black Cockatoo Survey

The objective of this survey was 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, Baudin's Black Cockatoo and Carnaby's Black Cockatoo. Searches for feeding signs were conducted at up to 20 sites per season (Figure 10). Sites were associated with creek lines, seeps, dams, and granite outcrops, as they were also utilised for amphibian surveys. A search was undertaken for Marri nuts on the ground within a 50 m radius at each site. Differences in mandible size between the species produce noticeably different feeding marks on the nuts, 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).

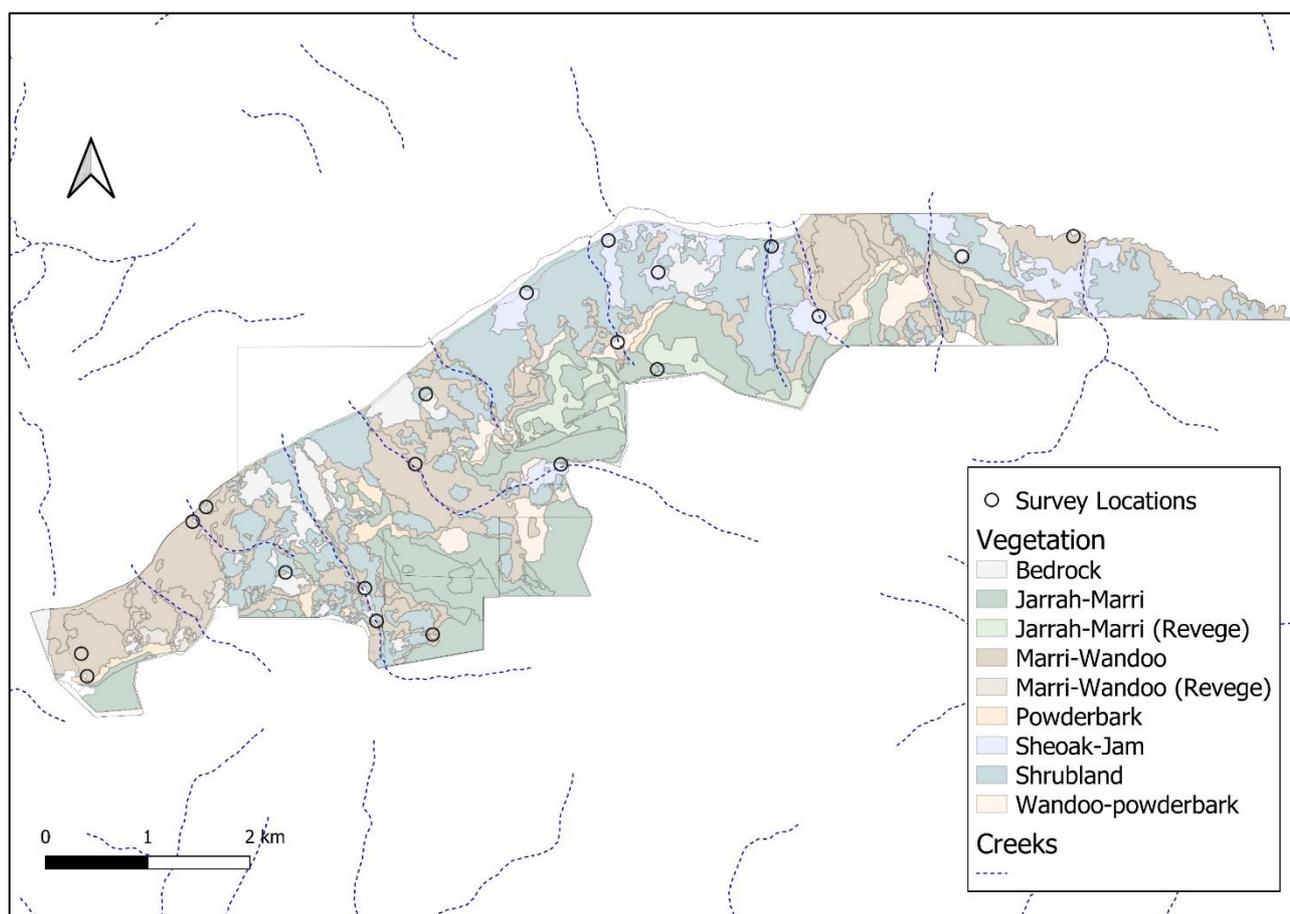


Figure 10. Black Cockatoo survey site locations (circles) in relation to major habitat types on Paruna.

Analysis methods

Unless noted otherwise, the metrics are calculated as set out in Table 5.

Table 5. Metrics and associated calculations for Paruna.

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 Common Brushtail Possum Tamar Wallaby Chuditch Short-beaked Echidna Western Grey Kangaroo Black-gloved Wallaby Feral cats Red foxes Rabbits Feral goats	Occupancy	Sanctuary-wide Camera 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

Indicator	Metric	Survey data sources	Description	Analysis summary/calculation
Feral Pigs Feral Sheep Deer				
Black-flanked Rock-wallaby	Population estimate	Rock-wallaby Trapping Survey	Estimate of total number of individuals in the population based upon 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). Mark-recapture was used to estimate total population size 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.
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

Fire Scar Analysis

Fire scars were assessed on ground and mapped using Google Earth.

Results

Reintroduced species

Quenda

In 2021, Quenda occupied 4% of the survey sites. This species has occurred at a low number of sites throughout the survey period (<6%; Figure 11). In 2021, there were 13 detections of Quenda across 7 sites, compared to 17 detections across 10 sites in 2020.

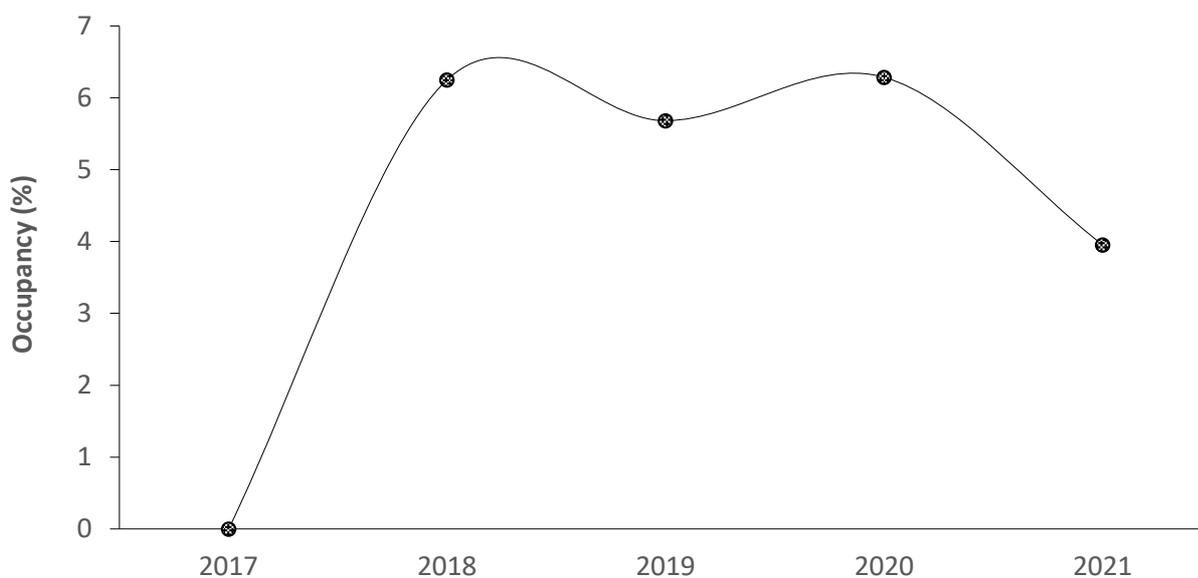


Figure 11. Occupancy (proportion of sites detected) for Quenda over the period 2017-2021.

Common Brushtail Possum

Occupancy of Common Brushtail Possum/Koomal was 5% in 2021, a moderate increase from a low of 1% in 2020 (Figure 12). Common Brushtail Possum occupancy has varied between 2017 and 2021, with a decline between 2018 and 2020, from which the population may now be recovering. In 2021, there were 12 detections of Common Brushtail Possum at 8 sites, up from 4 detections across 2 sites in 2020.

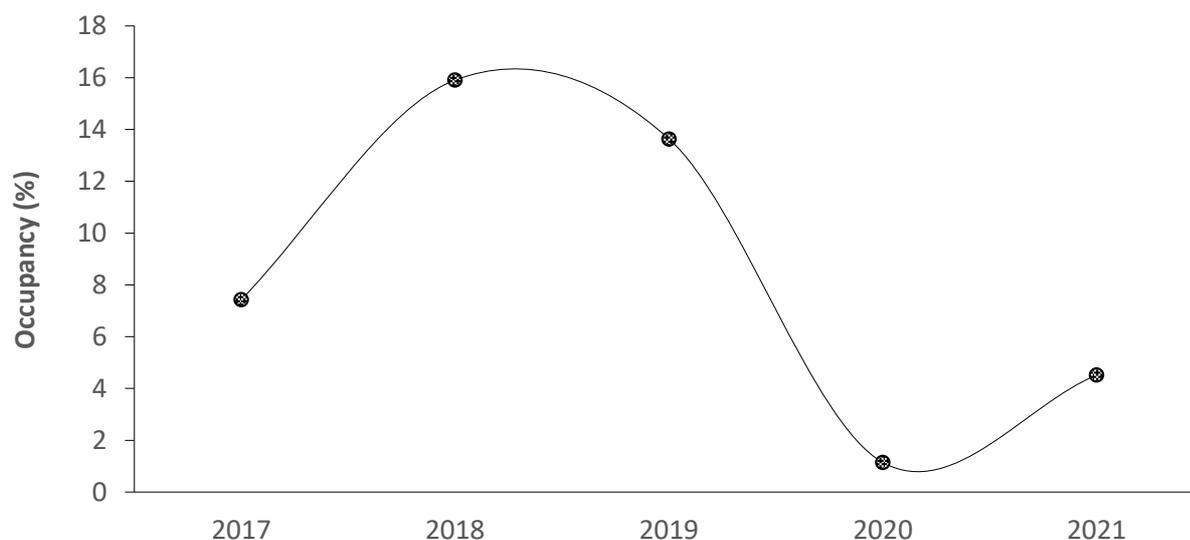


Figure 12. Occupancy (proportion of sites detected) for Common Brushtail Possum over the period 2017-2021.

Tammar Wallaby

In 2021, the occupancy of Tammar Wallabies was 14% of the Sanctuary-wide Camera Trapping Survey sites (Figure 13). There has been a small decline in Tammar Wallaby occupancy since 2017-18 (occupancy 23-25%) but the population appears relatively stable in the last few years (between 15-19%). In 2021, there were 55 detections of Tammar Wallabies across 24 Sanctuary-wide Camera Trapping Survey sites, down from 96 detections across 33 sites in 2020. Detections in 2021 included 9 ear-tagged individuals, which were translocated from Karakamia to Paruna. The last translocation of Tammar Wallabies occurred in 2018.

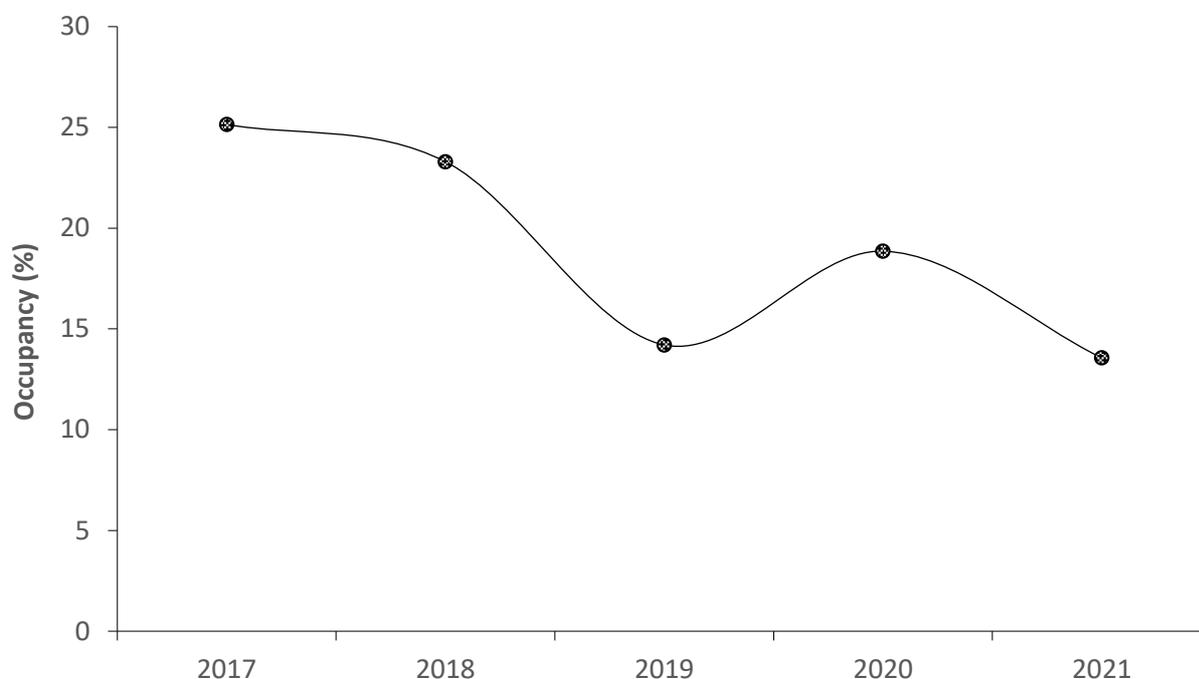


Figure 13. Occupancy (proportion of sites detected) of Tammar Wallaby over the period 2017-2021. Translocations of Tammar Wallabies to Paruna were conducted in 2017 (15 individuals) and 2018 (84 individuals).

Black-flanked Rock-wallaby

The Rock-wallaby Trapping Survey was not conducted in 2021; results from 2011-2020 are reported here. In 2020, there were 18 captures of 8 individual Black-flanked Rock-wallabies. Three new individuals were captured, including two subadults (both males), and all three of the captured females had pouch young or were lactating. Six individuals were captured at the “main” outcrop (the original translocation release site), and the remaining two were captured in the “gorge” site (see Figure 9). No individuals have been trapped at the “second outcrop” since a single male was captured at this site in 2018. Individuals GPS-collared in 2019 did not visit this outcrop, however, a single Black-flanked Rock-wallaby was detected during the Sanctuary-wide Camera Survey in 2020, between the “gorge” and “second outcrop” sites (see Figure 9).

The Rock-wallaby population size was estimated at 17 individuals in 2020. The estimated population size has varied between 10 and 25 individuals over the past decade (Figure 14).

Although it does not target Black-flanked Rock-Wallabies, the species was recorded at three sites during Sanctuary-wide Camera Survey in 2021, including at one location more than 3 km from the trapping sites.

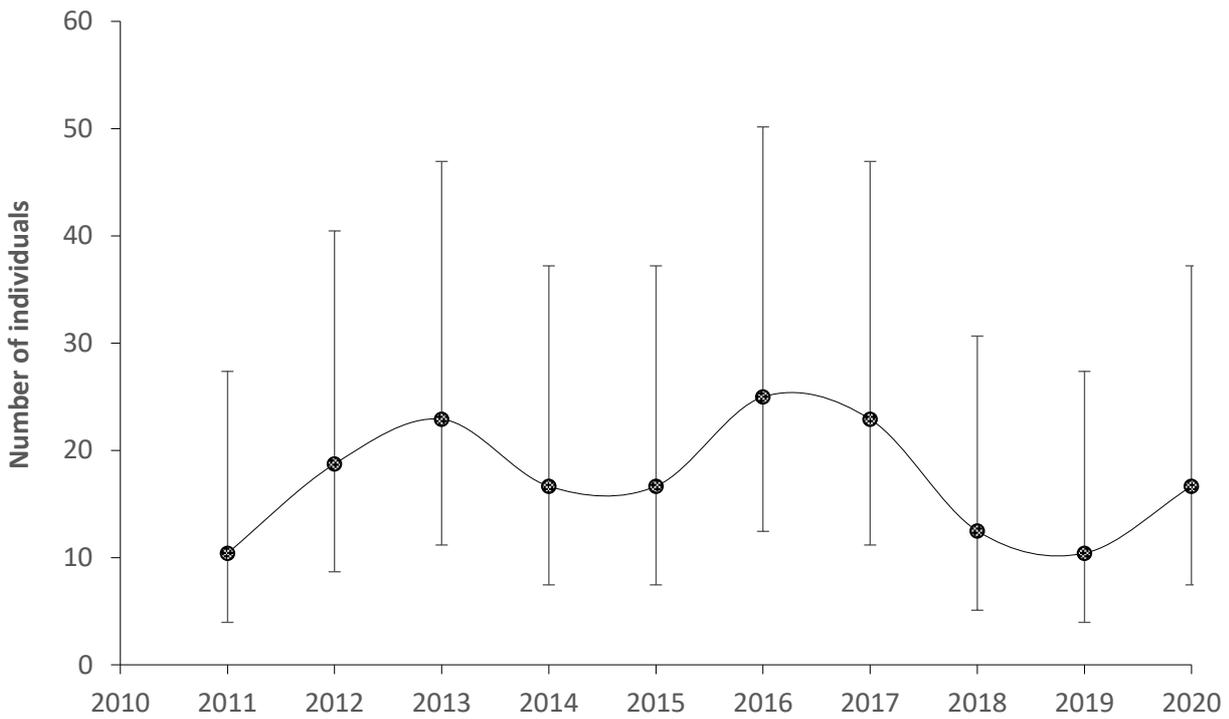


Figure 14. Estimated population size of Black-flanked Rock-wallabies at Paruna (95% CI), 2011-2020.

Key threatened and iconic species

Chuditch

In 2021, Chuditch occupied 3% of survey sites, a moderate increase from the 1% of sites recorded in 2020 (Figure 15). Detections of Chuditch at Paruna are generally low. Occupancy rates vary from year to year, with the highest occupancy recorded in 2018 (8%). In 2021, there were 7 detections of Chuditch at 5 Sanctuary-wide Camera Trapping Survey sites, compared to 9 detections at 2 sites in 2020.

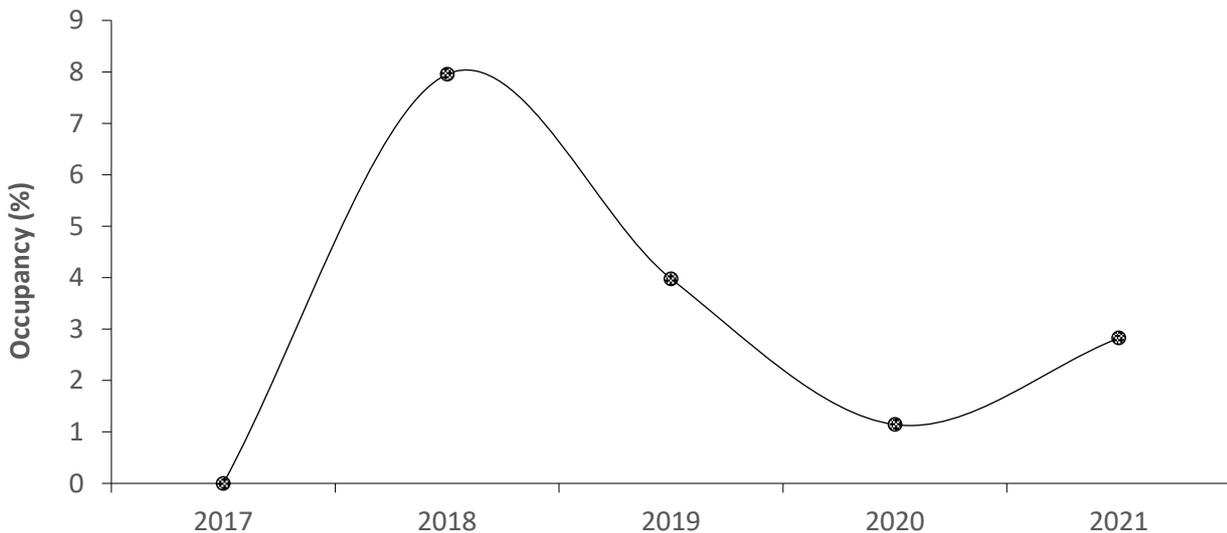


Figure 15. Occupancy (proportion of sites detected) for Chuditch over the period 2017-2021.

Black cockatoo species

This survey was not conducted in 2021, so results from 2020 are reported here. Red-tailed Black Cockatoos were detected at 65% of sites. Baudin’s and Carnaby’s Black Cockatoos were each detected at 45% of sites.

Vertebrate assemblages and surveillance species

Mammals

Assemblage richness

Twelve species in this guild recorded from 2020-2021, from 21 known or likely to occur. Species from this guild were detected during the Sanctuary-wide Camera Survey, the Rock-wallaby Trapping Survey and the Standard Trapping Survey. Missing species were predominantly bats for which there has been no targeted surveys.

Short-beaked Echidna

Short-beaked Echidna occupancy was 35% in 2021 and has increased since 2017 (Figure 16). In 2021, there were 122 detections of the species across 62 sites (compared to 105 detections across 63 sites in 2020). Continued monitoring is required to clarify whether this increase is part of long-term variation in response to multi-year environmental patterns or indicative of a trend.

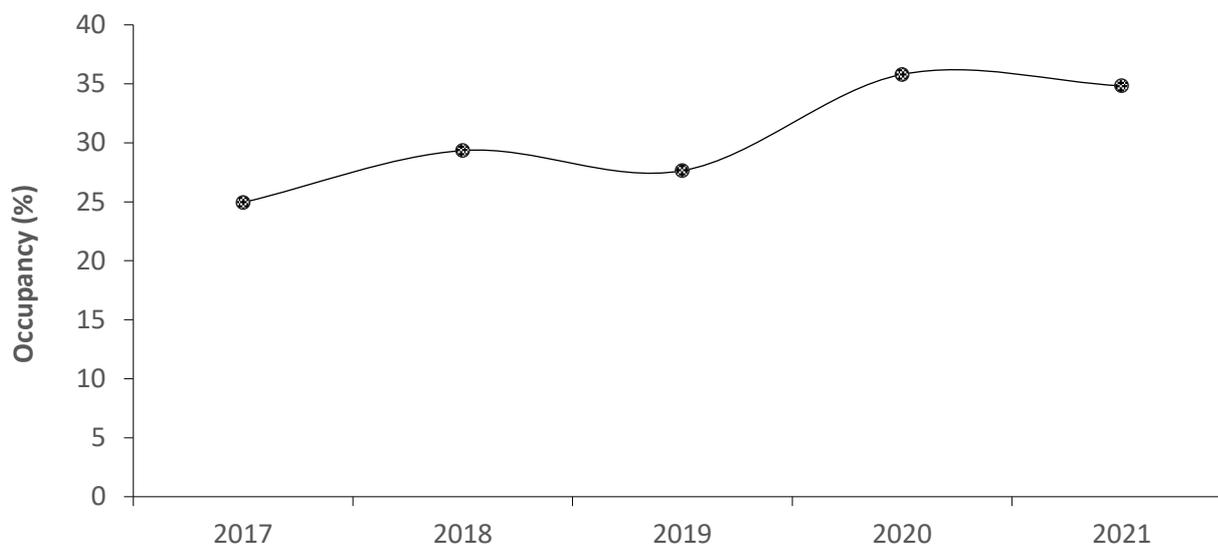


Figure 16. Occupancy (proportion of sites detected) for Short-beaked Echidna over the period 2017-2021.

Western Grey Kangaroo

Western Grey Kangaroo occupancy was 39% in 2021. The species' occupancy has been relatively stable, with some interannual variation, since 2017 oscillating between 40-50% (Figure 17). In 2021, there were 217 detections of Western Grey Kangaroo across 69 sites (compared to 200 detections across 75 sites in 2020). Continued monitoring is required to clarify whether interannual variation shown is part of a long-term pattern in response to multi-year environmental conditions or indicative of any longer-term trends.

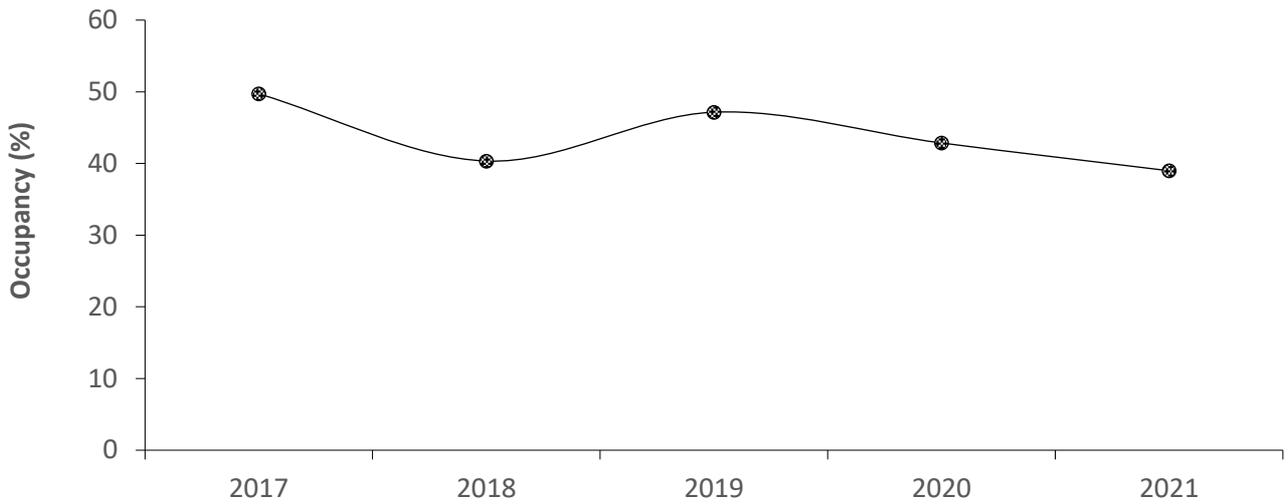


Figure 17. Occupancy (proportion of sites detected) for Western Grey Kangaroo over the period 2017-2021.

Black-gloved Wallaby

Black-gloved Wallaby occupancy was 3% in 2021 and, although there is some variability between years, appears to have remained relatively stable since 2017 (Figure 18). In 2021, there were 10 detections of Black-gloved Wallaby across 6 sites compared to 4 detections across 4 sites in 2020.

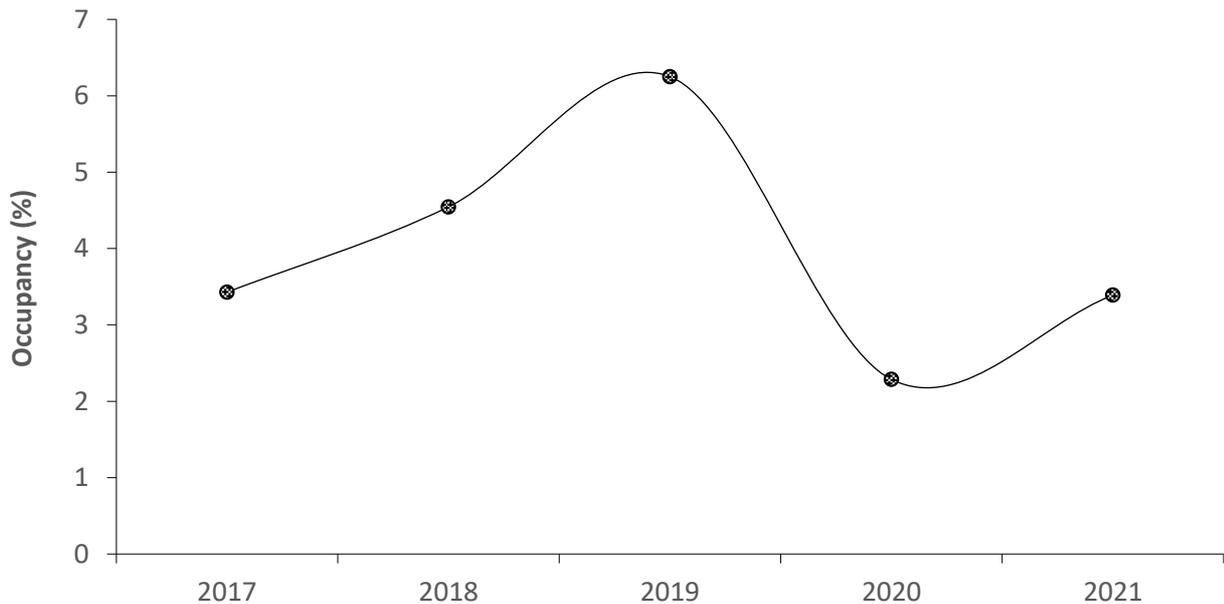


Figure 18. Occupancy (proportion of sites detected) for Black-gloved Wallaby over the period 2017-2021.

Reptiles

Assemblage richness

Of the 43 known to occur on Paruna, 19 reptile species were recorded in 2020-2021. The missing species include the 7 species of large snakes, for which no targeted survey was conducted, as well as many smaller reptiles known or likely to occur but not detected during pitfall trapping.

Birds

Assemblage richness

Of the 124 species known to occur on Paruna, 51 species in this assemblage were recorded in 2020-2021. The missing species include most waterbirds, nocturnal species and many nomadic or migratory species.

Threat indicators

Feral cats

In 2021, occupancy of feral cats was 5%, similar to the result since 2019 (Figure 19). Occupancy of feral cats at Paruna has more than halved since 2018. There were 10 detections of feral cats at 9 sites in 2021.

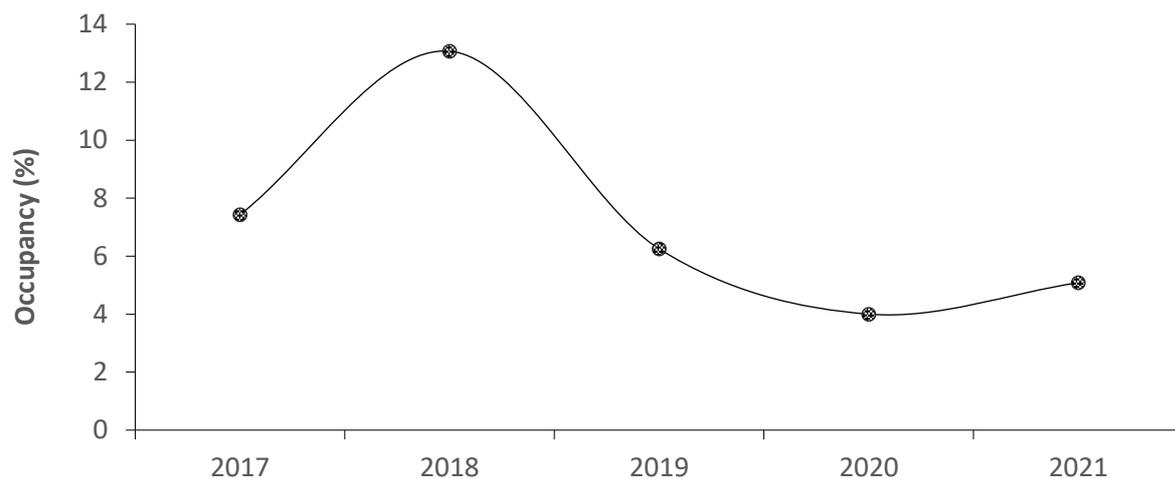


Figure 19. Occupancy (proportion of sites detected) for feral cats over the period 2017-2021.

Red foxes

Occupancy of red foxes was 3% in 2021, remaining lower than the peak of 6% occupancy in 2018 (Figure 20). In 2021, there were 6 detections of red foxes across 5 sites.

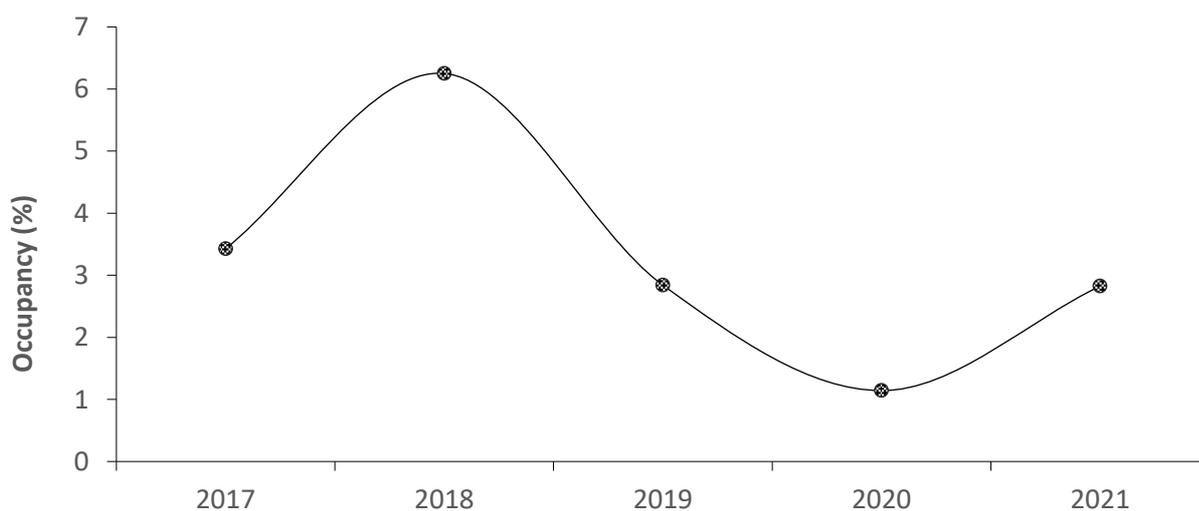


Figure 20. Occupancy (proportion of sites detected) for red foxes over the period 2017-2021.

Introduced herbivores and omnivores

Of the six herbivorous and omnivorous introduced species at Paruna, two (goats and house mice, *Mus musculus*) were detected during the Sanctuary-wide Camera Survey in 2021 (Table 6). However, due to the difficulties in detecting and identifying small rodents on camera traps, the Sanctuary-wide Camera Survey is not used to calculate occupancy for house mice. Results from the Standard Trapping Survey, which was not

conducted in 2021, are used instead. Rabbits, pigs, sheep and deer were not recorded by the Sanctuary-wide Camera Survey in 2021. Rabbits and pigs were recorded in 2021 by the operations team during their routine feral species control programs.

Table 6. Introduced herbivorous and omnivorous animal metrics for Paruna for 2021. Note: the value for house mice was obtained from the 2020 Standard Trapping Survey.

Indicator	Metric	Current value	Year	Performance/comments
Pest animals				
Rabbit	Occupancy	0%	2021	↔ Results similar to most previous years
Goat	Occupancy	2%	2021	↔ Results similar to most previous years
Pig	Occupancy	0%	2021	↔ Results similar to most previous years
Sheep	Occupancy	0%	2021	↔ Results similar to most previous years
Fallow deer	Occupancy	0%	2021	↔ Results similar to most previous years
House mouse	Occupancy	15%	2020	↔ Results similar to most previous years

Fire

Six hectares were burnt in prescribed burns at Paruna in 2021 (Table 7). This burn was primarily conducted to protect assets and infrastructure. In 2021, weather conditions outside of the total fire ban period were largely unsuitable for undertaking prescribed burns which meant only 6 ha of a planned 280 ha of prescribed burns were completed. No unplanned fires occurred at Paruna in 2021.

Table 7. Fire metrics for Paruna for 2021. Note: A long-term Fire Management Strategy is currently being developed to address the complexity of fire control at Paruna.

Indicator	Metric	Current value	Year	Performance/comments
Fire				
Extent of planned and unplanned burns (ha)	Area burnt in planned fire (ha)	6	2021	↔ Results similar to most previous years
	Area burnt in unplanned fire (ha)	0	2021	↔ Results similar to most previous years

Discussion

Occupancy of Common Brushtail Possum and Chuditch increased slightly in 2021, after declining between 2018 and 2020, indicating that these previously apparent declines may be part of long-term variation in response to multi-year environmental patterns. Continued monitoring over the coming years is required to verify this. Most reintroduced and extant mammals, particularly the small to medium-sized native mammals monitored by the Sanctuary-wide Camera Trapping Survey, appear relatively stable, although occupancy rates are generally low. Feral animal occupancy is lower in recent years than previously. Reintroduced Tammar Wallabies have successfully established at Paruna post reintroduction, likely facilitated by ongoing cat and fox control. Similarly, the results from the 2020 Black-flanked Rock-wallaby Trapping Survey show that the reintroduced population of Black-flanked Rock-wallabies is stable, although it remains small. It is possible that even low levels of predation may jeopardise the long-term persistence of these two species at Paruna and additional supplementary translocations may be required to maintain these populations in the future.

The Black Cockatoo Survey conducted in 2020 confirmed the presence of the three threatened species across 45% to 65% of survey sites. This survey was conducted as a trial in 2020, and the results will be used to develop a comprehensive survey for commencement in 2022.

The Sanctuary-wide Camera Trapping Survey confirmed that the number of feral predators and herbivores on Paruna remains low, presumably as a direct consequence of ongoing management undertaken by AWC. AWC's prescribed burning program was impeded by unsuitable conditions. As climate change continues to

affect weather patterns in the region, this issue is likely to become more common and will increase the complexities of conducting the fire management program at Paruna.

Acknowledgments

AWC acknowledges the Noongar people, the Traditional Custodians, of Noongar Country on which Paruna resides. We also acknowledge their continuing connection to land, culture and community. We pay our respects 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 our dedicated and passionate volunteers who donate their time in assisting the science team in their work. Thank you to the entire South-West Science and Operations teams for their hard work at Paruna that has made the running and collection of data from all our surveys possible.

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Enquiries should be made to John.Kanowski@australianwildlife.org