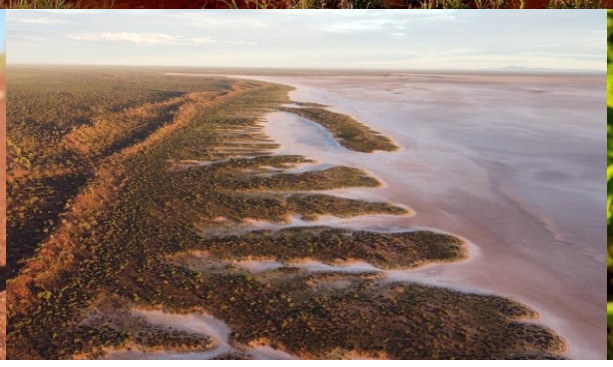
Newhaven Wildlife Sanctuary

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 Newhaven Wildlife Sanctuary (Newhaven). Metrics from the program are reported in annual Ecohealth Reports and Scorecards. This is the Ecohealth Report for 2020. Values of metrics presented in this report were based on data collected during surveys carried out in 2020. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In implementing the Ecohealth program in 2020, AWC closely monitored populations of two locally-extinct mammals reintroduced to Newhaven (Mala and Red-tailed Phascogales), and conducted targeted surveys of two extant species (Black-footed Rock Wallabies and Great Desert Skinks). Due to Covid-19, two planned 'surveillance monitoring' surveys - the annual Standard Trapping Survey for small mammals and reptiles, and the Standard Bird Survey - did not take place in 2020.

Newhaven was in its third year of drought conditions in 2020, of which 2019 was a year of record low rainfall. Generally, wildlife species in semi-arid Australia are at their lowest levels of abundance during these 'bust' conditions.

Reintroductions of the two species of locally-extinct mammals conducted to the fenced feral predator-free area on Newhaven have met success criteria to date, despite the dry conditions.

Overall survival of translocated Mala has been high. In a health check of the Mala population conducted in September – October 2020, half the females were carrying pouch young, adult weights were stable and average body condition has improved over time.

Surveys conducted at the end of 2020 showed that Red-tailed Phascogales are persisting around the release site.

The extant Black-footed Rock Wallaby has been adversely affected by the drought, with overall activity declining over the last few years. In 2020, overall activity and occupancy were at their lowest levels since 2016. Encouragingly, the activity of rock-wallabies on Wartikipirri Range, now within the fenced feral predator-free area, has increased slightly over the last few years - despite the drought - and in 2020 this metric was higher on Wartikipirri than populations outside the fence.

There was no evidence that drought was adversely impacting the Great Desert Skink. A measure of the activity of Great Desert Skinks (the mean number of active burrows) has increased by nearly 80% over the period 2015-20, including a slight increase from 2019-20.

In relation to threats, there were no breaches of the fenced area by foxes or cats in 2020. Densities of rabbits were at their lowest since 2015, presumably because of the drought. There was no prescribed burning and only one small wildfire on Newhaven in 2020. A number of fire-related metrics relating to the implementation of a conservation-oriented fire regime are on target.

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Cover photograph: Clockwise from top left: Wartikinpirri range, Thorny Devil (AWC/Kirsten Skinner, Lake Bennett (AWC/ John Massingham), Wild Parsnip (*Trachymene glaucifolia*)(AWC/Kirsten Skinner).

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. 2018a). The program focuses on selected 'indicator' species, guilds, processes and threats, using metrics 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 Newhaven 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 Newhaven Ecohealth Scorecard 2020 presents these metrics in a summary format.

Newhaven Wildlife Sanctuary

Newhaven (261,501 ha) is located in the south-western corner of the Northern Territory (Figure 1), near the intersection of three central Australian bioregions (Great Sandy Desert, Burt Plain and the MacDonnell Ranges Bioregions). It is surrounded by Yunkanjini Aboriginal Land Trust (ALT) to the north and west, Haasts Bluff ALT to the south and the Ngalurrtju ALT to the east.

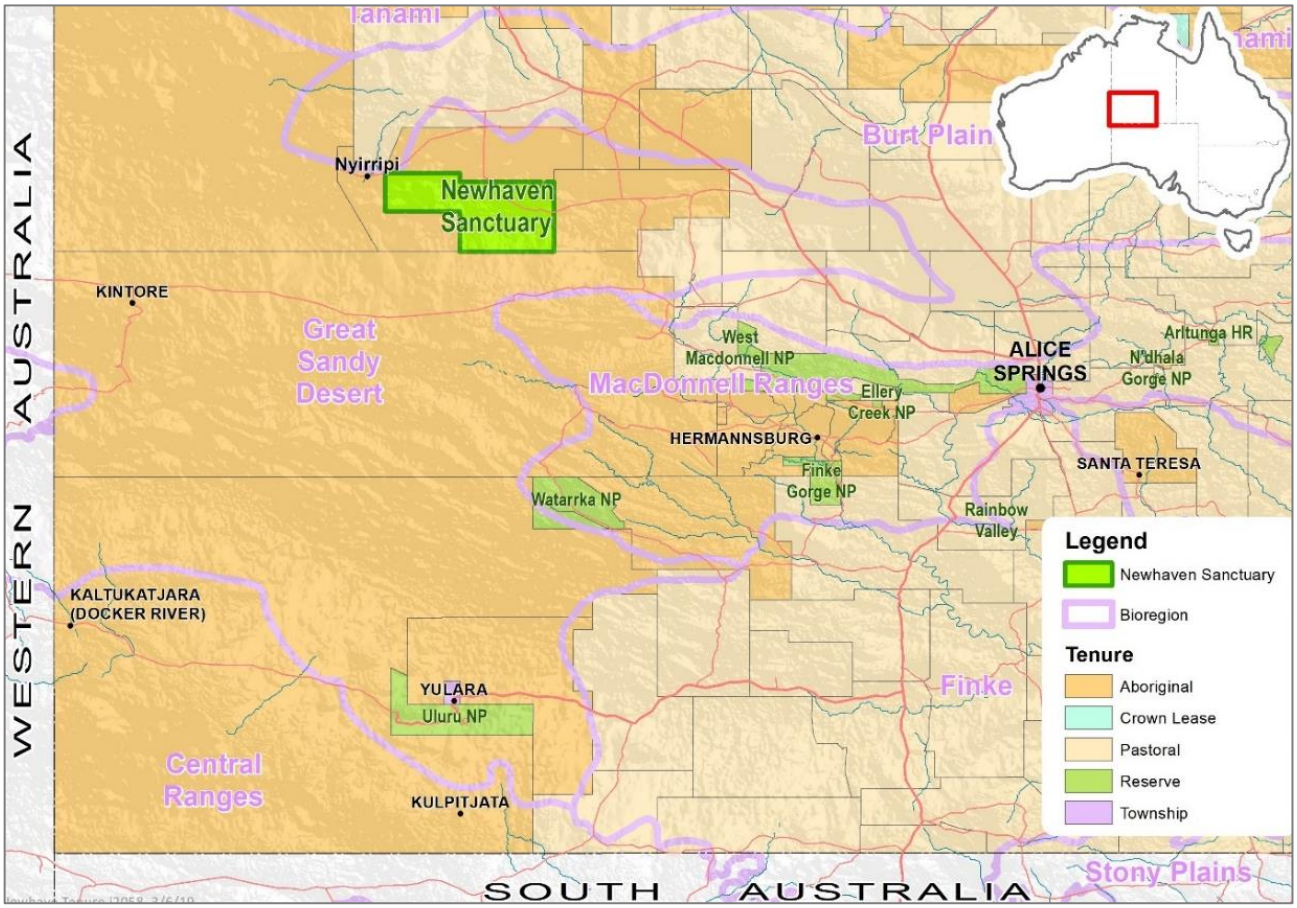

Figure 1. Location and regional context of Newhaven

The ranges, salt lakes, woodlands and sand plains of Newhaven are the traditional lands of the Ngalia-Warlpiri and Luritja people. Traditional Aboriginal land management was practiced up until the 1950s when people moved to newly established government settlements and cattle stations in the area. However, many Aboriginal people still maintain strong cultural links to the area. The communities of Nyirripi, Yuendumu, Karrinyarra, Papunya, Mt Liebig and Walungurru (Kintore) and the land trusts on which they sit, surround Newhaven. People with traditional ties to Newhaven live in all of these communities.

Newhaven was managed as a pastoral station from 1961 to 2000. The property was stocked (at relatively low numbers) with cattle, horses, donkeys and sheep.

Bird Life Australia (then Birds Australia) purchased Newhaven in 2000. The property was destocked in 2003.

In 2006, AWC acquired Newhaven and began to implement fire management, feral animal management and weed control on the property. In 2010, the Ngalia Warlpiri were formally recognised as the Traditional Owners of Newhaven. Traditional Owner and ranger groups are actively involved in delivery of land management and science programs on Newhaven including fire management, feral animal control and biological surveys.

Newhaven contributes to the protection of the ecosystems of the Great Sandy Desert Bioregion. This bioregion is well represented within the National Reserves System, with >30% protected (Australian Government, Dept. of Environment and Energy 2016). Newhaven Sanctuary protects 67% of the Newhaven Lakes region, listed as a site of national significance for biodiversity conservation by the NT government.

Over 294 species of native vertebrates are currently known or considered likely to occur on Newhaven. These include 29 mammals, 175 birds, 84 reptiles and 6 frogs. Seven of these species are listed as threatened by the Commonwealth (Environment Protection and Biodiversity Conservation Act 1999) or Northern Territory (Territory Parks and Wildlife Conservation Act 2000). At least 19 mammal species have been lost from Newhaven: of which eight are globally extinct.

In early 2019, Newhaven's 9,400 ha introduced predator-free exclosure, Stage 1, was completed (Figure 2) and declared free of introduced cats, foxes, camels and rabbits. At least 10 locally extinct mammal species are planned to be reintroduced to Newhaven. Mala (*Lagorchestes hirsutus*) were successfully reintroduced and translocated into Stage 1 during 2019 and 2020, and Red-tailed Phascoglaes (*Phascogale calura*) in 2020. This exclosure is also expected to benefit extant fauna such as the Black-footed Rock-wallaby (*Petrogale lateralis*) and Great Desert Skink (*Liopholis kintorei*) that are threatened by introduced predators (cats (*Felis catus*) and foxes (*Vulpes vulpes*)).

The vegetation of Newhaven was mapped by Latz et al. (2003), with additional detailed work focused on the central part of Newhaven (Schubert and Latz 2015), where the introduced predator-free area was established. Over 600 plant species have been recorded on Newhaven, including nine species listed as 'near threatened' in the NT. A total of 23 vegetation types have been identified on the property; these have been categorised into seven broad vegetation communities, in addition to salt lakes (Figure 2). Spinifex-dominated vegetation communities are widespread on Newhaven. Three vegetation communities cover two-thirds of Newhaven: these are Hard Spinifex Sandplains, which occupy 33% of the total area, predominantly in the western and northern part of the sanctuary; Spinifex Dunefields, occupying 19% of the sanctuary, mainly in the south; and Semi-saline Spinifex Sandplains, occupying 14% of Newhaven, in the east. Calcrete Grasslands, which occupy 16% of the sanctuary, in the south-east, are the only extensive vegetation type not dominated by Spinifex (Figure 2).

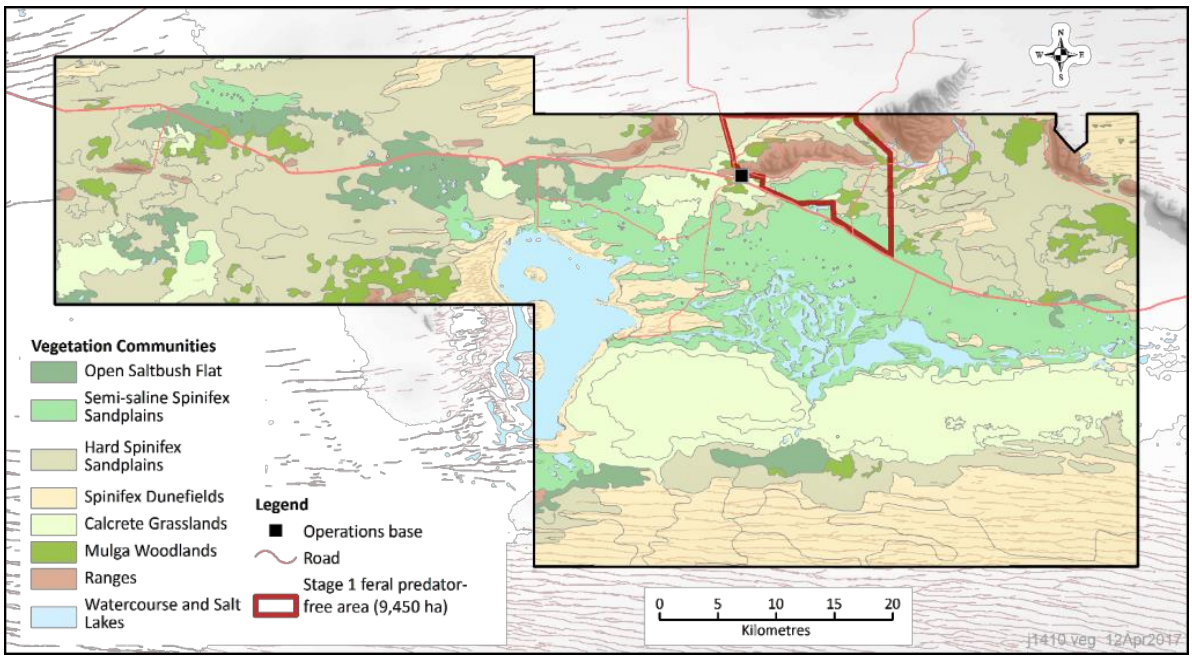

Figure 2. Newhaven vegetation types. The solid red line shows the fenced area.

Climate and weather summary

The climate at Newhaven is arid tropical (Thackway and Cresswell 1995) with hot summers and cool to cold winters. Mean annual rainfall, based on records collected at Newhaven homestead, from 1962 until present, is 322 mm (BOM) (Figure 3). However, variation in rainfall between years is very high, with long periods of drought interrupted by flooding rains. Rain events may occur at any time but are most common between November and March (Latz et al. 2003) (Figure 4). Rainfall is a key driver of biodiversity abundance and distribution across desert environments. Desert-specialised species are well-adapted to cope with these 'boom and bust' conditions; most can rapidly respond to rainfall events and endure prolonged dry periods.

The years 2018-20 have seen minimal rainfall at Newhaven with a record low of 42 mm recorded in 2019 followed by 183 mm in 2020 (BOM) (Figure 3). Consequently, in 2020, Newhaven's biodiversity experienced a 'bust' period with drought conditions providing low levels of resources, with consequences for the abundance of wildlife, especially eruptive species.

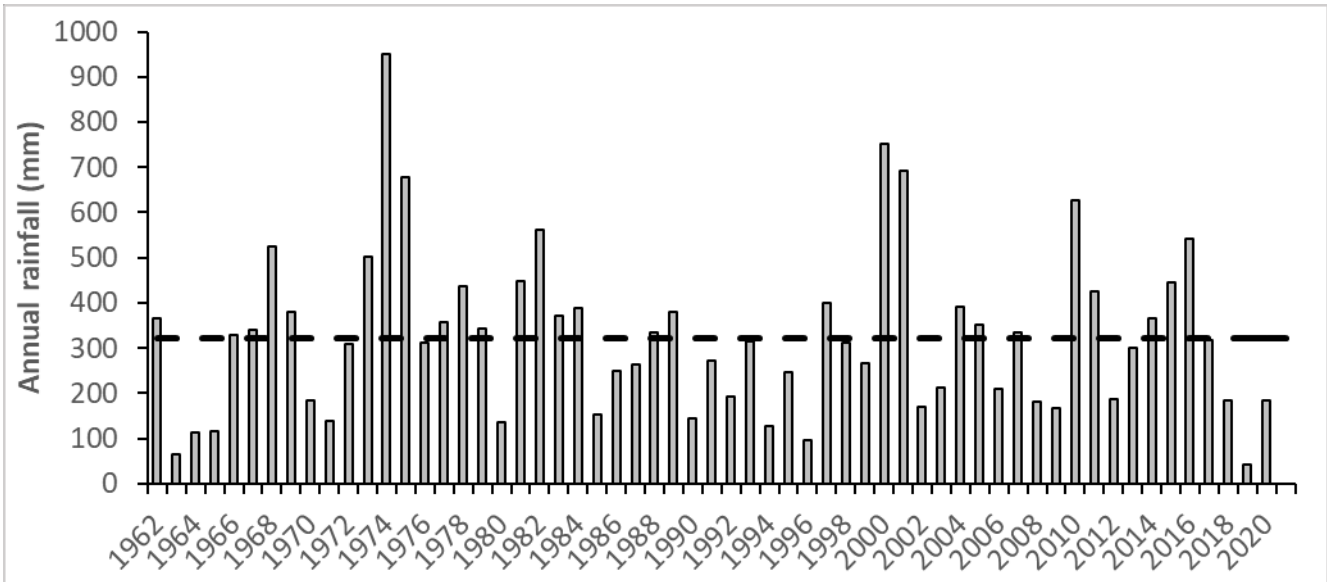

Figure 3. **Annual rainfall recorded at Newhaven homestead from 1962 to present.** The dashed horizontal line is the mean rainfall.

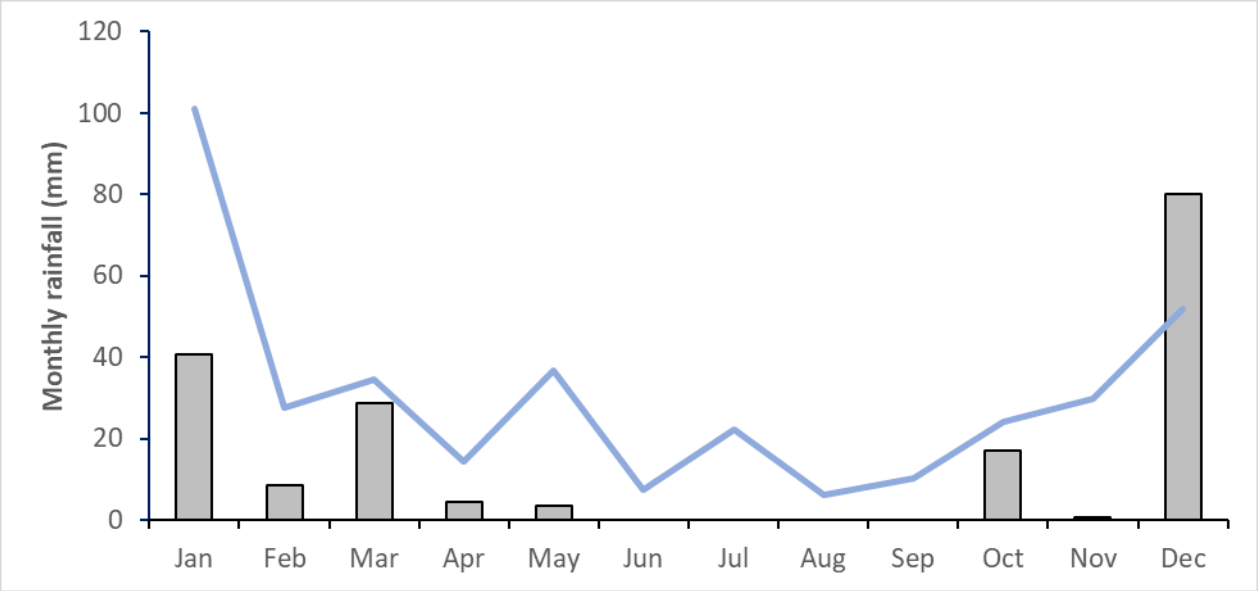

Figure 4. Monthly rainfall at Newhaven in 2020 (grey bars) compared to the decadal average (blue line)

Methods

Indicators and metrics

Newhaven'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). Threat metrics are selected to ensure monitoring the status and trends of introduced weeds, predators and herbivores and changed fire regimes (where appropriate).

There are 53 biodiversity indicators (species and guilds) selected for Newhaven sanctuary; the rationale for their selection is recorded for each indicator in Table 1. In this report, the methods and results are presented for 4 of these indicators for which surveys were carried out in 2020. Threat metrics relate to fire regimes, feral animals and weeds (Table 2), of which the first two are reported on in this report based upon 2020 surveys.

Table 1. Biodiversity indicators for Ecohealth monitoring plan for Newhaven. Rationale for selection: T = threatened or declining; D = strong driver of ecosystem function; S = surveillance monitoring. Metric definitions: Population estimate = number of individuals on Newhaven; abundance = number of individuals/100 trap nights (TN) [or site]; activity = number of records/survey (or site); mean activity = mean number of records/site; occupancy = proportion of sites recorded; richness = mean number of species/site.

Indicator	Rationale			Survey method (Survey Name)	Metric/s
	T	D	S		
Mammals					
Reintroduced mammals					
Mala (*Lagorchestes hirsutus*)	*			Telemetry Thomas traps (Mala Health Check)	Survival Condition, reproduction, [population estimate]
Red-tailed Phascogale (*Phascogale calura*)	*			Nest boxes, camera traps (Red-tailed Phascogale Survey)	Occupancy across Establishment Zone (camera traps), occupancy across Establishment Zone (nest boxes)
Small-medium mammals					
Black-footed Rock-wallaby (*Petrogale lateralis*)	*			Scat plots, transects (Black-footed Rock-wallaby Survey)	Activity, occupancy
Brush-tailed Mulgara (*Dasycercus blythi*)	*			Pitfall traps, box traps, tracks (Standard Trapping Survey)	Abundance, occupancy
Wongai Ningaui (*Ningaui ridei*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Fat-tailed Pseudantechinus (*Pseudantechinus macdonnellensis*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Stripe-faced Dunnart (*Sminthopsis macroura*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Ooldea Dunnart (*Sminthopsis ooldea*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Lesser Hairy-footed Dunnart (*Sminthopsis youngsoni*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Dasyurids – guild	*	*	*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance, richness
Spinifex Hopping-mouse (*Notomys alexis*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Desert Mouse (*Pseudomys desertor*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Sandy Inland Mouse (*Pseudomys hermannsburgensis*)			*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance
Long-haired Rat (*Rattus villosissimus*)			*	Box traps, pitfall traps	Abundance

Indicator	Rationale			Survey method (Survey Name)	Metric/s
	T	D	S		
				(Standard Trapping Survey)	
Rodents – guild	*	*	*	Box traps, pitfall traps (Standard Trapping Survey)	Abundance, richness
All small-medium mammals	*	*	*	Box traps, cage traps, pitfall traps (Standard Trapping Survey)	Abundance, richness
Large herbivores					
Red Kangaroo (*Osphranter rufus*)			*	Track Survey	Occupancy
Predators					
Dingo (*Canis lupis dingo*)		*		Camera Survey	Population estimate
Bats					
Microbats - guild			*	Songmeter SM4BAT detectors (Bat Survey)	Activity, richness
Reptiles					
Military Dragon (*Ctenophorus isolepis*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Central Netted Dragon (*Ctenophorus nuchalis*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Dwarf Bearded Dragon (*Pogona minor*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Reptiles – agamids (guild)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness
Leonardi's Skink (*Ctenotus leonhardii*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Leopard Skink (*Ctenotus pantherinus*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Bar-shouldered Skink (*Ctenotus inornatus*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Great Desert Skink (*Liopholis kintorei*)	*	*		Counts of active GDS burrows on fixed transects at known key sub-populations (Great Desert Skink Survey)	Activity, Occupancy
Reptiles – skinks (guild)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness
Reptiles – pygopods (guild)		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness

Indicator	Rationale			Survey method (Survey Name)	Metric/s
	T	D	S		
Bynoe's Prickly Gecko (*Heteronotia binoei*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Western Beaked Gecko (*Rhynchoedura ornata*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Spiny-tailed Gecko (*Strophurus ciliaris*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Reptiles – geckos (guild)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness
Short-tailed Pygmy Monitor (*Varanus brevicauda*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Pygmy Desert Monitor (*Varanus eremius*)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance
Gould's Goanna (*Varanus gouldii*)		*	*	Track Survey and/or Camera Survey	Abundance
Perentie (*Varanus giganteus*)			*	Track Survey and/or Camera Survey	Occupancy
Reptiles - varanids (guild)		*	*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness
Reptiles – snakes (guild)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness
All reptiles (less large varanids)			*	Pitfall traps, funnel traps (Standard Trapping Survey)	Abundance, richness
Birds					
Rufous-crowned Emu-wren (*Stipiturus ruficeps*)	*			TBD	Occupancy
Striated Grasswren (*Amytornis striatus*)	*			Playback (Grasswren Survey)	Occupancy
Dusky Grasswren (*Amytornis purnelli*)	*			Playback (Grasswren Survey)	Occupancy
Ground active birds - guild	*		*	20-min counts (Diurnal Bird Survey)	Activity, richness
Honeyeaters - guild			*	20-min counts (Diurnal Bird Survey)	Activity, richness
All birds (diurnal)			*	20-min counts (Diurnal Bird Survey)	Activity, richness
Nocturnal birds - guild			*	Acoustic recorders (Nocturnal Bird Survey)	Activity, richness
Frogs					
Main's Frog (*Cyclorana maini*)			*	Pitfall traps (Standard Trapping Survey), Frog Targeted Survey	Mean activity

Indicator	Rationale			Survey method (Survey Name)	Metric/s
	T	D	S		
Desert Spadefoot Toad (*Notaden nichollsi*)			*	Pitfall traps (Standard Trapping Survey), Frog Targeted Survey	Mean activity
All frogs			*	Pitfall traps (Standard Trapping Survey), Frog Targetted Survey	Mean activity and richness
Vegetation					
Tree cover and composition		*	*	Vegetation Survey	Percent canopy cover, richness
Shrub cover and composition		*	*	Vegetation Survey	Percent shrub cover, richness
Ground cover and composition		*		Vegetation Survey	Percent ground cover, richness

Table 2. Threat indicators for Ecohealth monitoring program for Newhaven. Metric definitions: Population estimate = number of individuals, density = detections or individuals per unit area or distance; activity = number of records per survey; abundance = detections/ 100 trap nights; occupancy = proportion of sites recorded.

Indicator	Rationale	Survey Method	Metric
Feral Herbivores			
Camels (*Camelus dromedarius*)	Threat to wildlife, vegetation	Camel Survey	TBD
Rabbits (*Oryctolagus cuniculus*)	Threat to wildlife, vegetation	Warren activity (Rabbit Survey) (outside Stage 1)	Density and Number removed
Feral Predators			
Cats (*Felis catus*)	Major threat to wildlife	Feral Predator Survey (Stage 1); Feral Predator Survey (Sanctuary-wide)	Activity
Foxes (*Vulpes vulpes*)	Major threat to wildlife	Feral Predator Survey (Stage 1); Feral Predator Survey (Sanctuary-wide)	Activity
Weeds	Potential to modify vegetation structure, composition and dynamics, habitat attributes, fuel loads	In development (Newhaven Weed Strategy)	In development
Fire	Key driver of vegetation dynamics, structure and composition, habitat attributes	Fire scar analysis (Moore et al. 2021)	1. Fire extent 2. Fire severity 3. Long unburnt vegetation 4. Diversity of age classes in spinifex vegetation communities

Survey types 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 Diurnal Bird Survey in 2007 and Standard Trapping Survey in 2017, however due to Covid-19 restrictions, these surveys did not take place in 2020. Other components of the Newhaven's Ecohealth monitoring program have been added in subsequent years. The surveys conducted in 2020 were:

- Mala survival;
- Mala Health Check;
- Red-tailed Phascogale Survey;
- Black-footed Rock Wallaby Survey;
- Great Desert Skink Survey;
- Rabbit Survey (outside Stage 1); and
- Feral Predator Survey (Stage 1).

Survey 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 history and effort for Ecohealth Monitoring Program surveys on Newhaven Wildlife Sanctuary in 2020

Survey name	Effort	Description/Comment	Previous Surveys
Mala survival	9 individuals tracked for three months	Mala released to Stage 1 tracked with radio-collars to determine survival.	2019 – 45 individuals tracked
Mala Health Check	374 trap nights.	Targeted trapping to monitor health following reintroduction.	2019 – 146 trap nights
Red-tailed Phascogale Survey	18,793 trap nights 634 nest-box checks	52 nest boxes with camera traps and 67 grid camera traps to monitor occupancy across Establishment Zone following reintroduction. Cameras deployed from June 2020.	Species was reintroduced in 2020
Black-footed Rock Wallaby Activity Survey	125 plots	1 m plot centroids at 125 plots over three separates ranges. Total scat count within each plot.	2020 – 125 plots on 3 ranges 2019 - 190 plots on 4 ranges 2018 – 215 plots on 5 ranges 2017 – 196 plots on 5 ranges 2016 – 215 plots on 5 ranges 2015 – 180 plots on 4 ranges
Great Desert Skink Survey	44 km	Eight sites each with 11 pre-defined, 500 m long, transects.	annually, 2015-19 – 44 km walked
Feral Predator Survey (Stage 1)	20,805 trap nights	57 sites inside and outside Stage 1 in 2020, left in situ for whole year.	
Rabbit Survey	10.5 hours assessing warrens	64 warrens at 13 sites outside Stage 1, searched for signs of activity	annually, 2015-19 – 10.5 hours assessing warrens

Survey design and methods

Reintroduced mammals

In 2020, two locally-extinct mammals - Mala and Red-tailed Phascogales - were reintroduced to Stage 1, the 9,400 ha feral predator-free fenced area. The survival and establishment of these species were monitored as per protocols set out in relevant Translocation Proposals (Kanowski et al. 2018b; Collett et al. 2020).

Mala

Survival

Nine of 42 Mala translocated from Scotia Wildlife Sanctuary to Newhaven in August 2020 were radio-collared to measure survival. A total of 45 individuals from two previous releases were radio-tracked in 2019.

Breeding, recruitment

'Health checks' of Mala were conducted in March and September-October 2020. To capture animals for assessment, targeted trapping was conducted over three nights, with trap site locations based on data from radio-collared individuals. Traps were set prior to sunset and baited, then left undisturbed for a minimum of 2 hours after sunset before checking. Data on body weight, condition, breeding status (whether females were carrying pouch young) and morphometric data were recorded for all captured animals. A condition score was allocated to each individual as follows:

1 Emaciated (no fat/muscle conditions

2 Very underconditioned (some bones prominent)

3 Underconditioned

4 Slightly under conditioned (lean but still with muscle mass)

5 Ideal condition (smooth lines).

Red-tailed Phascogales

In June and November 2020, two cohorts of Red-tailed Phascogales were reintroduced into Stage 1 from a breeding program at Alice Springs Desert Park. The first cohort comprised 29 animals (15 males, 16 females) and the second 61 animals (30 males, 31 females).

The Red-tailed Phascogale is a small semi-arboreal species that is challenging to monitor with standard techniques. Evidence of establishment throughout the 'Establishment Zone' (a 9 km^2 area within Stage 1, surrounding the release sites) was monitored using two methods: (1) a grid of 67 camera traps surrounding the release site, and (2) checks for occupancy of nest-boxes (Figure 5).

For method (1), 67 cameras were set up at a spacing of approximately 500 m in the Establishment Zone. In addition, a total of 52 cameras were positioned beneath all nest-boxes (Figure 5). Traps were unbaited for the first two weeks post-release, after which time they were lured with universal bait (i.e., peanut butter, sardines, oats). All cameras were set 1.5 m above the ground, facing downwards at a 45^o angle towards a bait, and set to take 3 images with no delay between triggers. The cameras were checked weekly in the first month following release, and monthly from five weeks post-release.

For method (2), nest-boxes used to release animals were checked weekly for signs of occupation in the first month post-release. Subsequently, all 52 nest boxes within the Establishment Zone were checked monthly, commencing from the fifth week post-release. Occupation was defined as either the physical presence of an animal or the presence of Red-tailed Phascogale scat and scent.

Extant threatened species

Black-footed Rock-wallaby

Black-footed Rock-wallaby (BFRW) on Newhaven occur as small, presumably isolated, populations on quartzite ranges distributed across the northern portion of the sanctuary. The activity of Black-footed Rock-wallaby has been monitored annually since 2015 (Schofield 2015). Originally four locations were targeted for surveys: Mount Gurner, Robb's Hill, Wartikinpiri Range and Siddeley Range (Figure 6). AWC subsequently gained access to Yaripilangu with colonies there first surveyed in July 2017. Mt Gurner has not been surveyed since 2018, because no evidence of BFRW occupation was detected during the 2017 survey. In 2020, the Siddeley Range was not surveyed due to Covid-19 restrictions affecting the availability of volunteers to undertake the survey.

The activity survey measures the accumulation of Black-footed Rock-wallaby scats over a 12-month period. There are 191 permanent monitoring plots across the four known occupied ranges.

In 2020, 125 1 m^2 permanent scat plots were surveyed across three known sites of Black-footed Rock-wallaby occupancy. Centroids for these plots are permanently marked. A string 56.4 cm long was used to measure a radius of a circle ($1m^2$) that defines the plot. Only scats found within this circle were recorded. As scats were counted and recorded they were removed from the plots and discarded.

Total scat counts were recorded of the Black-footed Rock-wallaby (classified separately as Adult, Sub-adult and 'ancient', based on size and shape (Table 4) and appearance – i.e., sheen, colour and surface integrity (Table 5). Rock-wallaby scats were distinguished by size and shape from Euro (*Macropus robustus*).

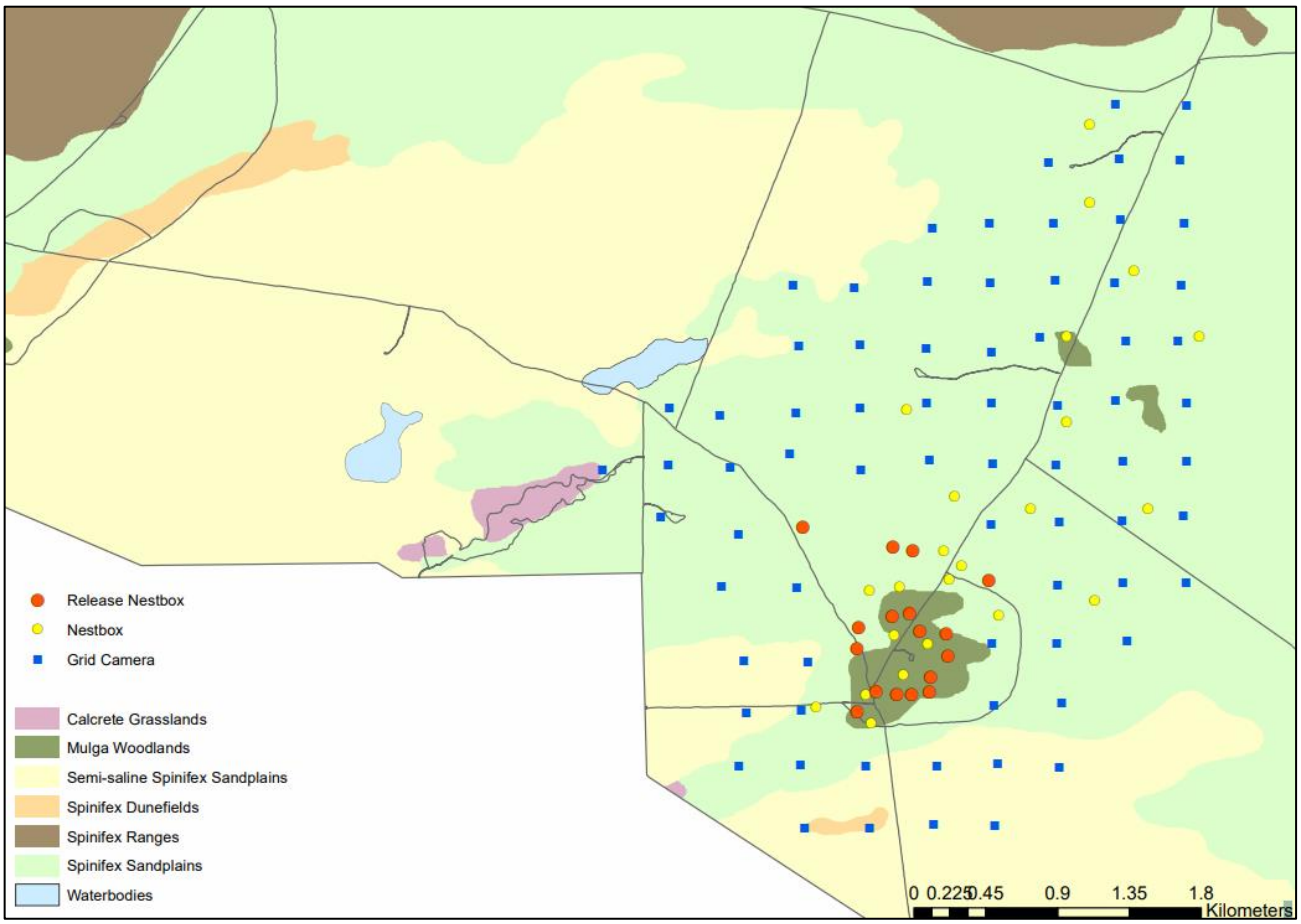

Figure 5. Location of Red-tailed Phascogale nest boxes and camera traps throughout the Establishment Zone on Newhaven

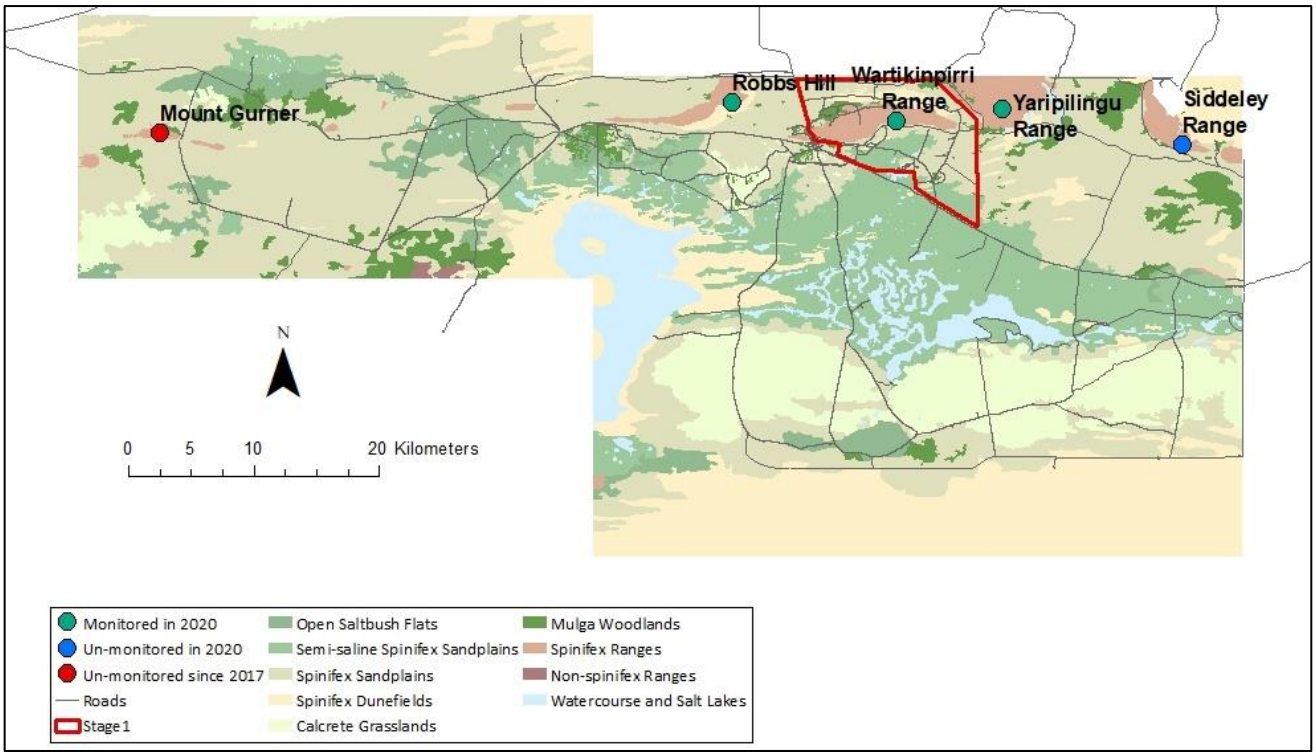

Figure 6. Location of monitoring sites and status of BFRW Activity Survey on Newhaven

Table 4. Black-footed Rock-wallaby animal age scat classification

Classification	Scat Appearance
Adult BFRW	All macropod scats <2 cm in length and >1 cm in diameter. For visual identification characteristics see Appendix 1: Pictorial Guide to macropod scats found on Newhaven.
Sub-adult BFRW	All macropod scats <2 cm in length and <1 cm in diameter. For visual identification characteristics see Appendix 1: Pictorial Guide to macropod scats found on Newhaven.

Table 5. Black-footed Rock-wallaby scat age classification definitions

Classification	Scat Appearance
Fresh	Black scat with majority of surface glossy, 70% of surface intact, but including some scats with widespread surface cracking, tessellated appearance, or with areas of dullness or breaks in surface.
Old	Grey or whitish scat or black/dark brown with no glossy sheen, or some gloss but less than 70% surface intact.
Ancient	Grey-brown to whitish with the outer surface powdery and lacking any fibrous material. These can be reduced through decomposition to 'sub-adult' scat size. Check timing of last fires as if more than 12 months prior any burnt scats can be categorised as 'Ancient'.

Great Desert Skink

The abundance of Great Desert Skinks (GDS) was monitored at eight sites, each 50 ha in extent, distributed across suitable habitat on Newhaven, representing a range of population densities and fire histories (Figure 7). The survey has been undertaken annually since 2015 in February when Great Desert Skink populations are at peak activity. These sites are predominantly within the habitat Semi-Saline Spinifex Plains. This vegetation type occupies around 13 per cent of Newhaven and is typically dominated by *Triodia pungens,* and a range of shrubs, such as *Hakea leucoptera* and *Melaleuca glomerata* (Latz et al. 2003).

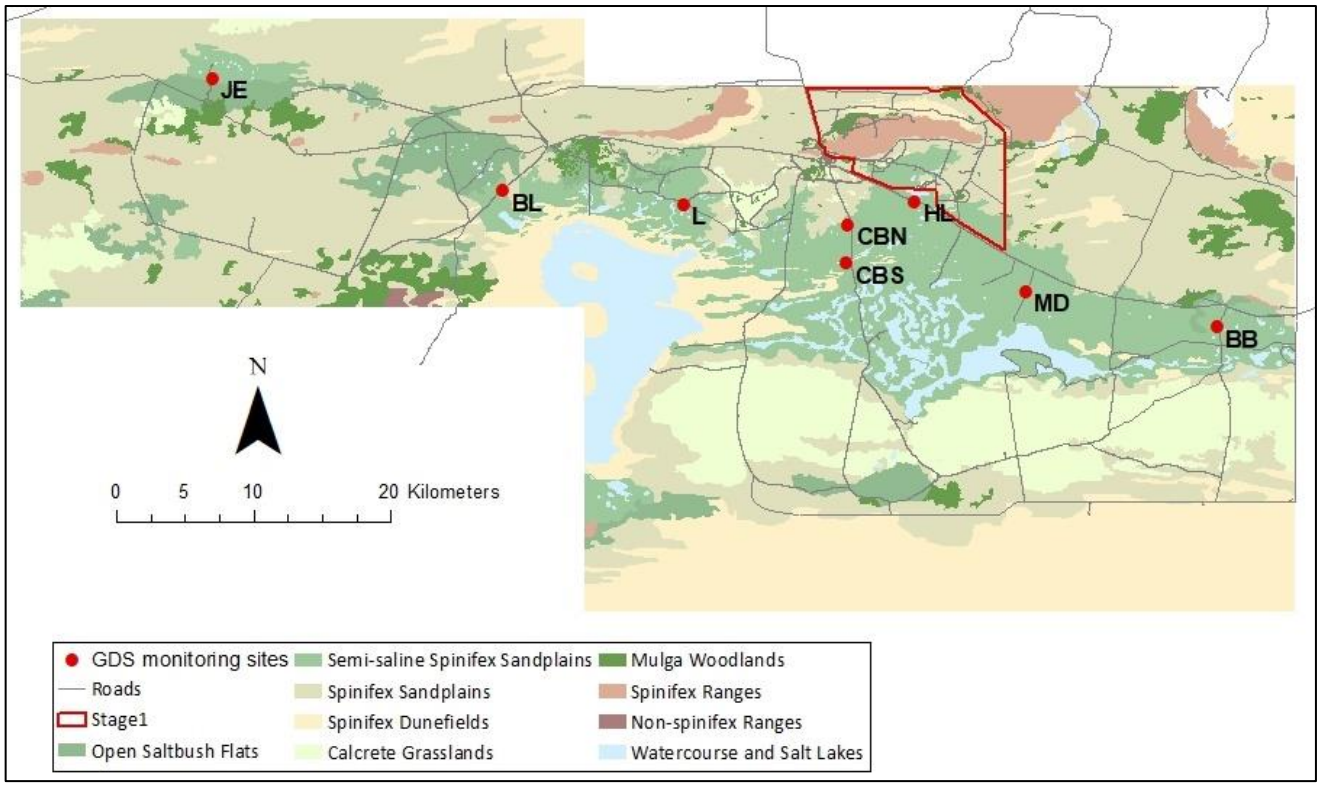

Figure 7. **Great Desert Skink monitoring sites on Newhaven.** JE = Jilpalpa East, BL = Blue Lagoon, L = Lakes Tour, CBN = Camel Bore North, CBS = Camel Bore South, HL = Honeymoon Lake, MD = Mulgara Drive**,** BB = Blom Bore.

At each site, surveys are conducted along 11 parallel transects, each 500 m in length and spaced at 100 m intervals (Figure 8). Some transects encompass waterbodies, reducing the total area of GDS habitat. The pre-defined transects were walked by two observers searching 5 m either side of the transect line for GDS burrow systems. The burrow systems were confirmed by the presence of a latrine. For each new and previously located burrow-system the following data were recorded:

- burrow system ID or coordinates;
- burrow system occupancy;
- number of active or inactive burrow entrances;
- number of latrines;
- presence and count category (0-5, 6-10, >10) of adult, sub-adult and juvenile GDS scats in the latrine;
- approximate dimensions of the complete burrow system;
- vegetation cover abundance;
- burn type; and
- sign of predator activity at burrow system.

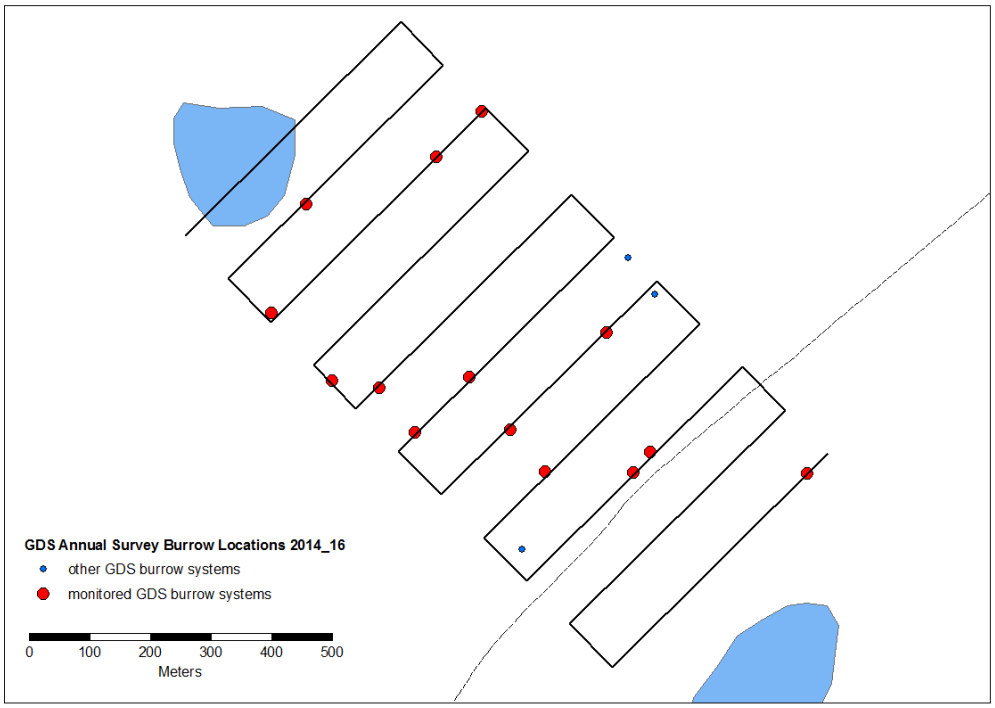

Figure 8. An example of a Great Desert Skink monitoring site with tracking transect and previously recorded burrow-systems. Map also shows roads (dashed line) and waterbodies across the site.

Threats

Rabbit Survey

Based on surveys conducted in 2012-2015 assessing the distribution and abundance of rabbits on Newhaven, 13 sites were selected within areas identified as preferred rabbit habitat for long-term monitoring outside the fenced area (Figure 9). The survey is conducted annually in September/October to avoid typical breeding times for rabbits in the arid zone. During periods of above average rainfall, these dates may be altered to avoid overlap with extended breeding periods.

At each monitoring site, all warrens within a 25 ha (500 m X 500 m) were mapped. The number of active and inactive entrances at each warren was assessed using criteria adapted from Williams et al. (1995), with each of the 64 mapped warrens searched for approximately 10 minutes. Indicators of activity were:

- Fresh tracks/ scats in entrance
- No spider webs and no accumulated leaf litter in entrance
- Powdery loose soil on floor of entrance.

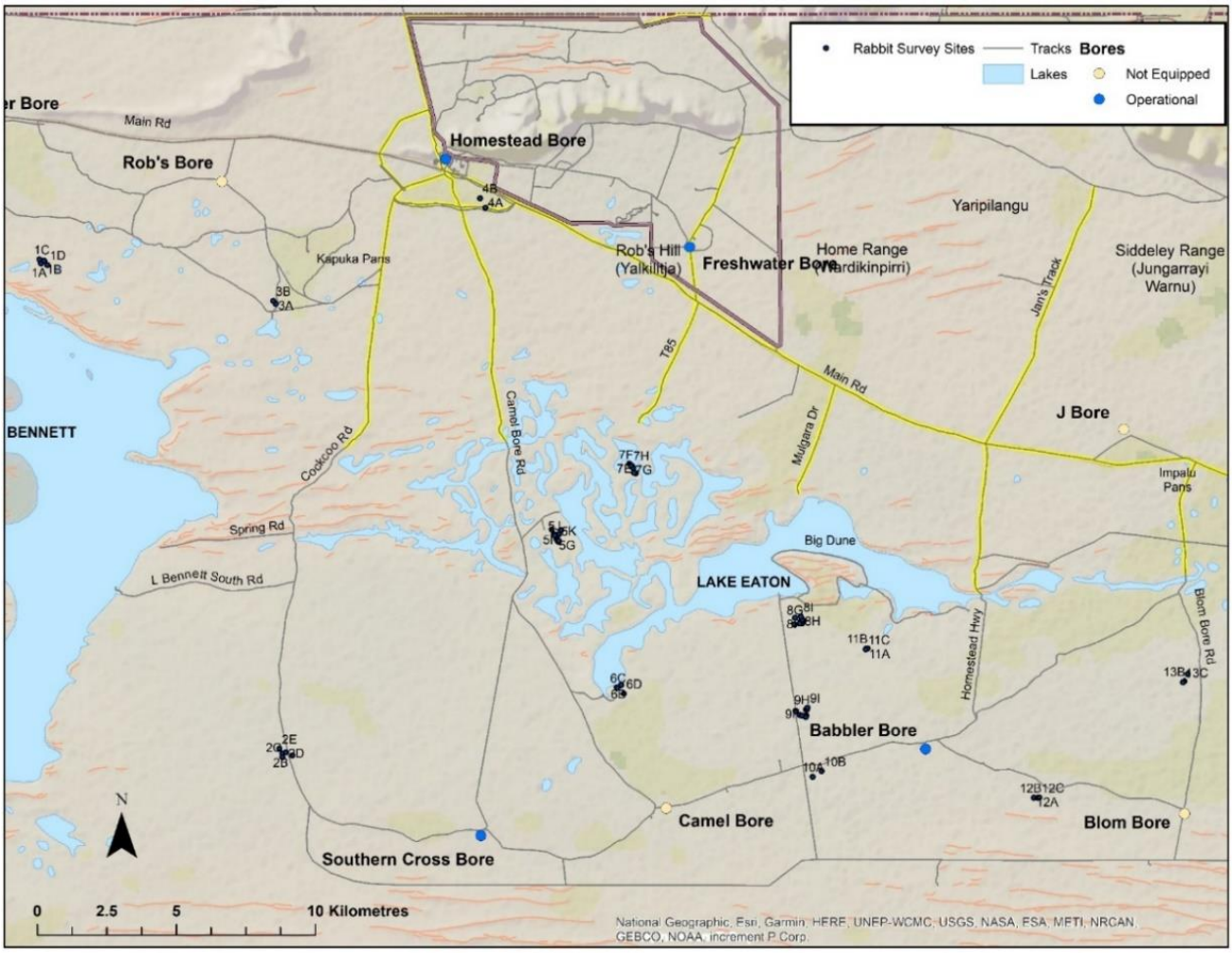

Figure 9. Newhaven rabbit warren survey sites outside Stage 1 fenced area.

Feral Predator Survey (Stage 1)

An array of 57 camera traps was employed to monitor introduced predator incursions in the fenced area (Figure 10). Cameras were placed at strategic locations along the fence, at road junctions and in the Wartikinpirri Range, set at a height of 1.5 m facing along tracks or towards the fence, were not baited and were set to take 3 images with no delay between triggers. The cameras were checked on a quarterly basis.

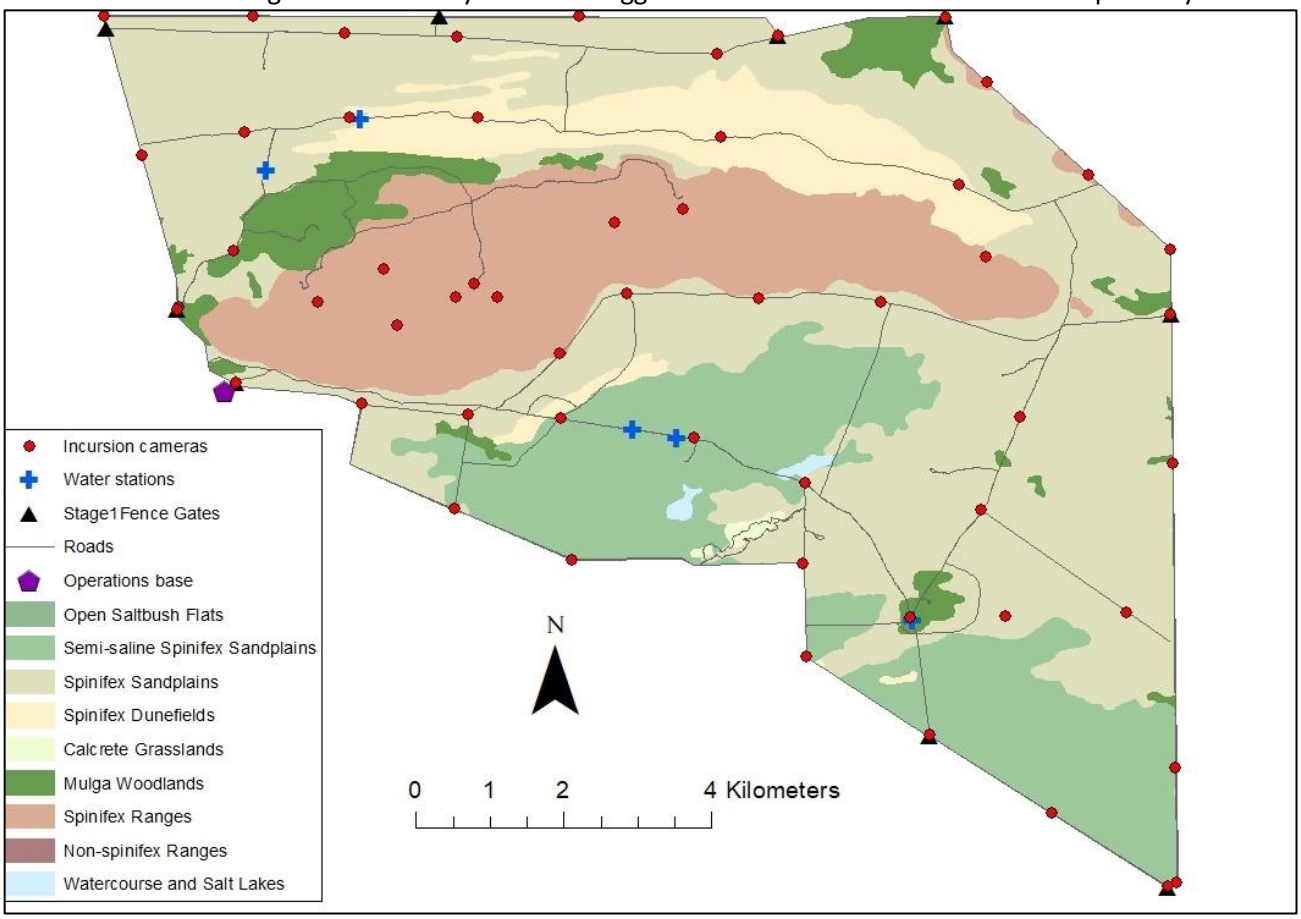

Figure 10. Stage 1 introduced predator incursion monitoring camera trap sites.

Analysis methods

Reintroduced species

Metrics for reintroduced species were assessed in relation to performance criteria relevant to the stage of the translocation as nominated in the Translocation Proposals for each species (Kanowski et al. 2018b; Collett et al. 2020).

For **Mala**, relevant metrics included survival, breeding and recruitment. Information was also collected on weight and body condition, the latter collated as the range and average value of scores.

The **Red-tailed Phascogale**. For this species, we monitored occupancy in the 'establishment zone' (that is, the area around release locations), using two techniques as follows:

- the percentage of camera traps at which Red-tailed Phascogales were detected: there were 115 camera traps over July to October 2020, and 119 over November 2020 to March 2021.
- the percentage of all 52 nest boxes at which Red-tailed Phascogales were detected.

Extant threatened species

Black-footed Rock-wallaby

Total rock-wallaby scat count (accumulated over a 12-month period) were used to report against:

- Activity – average number of combined fresh and old scats per plot (by age class), for each range surveyed, and across all ranges surveyed.
- Occupancy – proportion of plots with fresh rock-wallaby scat detected (by age class), for each range surveyed, and across all ranges surveyed.

Great Desert Skink

The metrics for monitoring GDS populations are activity and occupancy. Activity is the average number of active burrows at each of the eight closely-monitored sites, calculated first at the average number of active burrows per transect at each site, and then as the average across all sites. Only burrow systems located within 5 m each side of the transect were included in the data analysis.

Occupancy is the proportion of sites at which Great Desert Skink tracks are detected during the 'Track Survey' (a sanctuary-wide survey). This survey was not conducted in 2020.

Threats

Rabbits

The rabbit density is based on Williams et al (1995) data on burrow occupancy, where in a non-breeding period, 1.6 active entrances equals one adult rabbit. An estimate of rabbit density for each site was calculated as follows:

a=mean active entrances/warren
d=warren density at site (warrens/ha)
D=rabbits/ha
Estimated density of rabbits:

$$D = d\left(\frac{a}{1.6}\right)$$

The rabbit abundance estimates generated by this method are indices only but can be repeatedly collected to indicate changes in the population over time.

Feral Predators

An abundance index was calculated for cats and foxes, as the number of detections per 100 trap-nights.

Results

Biodiversity indicators

Reintroduced mammals

Mala

Survival

The final translocation of Mala to Newhaven was conducted in August 2020. Nine of the 40 individuals were fitted with radio-collars to monitor survival. One collar failed shortly after deployment. There were three mortalities from the monitored cohort, a survival rate of 63%. Survival rates from the two cohorts released in 2019 were 93% and 100%. The lower survival rate in the August 2020 release presumably reflects the fact that this was a 'salvage' translocation of all remaining animals at Scotia, i.e., it was not selective, with animals in any condition moved to relocate the Scotia population to Newhaven.

Across all translocations, 45 of 54 radio-collared Mala survived translocation to Stage 1 (assessed at 3 months post-release). The overall survival rate was therefore 83%, well above the success criterion of 50% set out in the Translocation Proposal.

Breeding, recruitment, body condition and weight

The health check conducted of the reintroduced Mala population in September-October 2020 involved assessment of 52 individuals which represented all source locations used to establish the Newhaven population.

Breeding and recruitment

Despite the dry conditions that followed the reintroduction of Mala to Newhaven, new individuals have been recruited into the population. At the September 2020 health check, half the adult females (50%) were carrying pouch young (PY), an increase from the previous figure of 38% in March 2020 (Figure 11). The September 2020 result is on the threshold of the success criteria set out in the Translocation Proposal (>50% female should be carrying pouch young two years post-release, presuming average rainfall or above). These results are encouraging, as Newhaven has been in drought up to 2020.

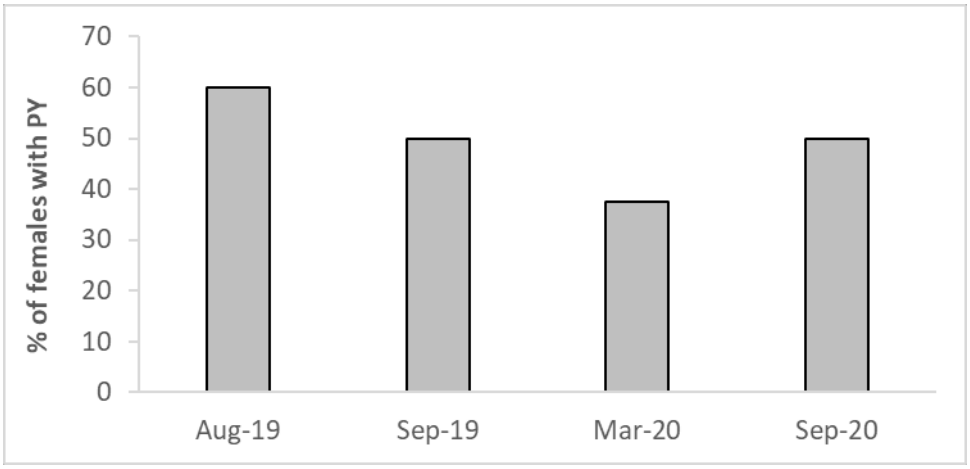

Figure 11. Proportion of adult females carrying pouch young in Mala health-checks, 2019-20

The number of sub-adult Mala captured has increased from March to September 2020 as the population has become established in Stage 1 (Table 6).

Table 6. Number of adult and sub-adult Mala captured during health checks at Newhaven

	Aug-19	Sept-19	Mar-20	Sep-20
Adults	25	22	20	45
Sub-adults	0	0	1	7
Total	25	22	21	52

Body condition

The condition of individuals captured in September-October 2020 ranged from 2 to 5. The average score was 3.7, higher than previous health checks (Table 7). Five individuals were scored at 5 (the ideal condition), 26 at 4 (slightly underconditioned), 17 at 3 (underconditioned), and three at 2 (very underconditioned: this last group included two recently translocated individuals from Scotia).

Table 7. Mala average condition score, August 2019 – September 2020. Number of individuals assessed at each period shown in brackets. See methods re scores; 'ideal' score is 5.

	Aug-19	Sept-19	March-20	Sep-20
Females	3.6 (10)	3.37 (8)	3.37 (8)	3.88 (26)
Males	3.4 (15)	3.57 (14)	3.67 (15)	3.46 (26)
All	**3.48**	**3.5**	**3.5**	**3.7**

Body weight

Despite the ongoing dry conditions, the average weight of captured Mala remained stable between August 2019 and September 2020 (Table 8), varying by no more than 5% for females and 2% for males.

Table 8. Average weight (g) of adult Mala captured during Stage 1 health-checks at Newhaven. These data exclude females with pouch young, and where relevant have been adjusted to exclude the weight of collars. Number of individuals assessed shown in brackets.

	Aug-19	Sept-19	Mar-20	Sep-20
Females	1,375 (4)	1,354 (4)	1,334 (5)	1,404 (11)
Males	1,437 (15)	1,471 (14)	1,450 (14)	1,435 (23)
All	**1,424**	**1,445**	**1,420**	**1,425**

Red-tailed Phascogales

Translocated Red-tailed Phascogales made some use of the nest-boxes provided for their use, although generally use declined over time (Figure 12). Across the Establishment Zone, 7% of nest boxes were occupied as of October 2020 (Figure 12) following the June release of 29 individuals), and 7.7% of nest boxes were occupied as at December 2020 (following the November release of 61 individuals). Following the June release, there were only two physical sightings of Red-tailed Phascogales in release nest boxes - all other detections were of phascogale sign (scent or scat), indicating potential inhabitance and/ or investigation.

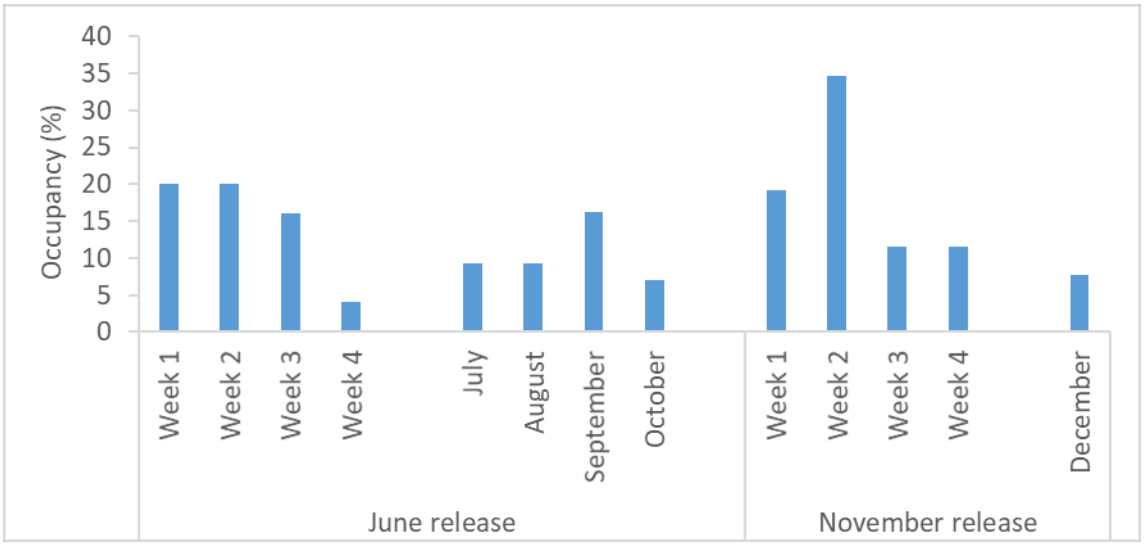

Figure 12. Use of nest-boxed by Red-tailed Phascogales post-release, June and November 2020. Only nest boxes used for releasing animals were checked in weeks 1-4, following which all nest boxes (52 spread throughout the Establishment Zone) were checked for signs of use.

Similar patterns of establishment were detected by the array of 115-119 camera traps in the Establishment Zone. Following the second release, occupancy declined from 25% in November 2020 to 8% in March 2021 (Figure 13).

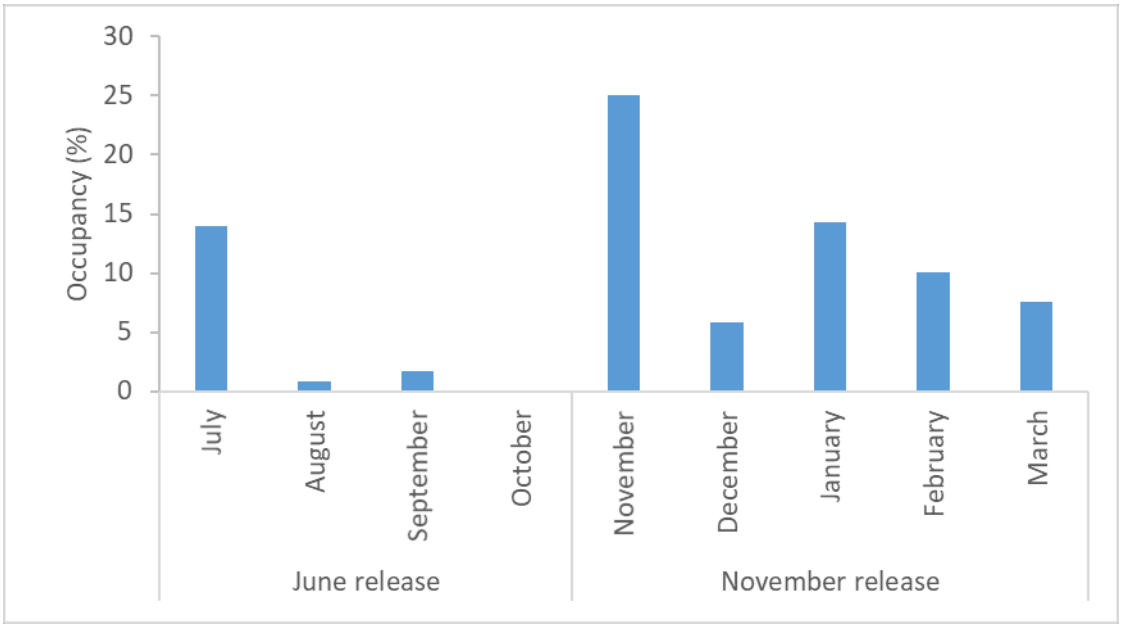

Figure 13. Proportion of camera trap sites occupied by Red-tailed Phascogale per month. This data excludes detections made in the first two weeks post-release when camera traps were not lured.

The generally low occupancy of nest boxes by Red-tailed Phascogales is similar to results obtained for AWC's reintroduction of the species to Mt Gibson (WA), where natural nest sites (e.g., tree hollows, under bark) were used in preference to nest-boxes. The low levels of detection across the camera trap grid may be due to the dispersal of individuals from the release site and/ or to the difficulty of monitoring this species. Incidental observations suggest that the Red-tailed Phascogales are successfully persisting on Newhaven.

Extant threatened species

Black-footed Rock-wallaby

Overall, there has been a substantial decline in activity of Black-footed Rock-wallabies on Newhaven over the past five years (Figure 14). This decline is primarily driven by trends in the activity of adult wallabies. Encouragingly, the activity of adult rock-wallabies in the Wartikinpirri population (now within Stage 1) has increased since the fence was constructed in 2018.

The activity of sub-adult rock-wallabies detected in scat plot surveys has generally been much less than that of adults (Figure 14). There have been no clear trends in sub-adult activity over time, other than a spike in numbers in 2019. Whether this is a genuine result, or an artefact of sampling is unknown.

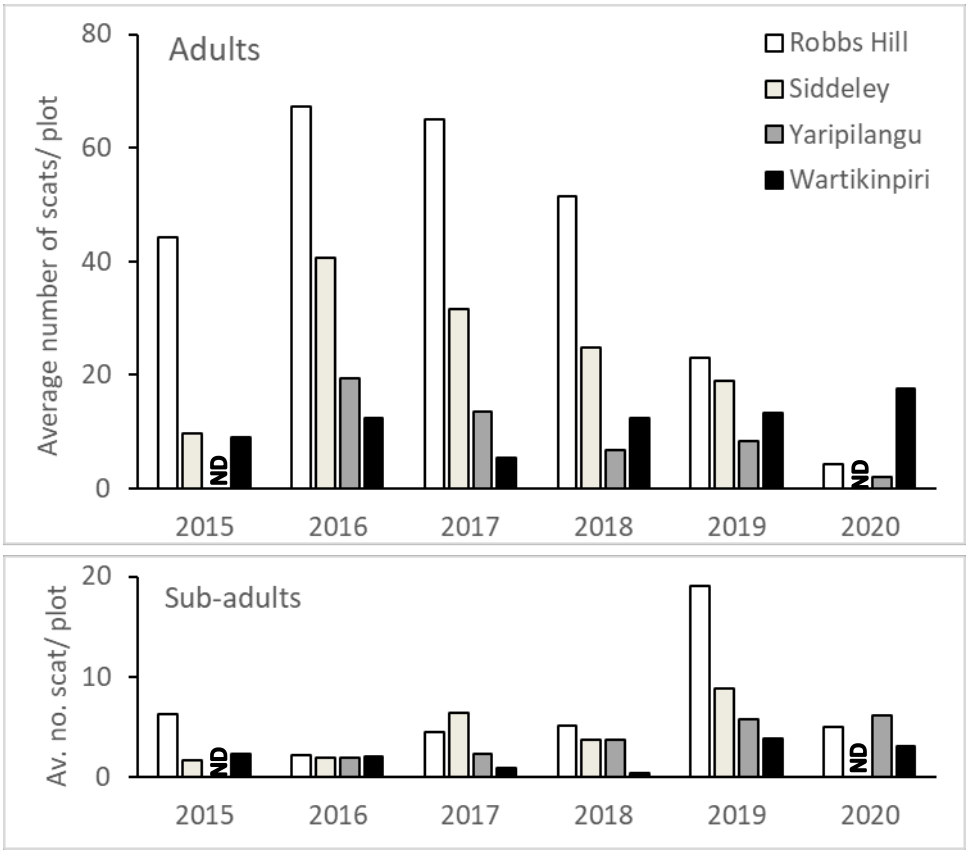

Figure 14. Black-footed Rock-wallaby activity (average number of scats per plot, +/- SE), across each of four ranges on Newhaven, 2015-2020. Top: adults; bottom: sub-adults. ND = no data. Note difference in scale between graphs.

The 2020 results (Figure 15) show the relatively high levels of activity of adult rock-wallabies in the Wartikinpirri Range population, compared with the two locations outside the fence. This result, together with data on trends in activity over time presented above, suggest that the fenced area is helping conserve rock-wallabies on the Wartikinpirri Range, with numbers increasing in that population even through the drought.

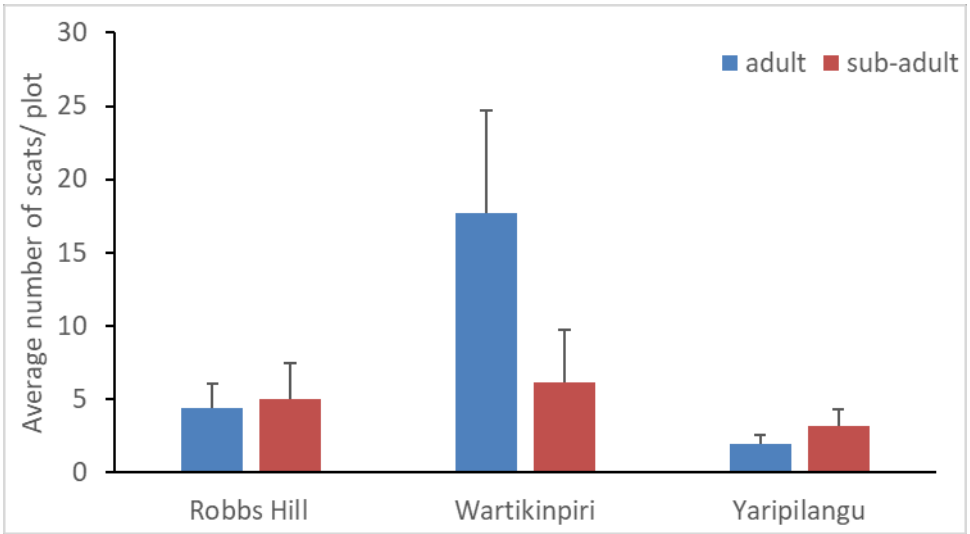

Figure 15. Black-footed Rock-wallaby activity (i.e. average number of scats per plot at each site, +/- SE), classified by adult and sub-adults, for the three ranges surveyed on Newhaven in 2020.

Occupancy data (i.e., the proportion of plots with scats) generally show similar patterns to the activity data presented above. There was a decline in the number of plots with adult rock-wallaby scats in 2020 compared with previous years (Figure 16). Nevertheless, in 2020, the population on the Wartikinpirri Range (within the fenced area) had the highest proportion of sites with evidence of adults (62%) and sub-adults (43%), well above figures for the two locations outside the fence (Figure 17).

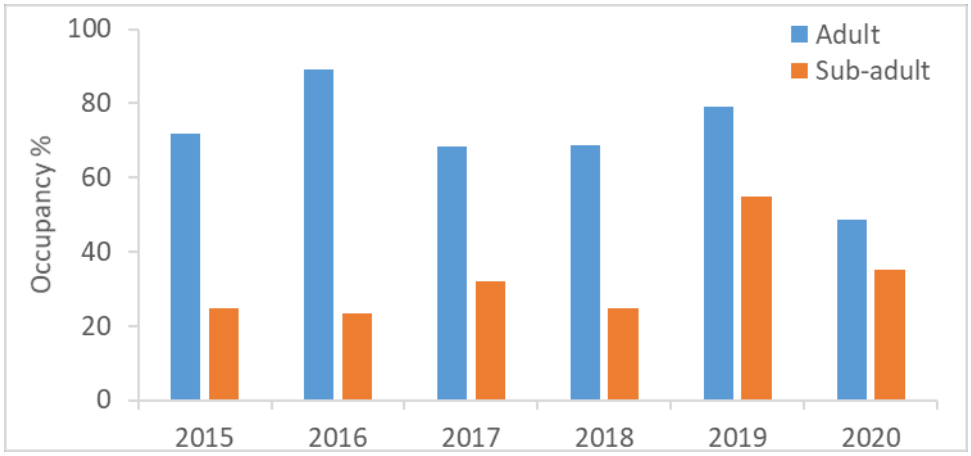

Figure 16. Sanctuary wide occupancy (i.e. proportion of plots with fresh scat) for Black-footed Rock-wallaby, categorised by age-class and year, 2015-20.

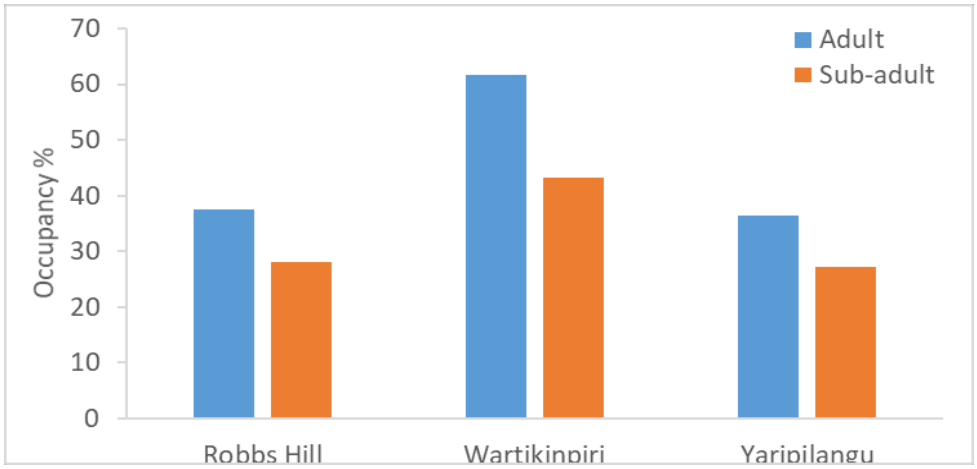

Figure 17. Occupancy at each range in 2020 for Black-footed Rock-wallaby adults and sub-adults.

Trends in occupancy for each range over the period 2015-2020 are presented in Figure 18. Occupancy levels declined to very low levels in the outlying Mt Gurner population in 2017; the population has not subsequently been monitored. On Robbs Hill, a small escarpment outside the fenced area, occupancy was high from 2015-18, but declined in 2019 and 2020. Occupancy on the two other ranges – Wartikinpirri (within the fence) and Yaripilangu (outside the fence) both declined from 2019 to 2020.

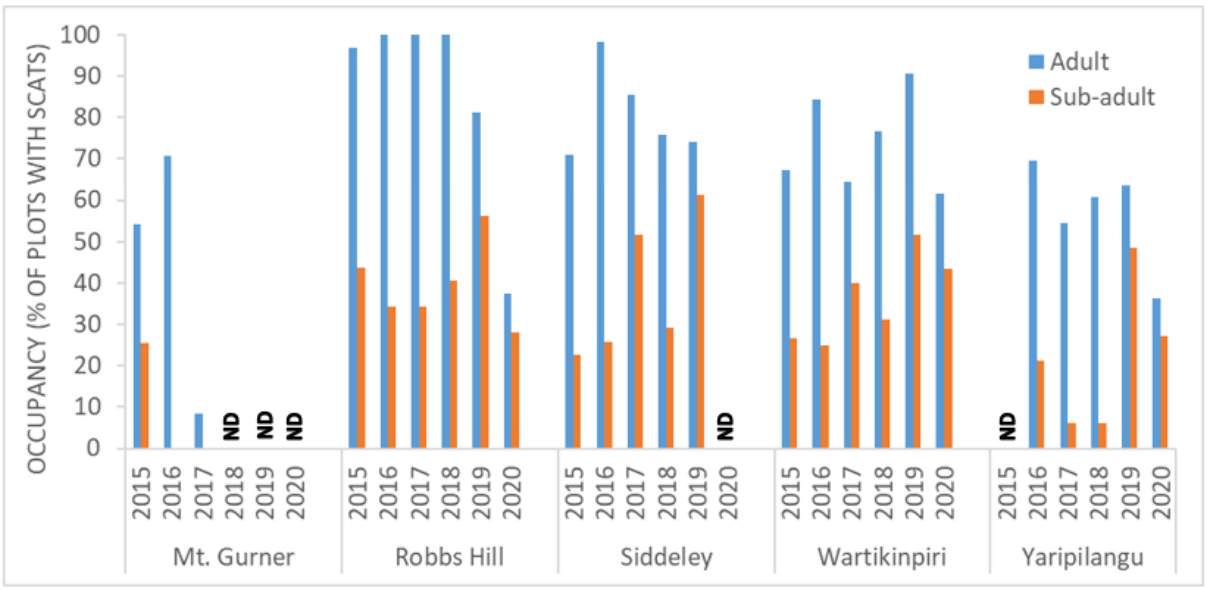

Figure 18.Occupancy of Black-footed Rock-wallaby by age class across each range, 2015-20. ND = no data.

Great Desert Skink

There has been a generally increasing trend in the mean number of active Great Desert Skink burrows at monitored sites over the period 2015-20 (Figure 19). In 2020, across all eight monitoring sites, 175 burrow systems were located, of which 49% were active, 14.3% inactive and 36% were no longer evident. Overall, 13 of the 175 burrow systems located in 2020 were new.

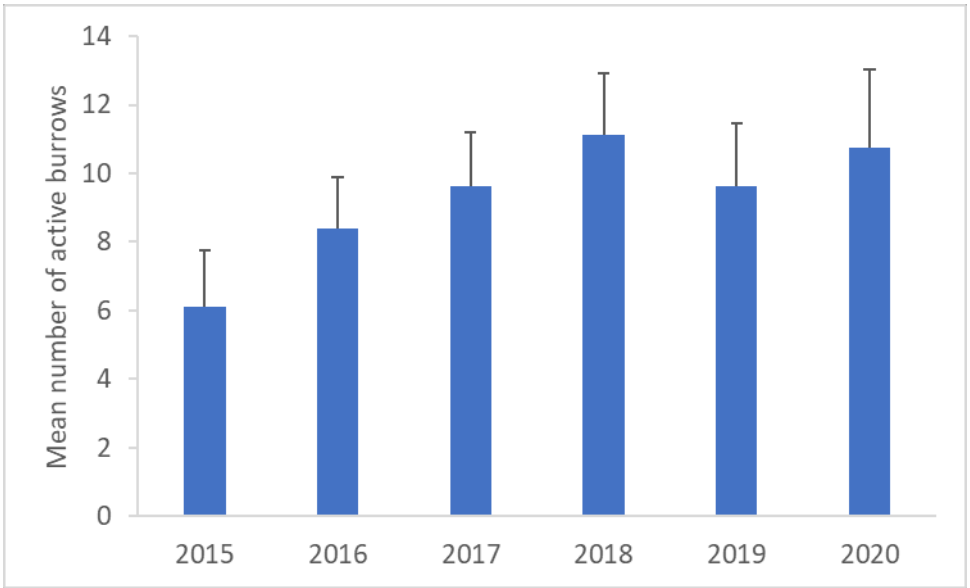

Figure 19. Activity (mean number of active burrows, +/- SE) of Great Desert Skink population, 2015-20

Data for trends in activity at each of the eight monitoring sites are presented in Figure 20. Four of the monitored sites showed an increase in the number of active burrows, with Camel Bore South (CBS) and Honeymoon Lake (HL) experiencing the largest increase in GDS activity for 2020. Activity remained constant at two sites, and declined at the remaining two.

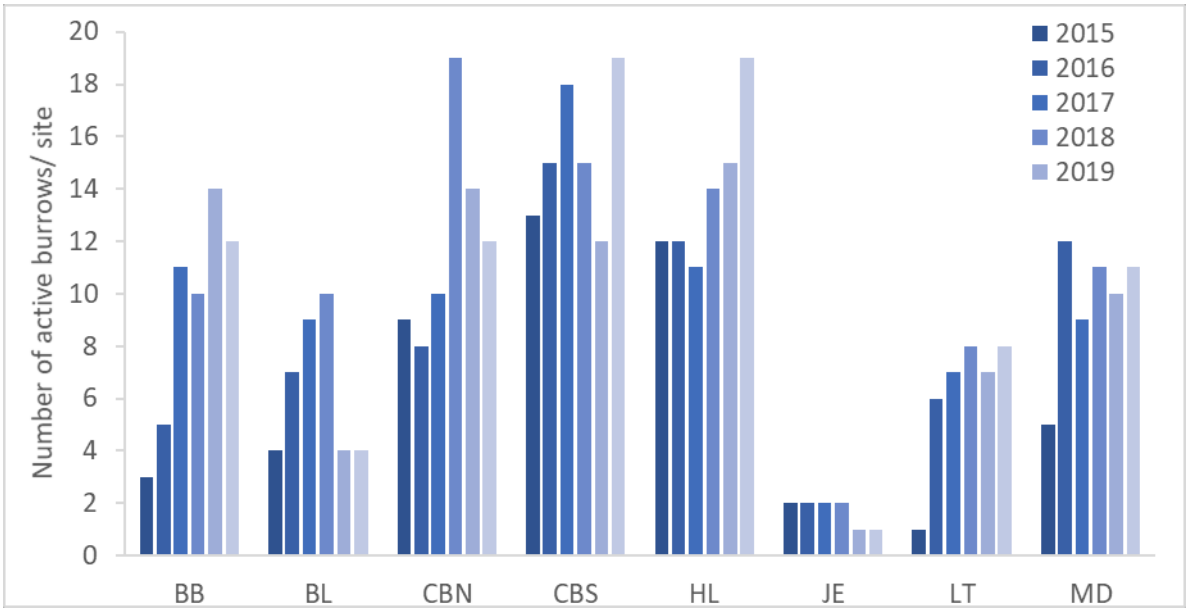

Figure 20. The number of active burrow systems at each site, 2015-20

The sites monitored for Great Desert Skinks are markedly different in levels of activity, suggesting a range of factors may influence activity, presumably including habitat suitability/ resource availability and predation, particularly by feral cats (Moore et al. 2017).

Threats

Rabbits

As a result of the continuing dry conditions, the rabbit population on Newhaven has been suppressed, with a mean of 0.21 rabbits/ha surveyed, the lowest recorded since 2015. Stage 1 continues to remain rabbit free.

Feral predators

In 2020, no 'sanctuary-wide' surveys were carried out to monitor cats and foxes on Newhaven.

As part of feral incursion monitoring inside and around the Stage 1 fenced area, there were 20,805 camera trap nights at 57 sites in 2020. Additionally, 5,672 km of fence patrol was carried out to check the integrity of the feral proof fence and look for any signs of incursion. There were no detections of cats or foxes within Stage 1 in 2020.

Fire

In 2020, due to the extremely dry conditions, no prescribed burning operations were undertaken. The only fire which occurred was an unplanned summer fire started by lightening, which burnt 23 ha. This fire required no intervention and its extent and severity were limited. Detailed information on fire patterns and metrics on Newhaven are provided in the annual Fire Pattern Analysis (Moore et al. 2021).

Discussion

The dry conditions experienced at Newhaven since 2018 have persisted into 2020, with evident impacts on the activity, abundance and occupation of key species.

The two species of locally-extinct mammals reintroduced to the fenced feral predator-free area on Newhaven in 2020 have met success criteria to date. Despite the dry conditions, survival of translocated Mala has been generally high, and in 2020 half the females were carrying pouch young, adult weights were stable and average body condition has improved over time. Red-tailed Phascogales are persisting around the release site, although challenges monitoring this species limit our capacity to measure progress towards establishment.

The two extant threatened species closely monitored by AWC – the Black-footed Rock-wallaby and Great Desert Skink – have also persisted through the drought.

The dry conditions have had an adverse impact on the rock-wallaby, which overall has declined in activity on Newhaven. Encouragingly, the population on Wartikinpirri Range, which is protected within the fenced area, has shown an increase in activity through the drought. These results illustrate the likely impact of predation by introduced cats and foxes on this species.

Great Desert Skink activity has generally increased since 2015. There are substantial differences in activity between sites, suggesting a range of factors such as resource availability and predation (interacting with fire) may drive populations of this species.

In relation to threats, AWC's management of fire on Newhaven has resulted in several targets being met relating to fire extent and seasonality, and the relative distribution of vegetation age-classes (time since fire). Rabbits were at low density on Newhaven in 2020, likely due to drought. There were no feral cat or fox incursions into the fenced area in 2020.

Acknowledgments

AWC acknowledges the Ngalia-Warlpiri and Luritja people as the Traditional Custodians of the country on which Newhaven Sanctuary resides. We also acknowledge their continuing connection to land, culture and community. We pay our respects to Ngalia-Warlpiri and Luritja Elders past present and emerging.

AWC's Ecohealth Program is only possible because of the generosity of AWC's supporters.

References

Collett R, Kemp L, Anson J, Foulkes J, Kanowski J (2020) *Reintroduction of the Red-tailed Phascogale to Newhaven Wildlife Sanctuary: Translocation Proposal.* Australian Wildlife Conservancy, Perth.

Dodson A (2020) Newhaven Wildlife Sanctuary: Black-footed rock-wallaby *(Petrogale lateralis)* activity monitoring. Australian Wildlife Conservancy, Perth.

Geyle HM, Guillera-Arroita G, Davies HF, Firth RS, Murphy BP, Nimmo DG, Ritchie EG, Woinarski JCZ, Nicholson E (2019) Towards meaningful monitoring a case study of a threatened rodent. *Austral Ecology*. 44:223-236.

Kanowski J, Joseph L, Kavanagh R, Fleming A (2018a) Designing a monitoring framework for Australian Wildlife Conservancy, a national conservation organisation. In: *Monitoring Threatened Species and Ecological Communities* (Eds S Legge, DB Lindenmayer, NM Robinson, BC Scheele, DM Southwell, BA Wintle) pp 241-253. CSIRO, Melbourne.

Kanowski J, Roshier D, Kemp L (2018b) *Translocation of Mala (Lagorchestes hirsutus) from Scotia Wildlife Sanctuary, NSW to Newhaven Wildlife Sanctuary, NT*. Australian Wildlife Conservancy, Perth.

Latz P, Paltridge R, Holmes J (2003) Vegetation survey of Newhaven Reserve. Unpublished report to the Australian Wildlife Conservancy.

Moore D (2018) Newhaven Wildlife Sanctuary Great Desert Skink, *Liopholis kintorei,* monitoring survey protocol. Australian Wildlife Conservancy, Subiaco, WA.

Moore D, Kearney MR, Paltridge R, McAlpin S, Stow A (2017) Feeling the pressure at home: predator activity at the burrow entrance of an endangered arid-zone skink. *Austral Ecology* 43, 102-109

Moore D, Schofield J, Webb T, Kanowski J (2021) Newhaven Wildlife Sanctuary: 2020 Fire Pattern Analysis. Australian Wildlife Conservancy, Perth, WA. Payne Z (2020) Newhaven Wildlife Sanctuary Great Desert Skink (*Liopholis kintorei)* Annual Monitoring Report. Australian Wildlife Conservancy, Perth.

Ridley J (2020) Reintroduction of the Mala to Newhaven. Australian Wildlife Conservancy, Perth.

Schubert A, Latz P (2015) Vegetation communities of the central-northern section of Newhaven Wildlife Sanctuary. Unpublished report to the Australian Wildlife Conservancy by Desert Wildlife Services, Alice Springs.

Scheele B.C., Legge S., Blanchard W., Garnett S., Geyle H., Gillespie G., Harrison P., Lindenmayer D., Lintermans M., Robinson N. & Woinarski J (2019) Continental-scale assessment reveals inadequate monitoring for threatened vertebrates in a megadiverse country. *Biological Conservation* 2 35: 273-278.

Schofield J (2010) Black-footed Rock-wallaby (*Petrogale lateralis*): Distribution Survey on Newhaven Wildlife Sanctuary, Northern Territory, 2010. Australian Wildlife Conservancy, Perth, Western Australia.

Schofield J (2013) Newhaven Burn Plan, 2013. Australian Wildlife Conservancy, Perth, Western Australia.

Schofield J, Cullen D, Moore D (2015) Newhaven Wildlife Sanctuary Black-footed rock-wallaby (*Petrogale lateralis*) distribution and activity monitoring protocol. Australian Wildlife Conservancy, Subiaco, WA.

Williams K, Parer I, Coman B, Burley J and Braysher M (1995) *Managing Vertebrate Pests: Rabbits,* Bureau of Resource Sciences and CSIRO Division of Wildlife and Ecology, Canberra.