

Scotia Wildlife Sanctuary Ecohealth Report 2021



Summary

Australian Wildlife Conservancy (AWC) has implemented an Ecological Health Monitoring Program (Ecohealth) across Scotia Wildlife Sanctuary (Scotia), 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. This report provides a description of the methodology and results of Ecohealth surveys conducted at Scotia. Values of metrics derived in this report were based on data collected during surveys carried out in 2021. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In implementing the Ecohealth program in 2021, AWC conducted 420 km of daytime driving transects, 420 km of nocturnal spotlighting transects, 1,368 cage trap nights and monitored 110 Malleefowl (*Leipoa ocellata*) mounds. Ecohealth surveys in 2021 largely focused on targeted monitoring of reintroduced species.

Surveys produced population estimates for each reintroduced species as follows: Numbat (*Myrmecobius fasciatus*): 161; Greater Bilby (*Macrotis lagotis*): 1,126; Burrowing Bettong (*Bettongia lesueur*): 321; Bridled Nailtail Wallaby (*Onychogalea fraenata*): 332. Population estimates for all reintroduced species were higher in 2021 compared to the previous year. Rainfall at Scotia returned to average in 2020-21, resulting in improved conditions following the record drought of 2018-19. These improved conditions facilitated population increases for reintroduced species after drought-induced declines in previous years.

Following the severe decline in the population of the Bridled Nailtail Wallaby in response to the 2018-19 drought, AWC developed a Population Management Plan (PMP) to guide management interventions aimed at minimising such declines in future. In line with the PMP, remaining Bridled Nailtail Wallabies at Scotia were consolidated in the Stage 2 fenced area. Since undertaking this intervention and in response to improved conditions, the Bridled Nailtail Wallaby population has increased in size. Plans are in place to supplement this population in 2022 with animals sourced from the last remaining remnant population in Queensland, to improve genetics.

Surveys of known Malleefowl mounds were conducted across Scotia to identify signs of breeding activity. From a total of 110 mounds surveyed, 13 (12%) were identified as being active. This is a slight increase from 2020 when 9% of monitored mounds were identified as active, but a major increase from the height of the drought in 2019, when none of 63 mounds inspected were active. A higher proportion of mounds inside the fence were active compared to those outside.

Surveys for species assemblages (birds, reptiles, mammals) and threats outside the fenced area were not undertaken in 2021. There were no planned or unplanned fires at Scotia in 2021.

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

Scotia Wildlife Sanctuary

Scotia is situated in the semi-arid Murray-Darling Basin Bioregion in far south-western New South Wales, approximately half-way between Wentworth on the Murray River and Broken Hill to the north, and adjacent to the South Australian border (Figure 1). Scotia encompasses a total area of 64,653 ha and is part of a broader landscape managed partly for conservation that extends south to the Murray River and into South Australia. The sanctuary is within the traditional lands of the Barkindji people. AWC acquired Scotia from Earth Sanctuaries Ltd (ESL) in 2002, completing establishment of the fenced feral predator-free areas that were begun by ESL.

Vegetation associations at Scotia are influenced by topography/soils and past land use. Mallee (*Eucalyptus* spp.) woodland with a spinifex (*Triodia scariosa*) understorey is found on deep sand soils associated with dunes. Mallee woodland with a shrubby understorey is found on sandy-loam soils associated with swales. Belah (*Casuarina pauper*) woodland occurs on flatter areas with heavier soils (Westbrooke et al. 1998). Shrubby regrowth consisting primarily of *Dodonaea* spp. and *Eremophila* spp. can also be found in previously cleared areas.

Scotia likely supports a total of 264 native vertebrate fauna species (256 species confirmed). This includes 29 mammal species of which 13 are considered threatened (national or state level), 174 bird species (23 threatened), 59 reptile species (six threatened), and two frog species. Locally extinct mammals have been reintroduced to two adjacent 4,000 ha feral predator-free fenced areas at Scotia (i.e., 8,000 ha total), including the Numbat (*Myrmecobius fasciatus*), Greater Bilby (*Macrotis lagotis*), Burrowing Bettong (*Bettongia lesueur*) and Bridled Nailtail Wallaby (*Onychogalea fraenata*). A reintroduced population of the endangered Brush-tailed Bettong (*Bettongia penicillita*) was also present at Scotia until recently, when remaining animals were translocated to AWC's Yookamurra Wildlife Sanctuary (in 2020) and to Mallee Cliff National Park (in 2021).

At Scotia, AWC's Ecohealth monitoring program has a particular focus on populations of reintroduced species, but extends to surveillance monitoring of vertebrate taxa and vegetation. Threats are also monitored. Information from the monitoring program allows AWC to evaluate the outcomes of our conservation activities on Scotia, and provides the data relied upon for management decisions.

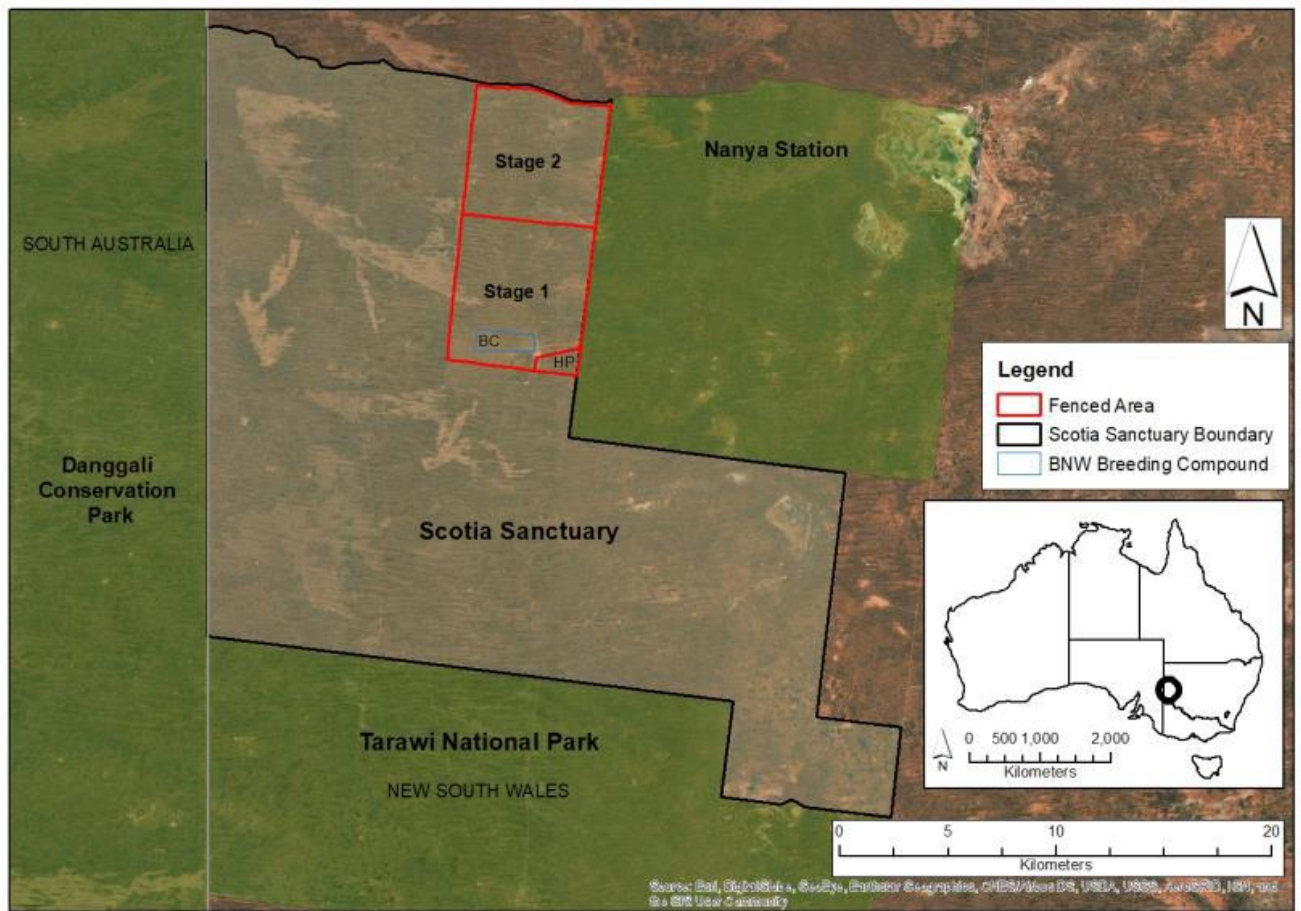


Figure 1. Location and regional context of Scotia.

Climate and weather summary

Scotia occurs on the boundary of the arid and semi-arid climate zone, experiencing hot summers and cold winters. Rainfall is irregular at Scotia but generally most falls over the spring and summer months (Figure 2). In 2021, Scotia received a total of 198 mm, similar to the long-term average of 194 mm (2002-2021; Figure 3). November was a much wetter than average month at Scotia, driven by the current La Niña weather system (BOM 2022).

Rainfall records for Broken Hill have been included in this summary as a comparison point to Scotia, as some entries from Scotia over the past 20 years have been missed, creating potential inaccuracies in reported annual rainfall patterns. Broken Hill is 140 km north of Scotia and lies in the arid climate zone. Significant differences in some years (i.e. 2012, 2016) between Scotia and Broken Hill may be due to reporting inconsistencies, as well as slight climatic differences between the two bioregions. Scotia's annual rainfall for 2021 was less than the long-term average for Broken Hill (222 mm, 2002-2021; BOM 2022).

Maximum and minimum temperatures are not recorded at Scotia directly; alternatively, records from Broken Hill are used. The maximum mean temperature of 32.4 °C occurred in January of 2021, and the minimum mean temperature of 5.4 °C occurred in July of 2021 (Figure 4).

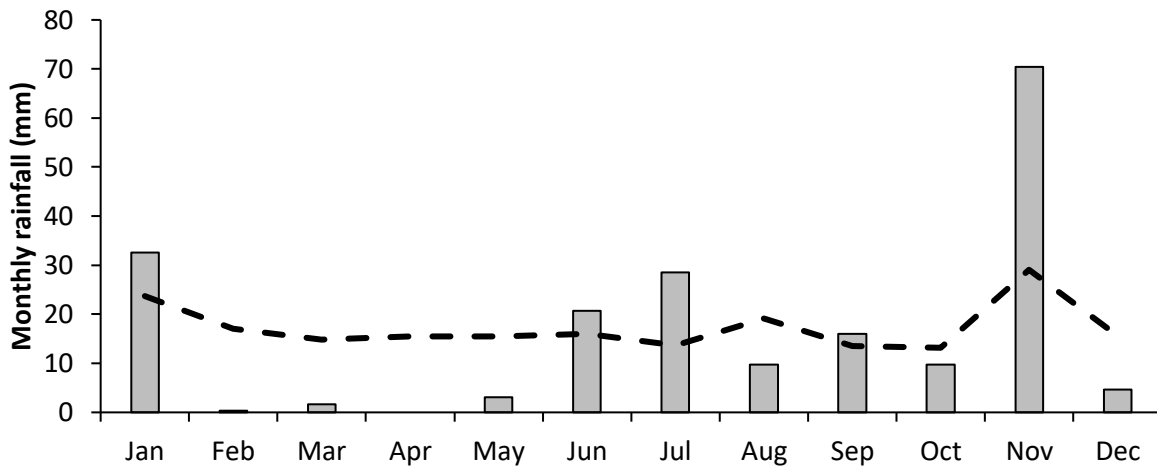


Figure 2. Monthly rainfall at Scotia Sanctuary for 2021. Dashed line = average monthly rainfall, 2002-2021.

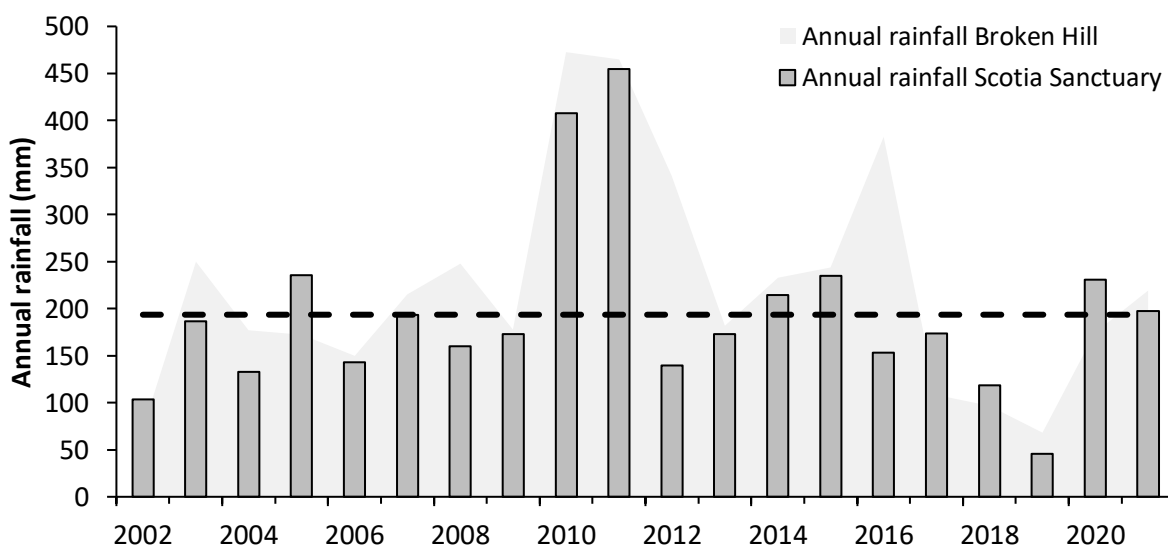


Figure 3. Annual rainfall at Scotia Sanctuary and Broken Hill, 2002-2021. Dashed line = average rainfall at Scotia 2002-2021. Data collected from Scotia Sanctuary and BOM 47048 Broken Hill Airport AWS. Broken Hill is used as comparison to Scotia Sanctuary data due to inconsistencies in past reporting of annual rainfall.

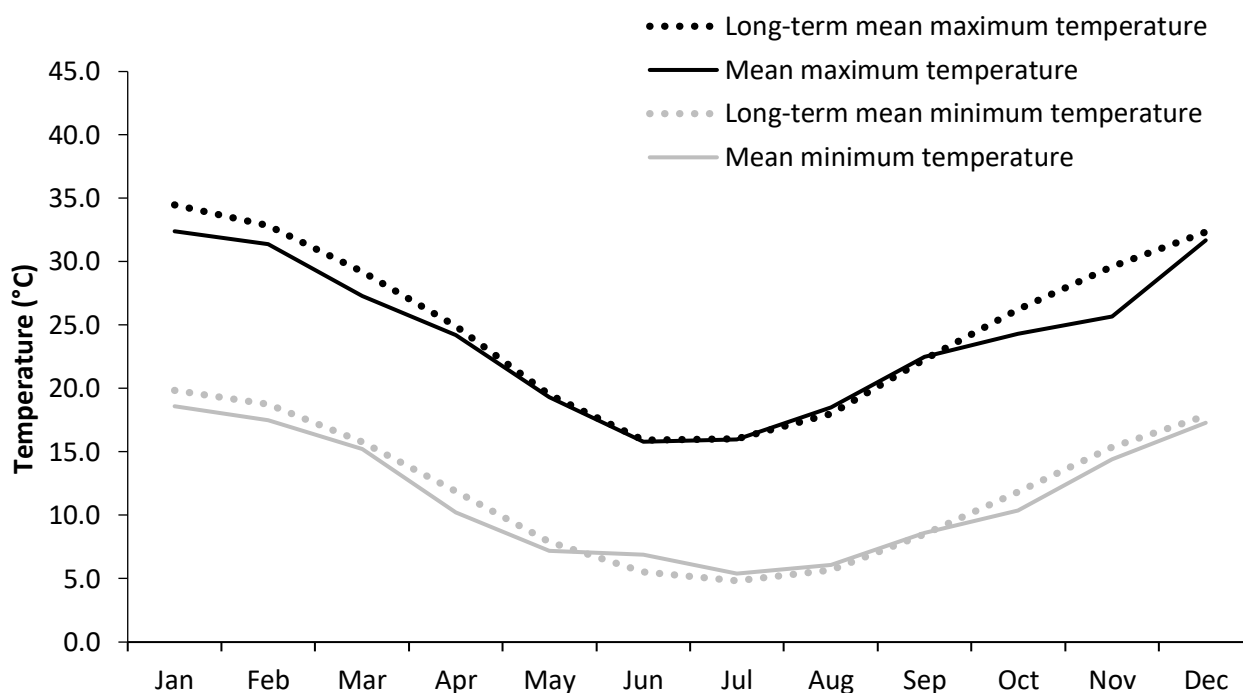


Figure 4. Mean monthly temperatures for Broken Hill for 2021 and long-term averages (2002-2021). Data collected from BOM 47048 Broken Hill Airport AWS, considered representative of Scotia Sanctuary.

Methods

Monitoring and evaluation framework

Scotia'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 are evaluated against performance criteria relevant to each species, guild or assemblage. The evaluation component of the program is being developed as we obtain information on the response of species or assemblage to environmental conditions and other factors.

Reintroduced, threatened and iconic species

Across AWC, 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. At Scotia, a plan has been developed for the Bridled Nailtail Wallaby (Berry et al. 2021).

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

Vertebrate assemblages and surveillance species

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

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

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

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

Indicators and metrics

On Scotia, 52 biodiversity (species and guilds) indicators have been selected for monitoring (Table 1). Five of these indicators were reported on in 2021, all related to threatened and iconic species of which, four are reintroduced species. Surveillance monitoring of faunal assemblages was not conducted in 2021.

Threat metrics have not yet been selected for Scotia, however pest management and fire regime strategies will be developed in the future. These strategies will be designed to monitor the status and trends of introduced weeds, predators and herbivores, and fire regimes. Six threat indicators that have been reported on in the past are listed in Table 2 below. No threat metrics were measured in 2021.

Table 1. Biodiversity indicators and metrics for Scotia.

Reintroduced vertebrates

Indicator	Survey name/ methods	Metric	Performance criteria
Numbat (<i>Myrmecobius fasciatus</i>)	Transects: diurnal	Population estimate	TBD
Greater Bilby (<i>Macrotis lagotis</i>)	Transects: nocturnal	Population estimate	TBD
Burrowing Bettong (<i>Bettongia lesueur</i>)	Mammal Trapping Survey	Population estimate	TBD
Brush-tailed Bettong (<i>Bettongia penicillata</i>)	Mammal Trapping Survey	Population estimate	TBD
Bridled Nailtail Wallaby (<i>Onychogalea fraenata</i>)	Transects: nocturnal	Population estimate	Threshold of management concern: 160 individuals in each of Stages 1 & 2 (320 in total)

Key threatened and iconic vertebrates

Indicator	Survey name	Survey method	Metric/s
Birds			
Malleefowl (<i>Leipoa ocellata</i>)	Malleefowl Mound Survey	Mound Inspection	Number of active mounds, activity

Vertebrate assemblages and surveillance species

Indicator	Survey name	Survey method	Metric/s
Mammals			
Assemblage richness	Standard Trapping Survey	Standard Trapping Survey	Number of species
Small-medium sized mammals			
Assemblage richness	Standard Trapping Survey	Standard Trapping Survey	Number of species
All Small-medium mammals	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Dasyurids - guild	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Rodents - guild	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Southern Ningau (Ningau yvonneae)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Fat-tailed Dunnart (Sminthopsis crassicaudata)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Stripe-faced Dunnart (Sminthopsis macroura)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Common Dunnart (Sminthopsis murina)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Western Pygmy-possum (Cercartetus concinnus)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Bolam's Mouse (Pseudomys bolami)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Large mammals			
Assemblage richness	Macropod Survey	Methods under development	Number of species
Western Grey Kangaroo (Macropus fuliginosus)	Macropod Spotlighting	Methods under development	TBD
Red Kangaroo (Macropus rufus)	Macropod Spotlighting	Methods under development	TBD
Bats			
Microbat - guild	Microbat Survey	Methods under development	Richness, occupancy
Reptiles			
Assemblage richness	Standard Trapping Survey	Standard Trapping Survey	Number of species
Small-medium reptiles			
Assemblage richness	Standard Trapping Survey	Standard Trapping Survey	Number of species
All reptiles (excl. varanids / snakes)	Standard Trapping Survey	Standard Trapping Survey	Abundance, richness
Reptiles – geckos (guild)	Standard Trapping Survey	Standard Trapping Survey	Abundance, richness
Reptiles – pygopodids (guild)	Standard Trapping Survey	Standard Trapping Survey	Abundance, richness
Reptiles – skinks (guild)	Standard Trapping Survey	Standard Trapping Survey	Abundance, richness
Reptiles – agamids (guild)	Standard Trapping Survey	Standard Trapping Survey	Abundance, richness
Three-lined Knob-tail Gecko (Nephurus levis)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Beaded Gecko (Lucasium damaeum)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy

Indicator	Survey name	Survey method	Metric/s
Eastern Tree Delling (<i>Geyhra versicolor</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Marbled-faced Delma (<i>Delma australis</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Barred Wedge-snout Ctenotus (<i>Ctenotus schomburgkii</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Southern Sandslider (<i>Lerista labialis</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Morethia skink (<i>Morethia obscura</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Mallee Dragon (<i>Ctenophorus fordi</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Nobbi Dragon (<i>Diporiphora nobbi</i>)	Standard Trapping Survey	Standard Trapping Survey	Abundance, occupancy
Large reptiles			
Reptiles-large varanids/snakes (guild)	Standard Trapping Survey	Methods under development	TBD
Frogs			
Amphibian guild	Targeted Frog Survey	Methods under development	Abundance, occupancy
Birds			
Assemblage richness	Standard Bird Survey	Standard Bird Survey	Number of species
All birds	Standard Bird Survey	Standard Bird Survey	Richness
Ground-active birds - guild	Standard Bird Survey	Standard Bird Survey	Richness
Nocturnal birds - guild	Nocturnal Bird Survey	Methods under development	TBD
Honeyeaters - guild	Standard Bird Survey	Standard Bird Survey	Richness
Pink Cockatoo (<i>Lophochroa leadbeateri</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy
Striated Grasswren (<i>Amytornis striatus</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy
Shy Heathwren (<i>Hylacola cauta</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy
Chestnut Quail-thrush (<i>Cinclosoma castanotum</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy
Gilbert's Whistler (<i>Pachycephala inornate</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy
Hooded Robin (<i>Melanodryas cucullate</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy
Southern Scrub-robin (<i>Drymodes brunneopygia</i>)	Standard Bird Survey	Standard Bird Survey	Occupancy

Vegetation indicators and surveillance species

Vegetation			
Vegetation structure and composition	Vegetation Survey	as per Kemp et al. (2021)	Frequency

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

Indicator	Survey name/ methods	Metric/s	Performance criteria
Pest animals			
Feral cat (<i>Felis catus</i>)	Camera array	Density, Mean occupancy	TBD
European fox (<i>Vulpes vulpes</i>)	Camera array	Density, Mean occupancy	TBD

Indicator	Survey name/ methods	Metric/s	Performance criteria
Feral goat (<i>Capra hircus</i>)	Camera array	Mean occupancy	TBD
European rabbit (<i>Oryctolagus cuniculus</i>)	Camera array	Mean occupancy	TBD
Weeds			
Possible species include: caltrop, saffron thistle, wild tobacco, horehound, Patterson's curse	TBD (by Weed Strategy)	TBD (by Weed Strategy)	TBD
Fire			
Fire	Fire Scar Analysis	Area burnt in planned fire (% of property; ha) Area burnt in unplanned fire (% of property; ha)	TBD

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, a range of targeted surveys including:

- Mammal Trapping Survey
- Transects: diurnal
- Transects: nocturnal
- Malleefowl Mound Survey

For surveillance monitoring of assemblages, these include:

- Standard Trapping Survey
- Standard Bird Survey
- Vegetation Survey

To monitor threats, a range of surveys are used, including:

- Camera Trap Grid
- Fire Scar Analysis

Four of the ecological surveys were conducted at Scotia in 2021. Below is a list of surveys reported upon in this Ecohealth Report (Table 3). The methodology is described and results of these surveys and computations are reported on in this document.

Table 3. Survey history and effort for Ecohealth surveys on Scotia.

Survey name	2021 Effort	Description/comment	Previous surveys
Transects: diurnal (Numbat)	420 km	56 road transects (28 in each of Stage 1 & 2) either 1 or 2 km in length, each surveyed on nine separate days. Random transects used 2010 – 2014; standard transects (as above) used 2015 onwards. Reduced effort in 2021 due to poor weather.	2021 – 420 km 2020 – 630 km 2019 – 630 km 2018 – 392 km 2017 – 630 km 2016 – 630 km 2015 – 630 km 2014 – 497 km 2012 – 822 km 2011 – 669 km 2010 – 695 km

Survey name	2021 Effort	Description/comment	Previous surveys
Transects: nocturnal (Greater Bilby, Bridled Nailtail Wallaby)	700 km	56 road spotlighting transects (28 in each of Stage 1 & 2) either 1 or 2 km in length, each surveyed on six separate nights. Random transects used 2010 – 2014; standard transects (as above) used 2015 onwards.	2021 – 700 km (two surveys) 2020 – 840 km (two surveys) 2019 – 420 km 2018 – 420 km 2017 – 420 km 2016 – 420 km 2015 – 420 km
Mammal Trapping Survey (Burrowing Bettong)	1,368 trap nights	114 trapping sites surveyed with three cage traps, repeated over four days. In 2015-2021 surveys were conducted annually, 2010-2014 surveys were conducted bi-annually.	2021 – 1,368 Trap nights 2020 – 1,368 Trap nights 2019 – 1,368 Trap nights 2018 – 1,368 Trap nights 2017 – 1,368 Trap nights 2016 – 1,368 Trap nights 2015 – 1,368 Trap nights 2014 – 1,368 Trap nights 2013 – 1,026 Trap nights 2012 – 1,026 Trap nights 2011 – 1,026 Trap nights 2010 – 1,026 Trap nights
Malleefowl Mound Survey	110 sites	Known Malleefowl mounds inspected annually between October and February. Number of mounds has changed (i.e., increased) through time as more mounds are discovered.	2021 – 110 sites 2020 – 130 sites 2019 – 63 sites 2018 – 26 sites 2017 – 62 sites 2016 – 54 sites 2014 – 45 sites 2013 – 27 sites 2012 – 31 sites 2011 – 29 sites 2010 – 27 sites
Standard Trapping Survey	0 trap nights	63 sites surveyed with 11 pitfall traps and 12 funnel traps over four days/nights. Stratified to cover a range of geography and major vegetation types.	2021 – 0 Trap nights 2020 – 0 Trap nights 2019 – 3,312 Trap nights 2018 – 4,374 Trap nights 2017 – 3,312 Trap nights 2016 – 3,312 Trap nights 2015 – 3,312 Trap nights 2014 – 3,312 Trap nights 2013 – 3,312 Trap nights 2012 – 3,312 Trap nights 2011 – 3,312 Trap nights 2010 – 3,312 Trap nights
Standard Bird Survey	0 surveys	48 sites, three replicates. Number of sites has varied across years.	2021 – 0 sites 2020 – 144 surveys (48 sites) 2018 – 189 surveys (63 sites) 2017 – 144 surveys (48 sites) 2015 – 144 surveys (48 sites) 2013 – 252 surveys (84 sites)
Vegetation Survey	0 surveys	32 plots across three treatments (Stage 1, Stage 2, Outside fence); stratified by three vegetation types (Mallee spinifex, Mallee shrub, Belah)	2016 – 32 plots surveyed

Survey design and methods

Transects

Diurnal

Diurnal road/driving surveys, targeting reintroduced Numbats, were conducted on 56 transects (28 in each of Stage 1 and 2; Figure 5; L'Hotellier et al. 2016a, 2016b) repeated over six days in November 2021. Transects were 1 km in length unless situated along a fence line, in which case they were 2 km long and only observed on the inside-fence (i.e., predator free) side. The survey vehicle travels along the transect (i.e., road) at slow speed (~12 km/h) while observers search for Numbats. Upon observing a Numbat, various details are recorded including the distance and bearing of the animal from the transect line. This survey is normally conducted over nine days however poor weather conditions in the 2021 survey meant fieldwork was limited to six days.

Nocturnal

Nocturnal road/driving transects using spotlights, targeting reintroduced Greater Bilbies and Bridled Nailtail Wallabies, were conducted on the same 56 transects used for diurnal surveys above (Figure 5). Surveys were conducted initially in September 2021, but due to wet weather, the full effort could not be achieved; for this reason, the survey was repeated over six nights in March 2022. As for diurnal transects above, the survey vehicle travels along the transect (i.e., road) at slow speed (~12 km/h) while observers search for the target species. Upon observing an animal, various details are recorded including the distance and bearing of the animal from the transect line.

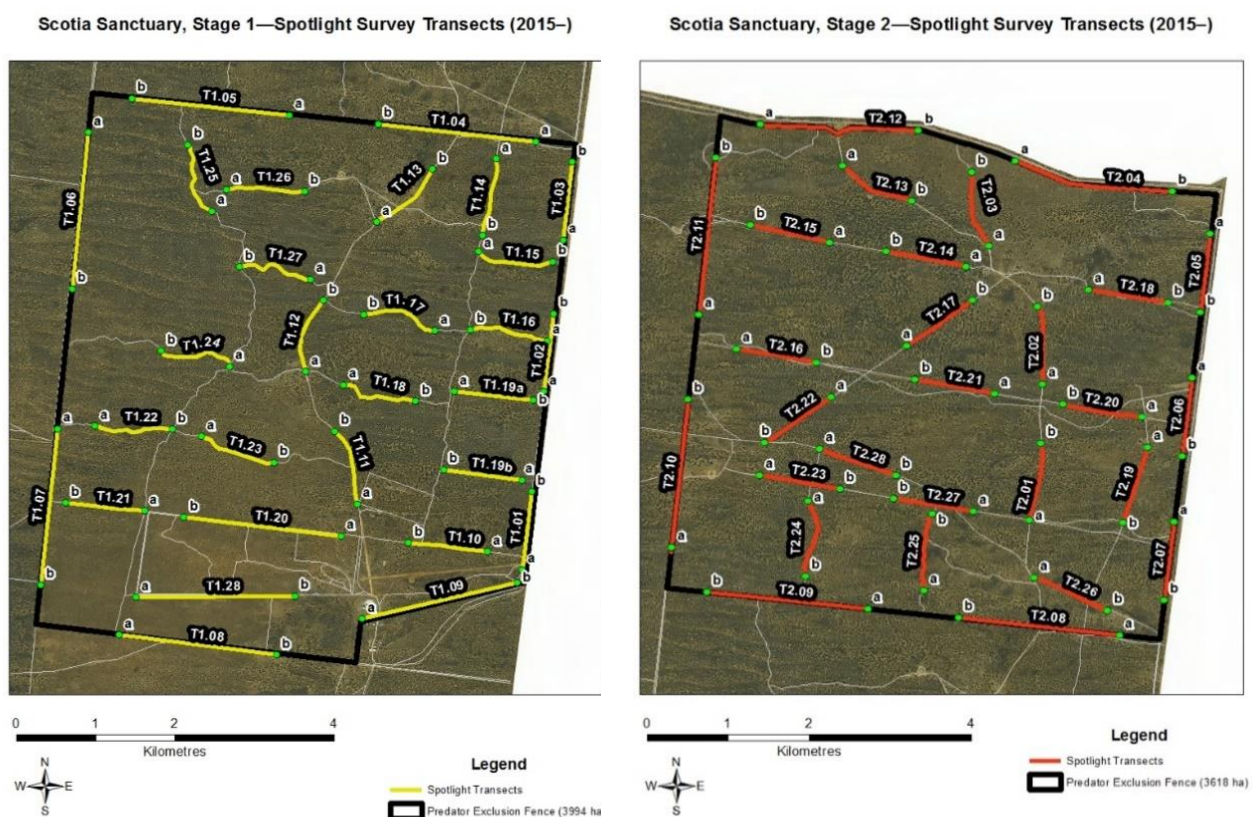


Figure 5. Driving transect locations in Stage 1 (left) and Stage 2 (right) used for surveys of Numbats (Transects: diurnal) and Greater Bilby and Bridled Nailtail Wallaby (Transects: nocturnal).

Mammal Trapping Survey

Burrowing Bettong

To obtain population estimates for the Burrowing Bettong, a four-night mark-recapture survey was undertaken utilising cage traps throughout Stage 1 of the feral predator-free enclosure (Kemp et al. 2016). Three traps were set at each of 114 sites located approximately 500 m apart along Scotia's existing road network (Figure 6). Traps were baited with a mixture of peanut butter, oats and honey. This is an annual survey and was undertaken in April 2021.

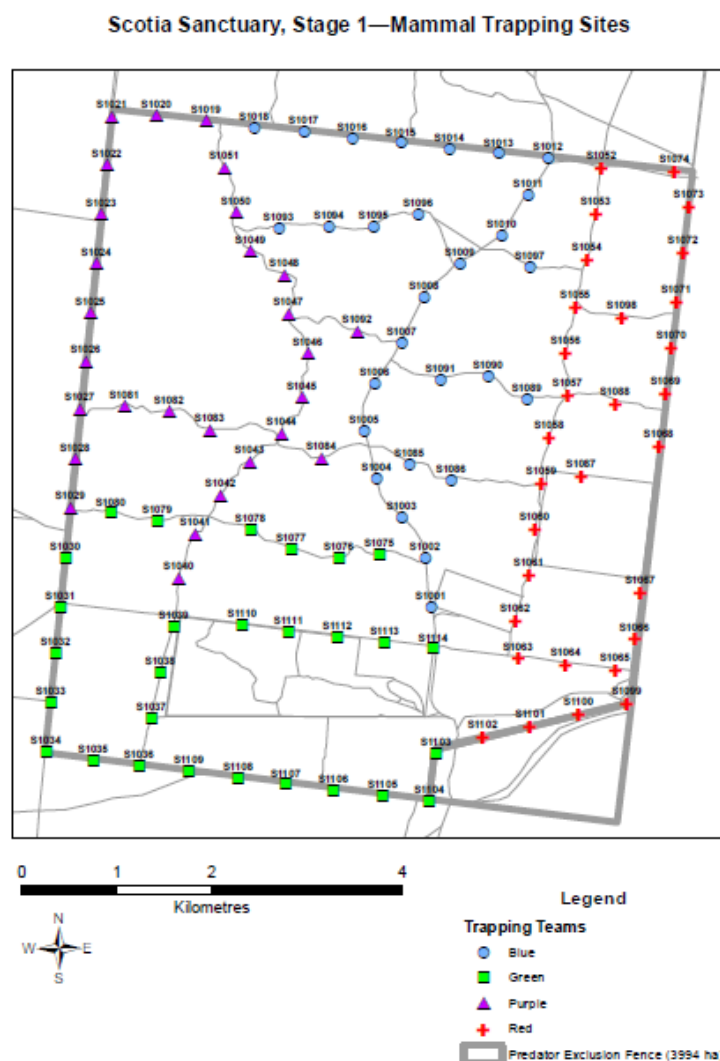


Figure 6. Trap site locations in Stage 1 for surveys of Burrowing Bettongs.

Malleefowl Mound Survey

Across Scotia 110 known Malleefowl (*Leipoa ocellata*) mounds were surveyed in February 2022. This survey followed the monitoring procedures set out by the Malleefowl Recovery Team. The diameter, depth, height, and shape of each mound was recorded. Each mound was also noted as being either active (i.e., signs of breeding activity) or inactive. This is an annual survey conducted during the Malleefowl breeding season (October – February).

Standard Trapping Survey

Standard Trapping Surveys were conducted annually at Scotia between 2010 and 2019 but were not conducted in 2021.

From 2010 to 2019, an annual live trapping survey targeting small mammals and reptiles was conducted across four survey mornings and afternoons. A total of 63 sites was stratified across three vegetation

communities: Mallee Triodia (MT), Mallee Shrub (MS) and *Casuarina pauper* (CP), and four management treatments were surveyed (Stages 1-4) (Figure 7).

Survey sites were 1 ha in area and comprised a total of 11 pitfall traps. Inset from each corner of the 1 ha site, two 20L buckets were positioned 25 m apart and connected by a 30 m drift fence. In the centre of the site a central 'cross' contained a third bucket halfway along the fence where two short drift fences (7.5 m) ran at 90° to the main fence. Each drift fence also had two funnel traps (apart from the middle array which has four; two along each short fence), with a total of 12 funnel traps per site (Figure 8).

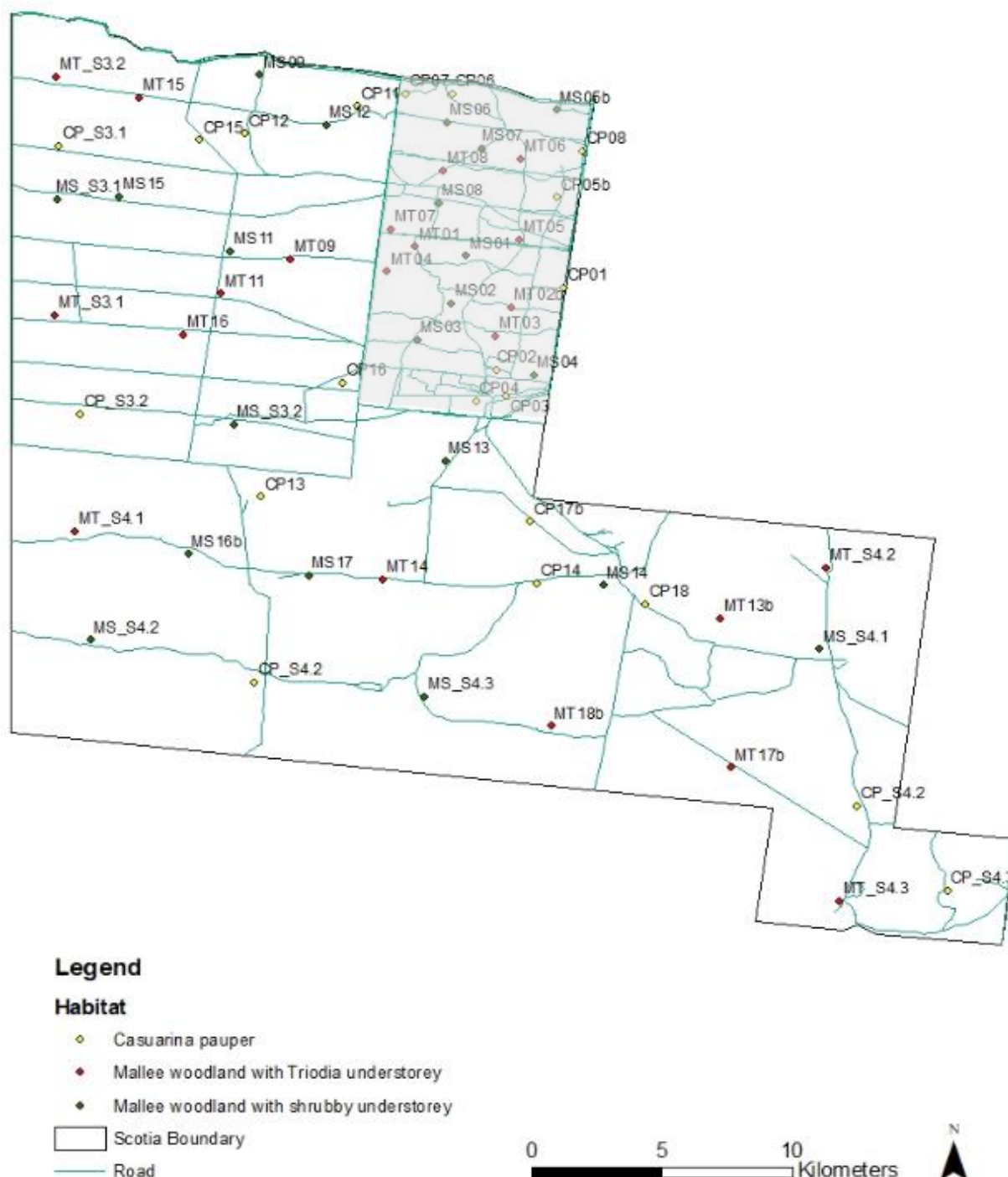


Figure 7. Location of permanent Standard Trapping Survey sites across Scotia. Shading = fenced area.

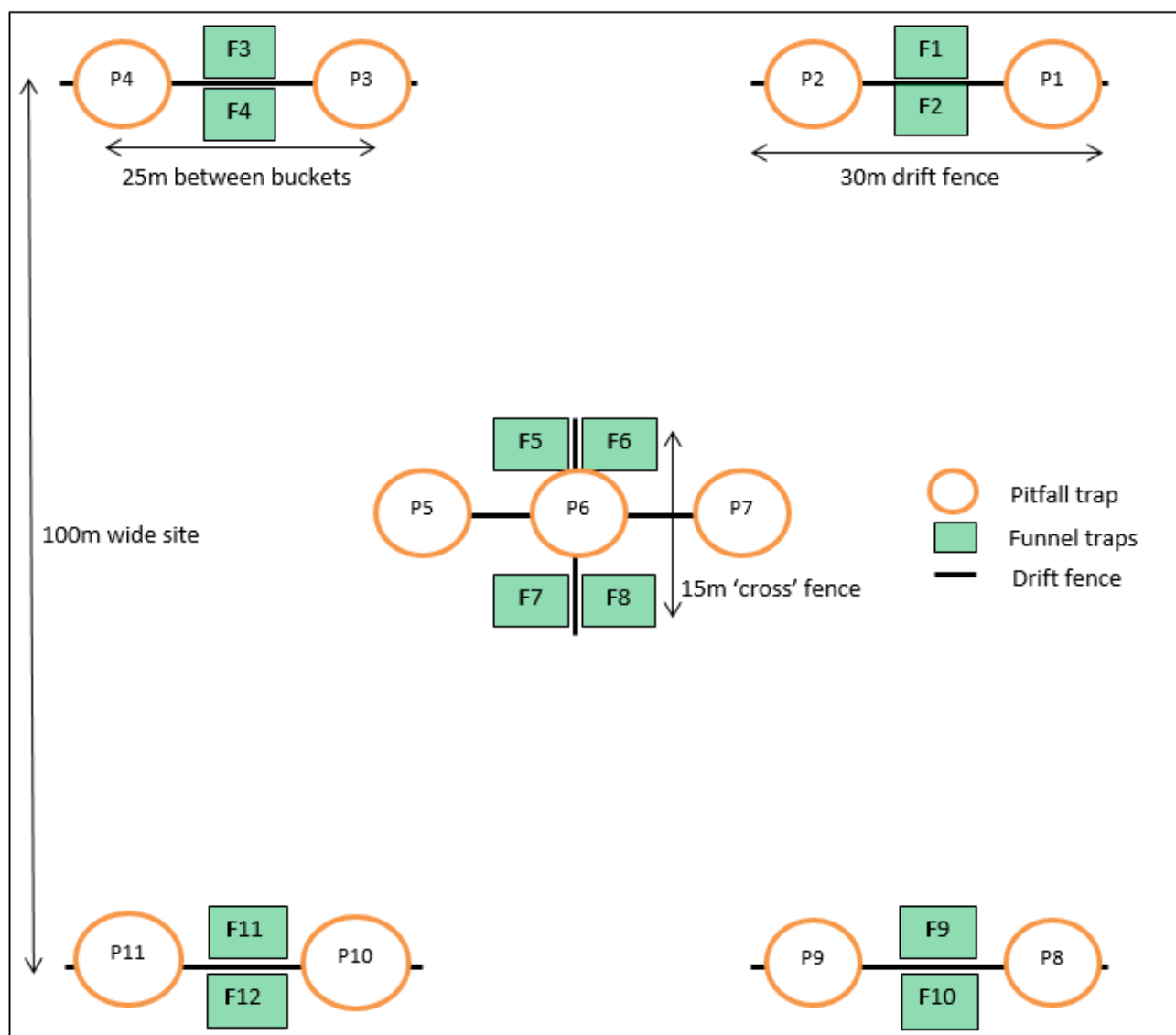


Figure 8. Site layout for Standard Trapping Survey sites at Scotia.

Standard Bird Survey

The Standard Bird Survey was not conducted in 2021.

In 2020, the Standard Bird Survey was conducted at 48 sites stratified across the three main vegetation communities: Mallee Triodia, Mallee Shrub and *Casuarina pauper*, within the four management treatments (i.e. Stages 1–4) on the sanctuary. Each treatment type (i.e. Stages 1–4) has different management histories. Of the 48 sites, 16 sites were located in each vegetation community, divided equally between the fenced (feral free; Stages 1 and 2) and unfenced treatments (Stages 3 and 4). Each site encompassed a 2-ha search area that was sampled by a single observer. The observer spent 20 minutes actively searching the area by wandering slowly across the entirety of the site, identifying and recording any sightings or vocalisations within the 2-ha area. This is the preferred survey technique used by BirdLife Australia.

In spring, each site was surveyed three times with no two replicates occurring on the same day, and all three preferably on consecutive days. Where possible, each replicate was completed by a different observer and effort was made to ensure that each replicate per site occurred at a different time post-sunrise.

Analysis methods

Most Ecohealth metrics are common across the indicator species for Scotia. Unless noted otherwise, the metrics are calculated as set out in Table 4 below.

Table 4. Metrics and associated calculations for Scotia.

Indicator	Metric	Survey Data Sources	Description	Analysis Summary / Calculation
Numbat, Greater Bilby, Bridled Nailtail Wallaby	Population estimate	Transects: diurnal (Numbat) Transects: nocturnal (Greater Bilby, Bridled Nailtail Wallaby)	Estimate of total number of individuals in the population based on strip-plot transects.	Strip-plot methodology (as per Kanowski et al. 2001). Transect surveys where animals are recorded within a fixed strip width (e.g., 9-m either side of transect centre line). Observations used to calculate density within the strip area which are then extrapolated across the whole study area (e.g., feral predator-free fenced area). (Total number of individuals seen inside the strip plot (i.e., within 9 m of the transect) during the survey / total ha surveyed (i.e., strip plot area) * total study area (Stage 1 or 2). Where multiple surveys were carried out in a year, the latest (i.e. most recent) survey estimate is presented in the Ecohealth Scorecard.
Burrowing Bettong	Population estimate	Mammal Trapping Survey	Estimate of total number of individuals in the population, based upon mark-recapture analysis.	Mark-recapture was used to estimate total population size using the closed design in the software program MARK (www.phidot.org/software/mark). Population estimates were derived from models using a closed captures design with full likelihood p (capture probability) and c (recapture probability) (as per White 2008). Where multiple surveys were carried out in a year, the latest (i.e., most recent) survey estimate is presented in the Ecohealth Scorecard.
Malleefowl	Activity	Malleefowl Mound Survey	Percentage of surveyed mounds identified as active.	Activity: (number of mounds at which activity was identified/ number of mounds surveyed) [x 100]
Small mammals Birds (all) Reptiles (all) Frogs (all)	Richness	Standard Trapping Survey Standard Bird Survey	Number of species per site.	Average number of species recorded at each site.
Small mammals Birds (all) Reptiles (all) Frogs (all)	Abundance	Standard Trapping Survey Standard Bird Survey	A measure of activity; either number of detections per 100 trap nights, or per site.	For individual species: Calculate the average over all survey sites of: ((No. individuals of that species recorded at survey site/ total number of trap nights at survey site) x 100)

Indicator	Metric	Survey Data Sources	Description	Analysis Summary / Calculation
				For guilds: Calculate the average over all survey sites of: ((Total no. individuals of the guild recorded at survey site/ total number of trap nights at survey site) x 100)
Small mammals Birds (all) Reptiles (all) Frogs (all)	Occupancy	Standard Trapping Survey Standard Bird Survey	A measure of distribution; the proportion of sites where the species was recorded using a particular technique.	For individual species: (number of sites at which the species was recorded/ number of sites surveyed) [x 100 if reporting as a %] For guilds: (number of sites at which any species within the relevant guild was recorded/ number of sites surveyed) [x 100 if reporting as a %]

Fire Scar Analysis

Fire scar data for 2020 fires were gathered by on-ground mapping using a handheld GPS. The area of the scar in hectares was calculated using ArcMap 10 with Spatial Analyst (Environmental System Research Institute Inc., Redlands, CA, USA).

There were no prescribed burns or wildfires during 2021.

Results

Reintroduced species

Numbat

The 2021 Numbat population estimate was 161 individuals (± 43 SE). This represents an increase on the 2020 estimate (135). This increase was driven by the higher estimate obtained in Stage 2 (Figure 9).

Long-term population monitoring of Numbats at Scotia indicates that numbers declined in response to the record drought conditions experienced in 2018/19 (Figure 9). Population estimates in 2020 and 2021 suggest that the population is now in a period of post-drought recovery, with two consecutive years of total population increases. The Numbat population at Scotia reached a peak in 2017, prior to the drought, when a population estimate of 629 individuals was obtained.

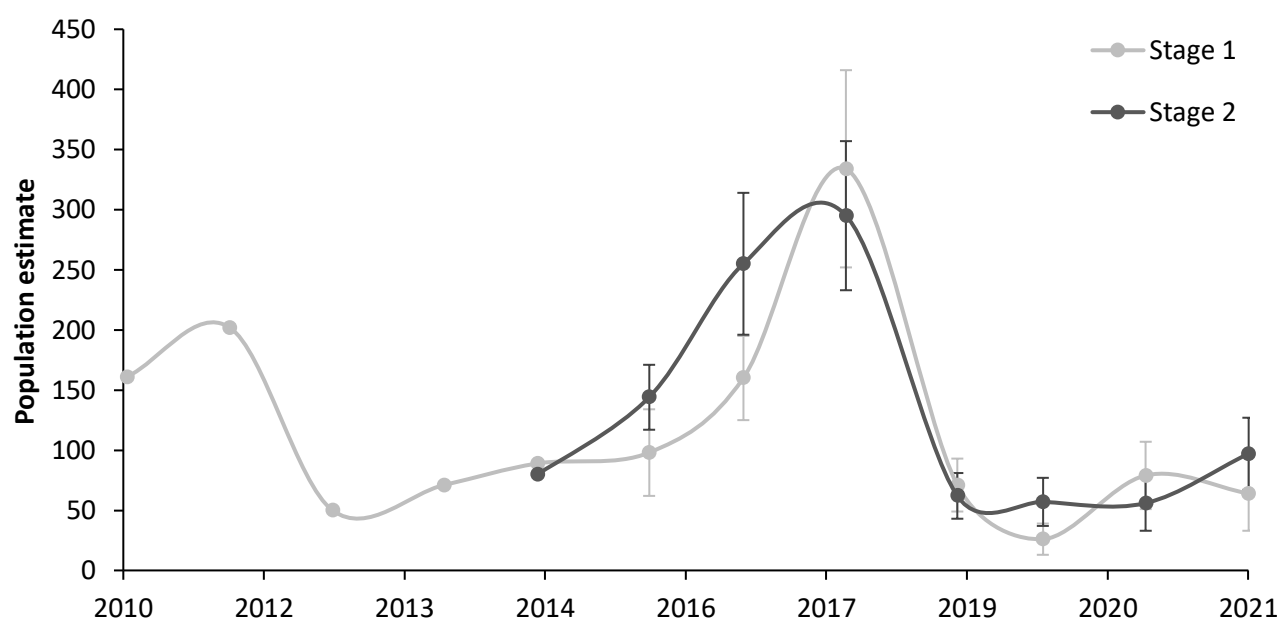


Figure 9. Population estimates for Numbats in Stage 1 and 2 at Scotia from strip-plot analysis. Error bars indicate the standard error of estimates.

Greater Bilby

Transect surveys conducted in March 2022 resulted in a Greater Bilby population estimate of 1,126 individuals (± 162 SE; Stage 1 = 665, Stage 2 = 461). This is a slight increase from the September 2021 survey when the population estimate was 1,037 (± 142 SE; Stage 1 = 710, Stage 2 = 327), but a four-fold increase on the population estimate obtained in 2020 at the end of the drought (Figure 10).

The Scotia Greater Bilby population declined markedly during drought conditions in 2019 and remained low in 2020. However, the most recent results indicate a rapid post-drought recovery, with estimates now comparable with previous population peaks (Figure 10).

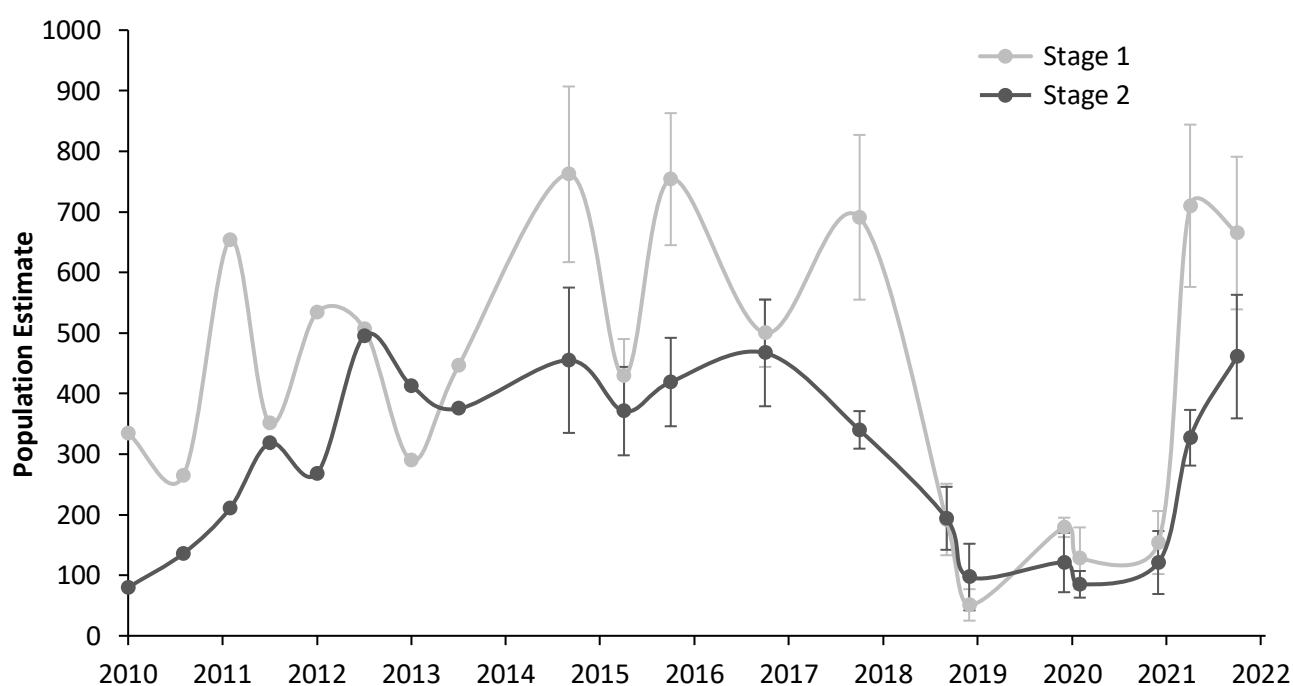


Figure 10. Population estimates for Greater Bilbies at Scotia in Stage 1 and 2 from strip-plot analysis. Error bars indicate the standard error of estimates.

Burrowing Bettong

The Burrowing Bettong population estimate for 2021 was 321 individuals (± 11 SE). This is more than twice that of the previous estimate obtained in 2020 (130). Burrowing Bettong population size declined during drought conditions in 2019 but is now showing good signs of recovery (Figure 11). The latest estimate is still well below the population peak observed from 2011-13.



Figure 11. Population estimates (solid line) for Burrowing Bettongs at Scotia (Stage 1) from mark-recapture analysis. Dotted lines represent upper and lower 95% confidence limits.

Bridled Nailtail Wallaby

Surveys for Bridled Nailtail Wallabies conducted in March 2022 produced a population estimate of 332 individuals (± 99 SE; Stage 1 = 77, Stage 2 = 255). This is a substantial increase from previous surveys (Figure 12). Bridled Nailtail Wallabies declined markedly during drought conditions in 2018-19. This led to the development of a Population Management Plan for the species at Scotia, part of which included moving all animals (that could be captured) from Stage 1 to Stage 2 in 2020-21. The purpose of this intervention was to maintain an effective breeding population in Stage 2, at least. The increase in population size evident in 2022, following the return of average rainfall conditions, indicates that the population of Bridled Nailtail Wallabies on Scotia is recovering from the drought.

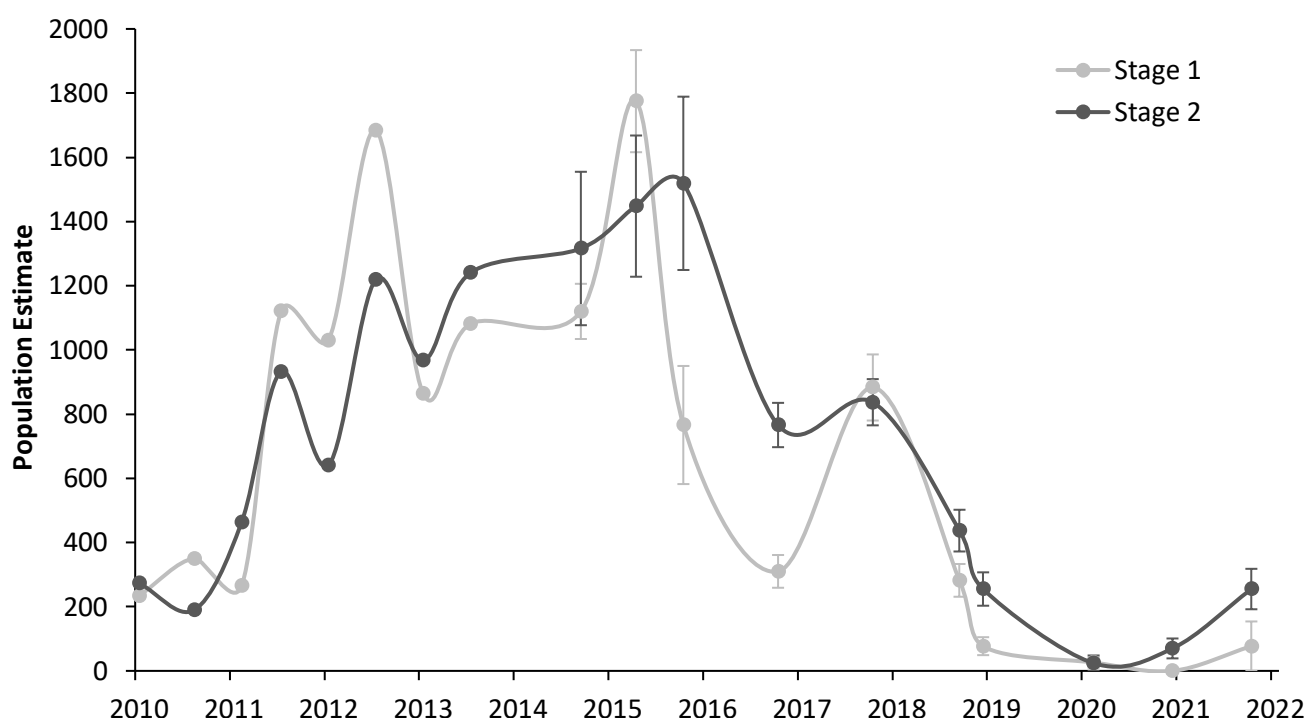


Figure 12. Population estimates for Bridled Naitail Wallabies at Scotia from strip-plot analysis. Error bars indicate the standard error of estimates.

Key threatened and iconic species

Malleefowl

A total of 110 previously identified Malleefowl mounds were surveyed for signs of activity in February 2022, with 13 (12%) identified as active (Table 5; Figure 13). This is a minor increase from 2020 when 9% of monitored mounds were identified as active. During the height of the drought in 2019, however, inspection of 63 mounds revealed none to be active (Table 5; Figure 13). The percentage of monitored mounds identified as active is currently lower than in 2012 and 2014, but comparisons may be confounded by the increase in the number of mounds being monitored through time. LiDAR mapping and associated ground-truthing at Scotia identified a large number ($n = 47$) of Malleefowl mounds not previously known, that have added to the number of mounds monitored since 2020.

Of the 13 active mounds identified in the most recent survey, eight were from those identified by LiDAR. Eight (62%) of the active mounds detected in 2021 were located inside the fenced area while five (38%) were located outside (Table 5). Expressed in relation to total mounds surveyed, 26% of all mounds surveyed inside the fenced area were active, compared to 6% outside the fenced area. This trend of higher Malleefowl breeding activity inside the feral predator-free fenced area compared to outside has been apparent since 2014 (Table 5). In addition, Malleefowl breeding activity appears to be influenced by rainfall, with greater breeding activity in wetter years (Figure 14).

Table 5. Active mounds inside and outside the fence 2012-2021. Surveys in any given year are conducted over summer (i.e., “2021” refers to the summer of 2021-22). No surveys were undertaken in 2015. Increase in total mounds surveyed in 2020/2021 due to use of LiDAR imagery.

Year	Total mounds surveyed	Active inside fence (% of total active)	Active outside fence (% of total active)
2012	31	4 (44.4)	5 (55.6)
2013	27	0 (0)	3 (100)
2014	44	7 (87.5)	1 (12.5)
2016	54	5 (100)	0 (0)
2017	62	3 (100)	0 (0)
2018	26	1 (100)	0 (0)
2019	63	0 (0)	0 (0)
2020	130	8 (66.7)	4 (33.3)
2021	110	8 (61.5)	5 (38.5)

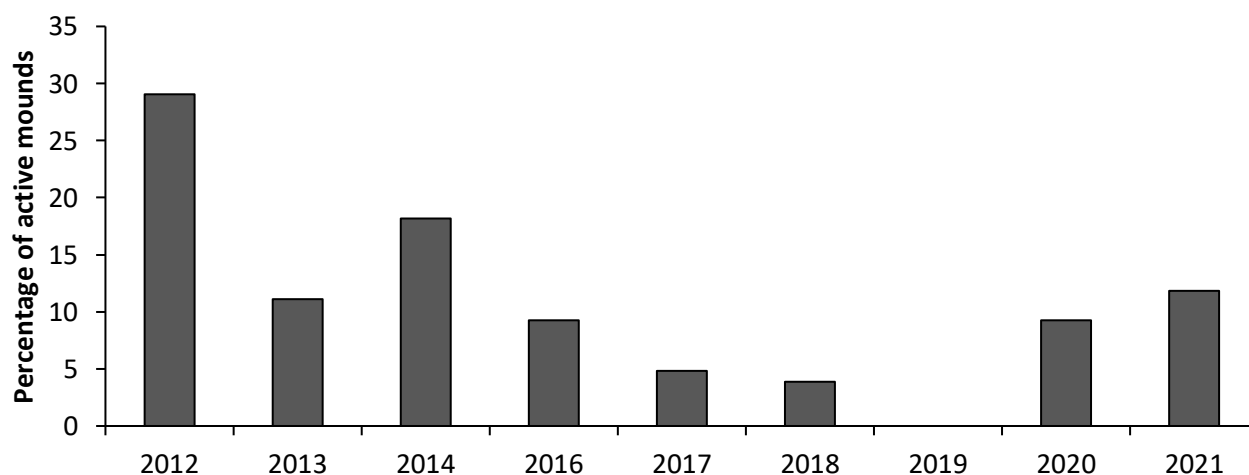


Figure 13. Active Malleefowl mounds recorded at Scotia 2008-2021 as a percentage of total mounds surveyed. Note: no surveys were undertaken in 2015.

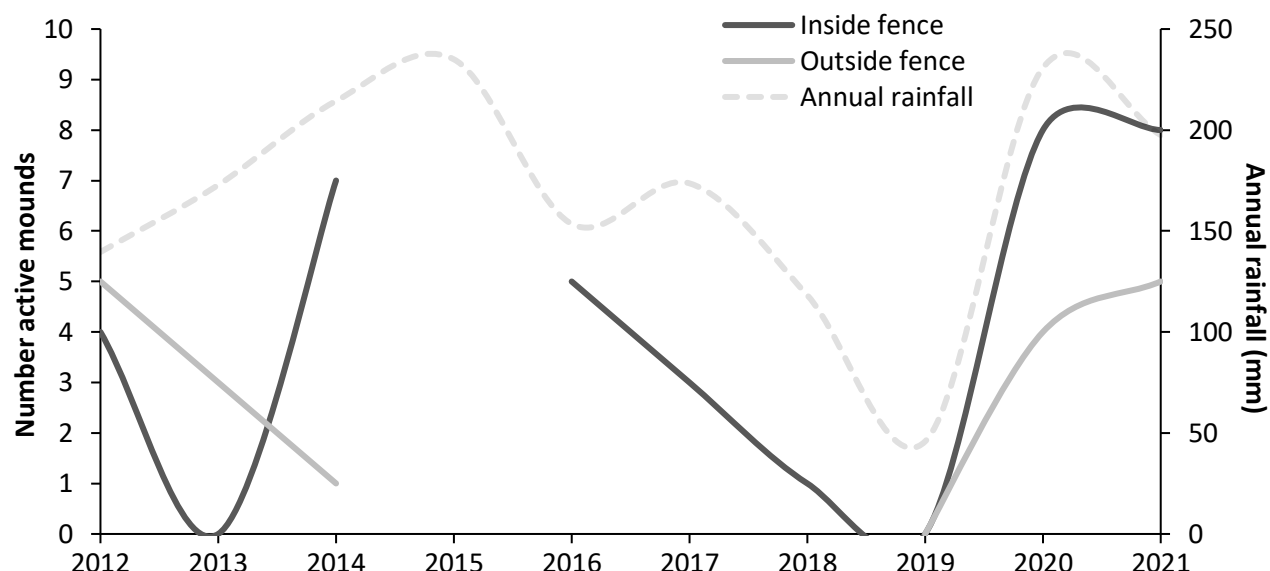


Figure 14. Comparing known active Malleefowl mounds inside vs outside fenced area at Scotia 2008-2021 with annual rainfall. Rainfall data collected from Scotia Sanctuary. Note that no surveys were undertaken in 2015.

Assemblages and surveillance species

Mammals

In 2019, 10 mammal species were detected from 19 known or likely to occur at Scotia (excluding microbats, which were not surveyed). Other species not seen include the Dingo (*Canis dingo*; wide-ranging species that occurs at low densities, especially during drought), Western Pygmy Possum (*Cercartetus concinnus*; rare and cryptic species), and irruptive native rodents (e.g., Bolam's Mouse, *Pseudomys bolami*) that are generally only reliably detected following periods of high rainfall.

Extant small mammals were not surveyed in 2021. Captures of small mammals from 2019 surveys are summarised in Appendix 1.

Reptiles and amphibians

In 2019, 32 reptile species were detected from 59 known or likely to occur at Scotia. Well represented amongst the species that were detected were dragons, geckoes and skinks. Species not detected included snakes (e.g., Curl Snake, *Suta suta*) that are not commonly detected in pitfall/funnel traps, and cryptic species such as the Mallee Worm-lizard (*Aprasia inaurita*) and Dark-spined Blind Snake (*Anilius bicolor*). Reptiles and amphibians were not surveyed in 2021. Captures of reptiles from 2019 surveys are summarised in Appendix 1.

Birds

In 2020, 63 bird species were detected from 174 known or likely to occur at Scotia. Commonly detected species included the Budgerigar (*Melopsittacus undulatus*) and Masked Woodswallow (*Artamus personatus*). A total of 10 honeyeater species was detected. Species not detected included various raptors that are typically only recorded opportunistically, species considered irregular visitors such as water birds, and more cryptic species that are only ever recorded sporadically (e.g., Shy Heathwren, *Hylacola cauta*; Hooded Robin *Melanodryas cucullata cucullata*). Standard Bird Surveys were not conducted in 2021. Records of birds from 2020 surveys are summarised in Appendix 2.

Threat indicators

Feral animals

Feral animals were not surveyed in 2021. A considerable body of research has been conducted by AWC on the ecology, movement patterns and home ranges of foxes and feral cats outside the fence at Scotia (e.g.,

Carter et al. 2019; Roshier and Carter 2021), resulting in well-supported estimates of density, and methodologies for monitoring indices of densities from camera-trap derived occupancy data. AWC plans to establish camera-arrays outside the fence at Scotia to monitor foxes, cats and feral herbivores (goats, etc), using methodologies developed from this research program.

Weeds

Weeds were not surveyed in 2021. Threat metrics have not yet been selected for Scotia, however a Weed Management Strategy will be developed in the future, which will identify weeds of highest conservation impact that will be prioritised for control, and monitoring methods and metrics to support implementation of that work.

Fire

In 2020, 40.6 ha (0.06% of the property) was strategically burnt within the feral predator-free fenced area for infrastructure protection. No areas were burnt outside the fenced area in 2020.

No prescribed or unplanned fires occurred in 2021.

Discussion

Reintroduced species

Severe drought conditions during 2018 and 2019 had a dramatic impact on populations of reintroduced mammals at Scotia, with all reintroduced species experiencing major reductions in population size. In 2020 and 2021, rainfall returned to average at Scotia, providing increased availability of foraging resources and vegetation for shelter. Encouragingly, populations of all reintroduced mammal species that remain on Scotia have increased in 2021 and early 2022 in response to improved conditions.

The population estimate obtained for Numbats in 2021 is considered conservative as grass growth from recent rains and cool temperatures limiting Numbat activity made seeing Numbats difficult in the most recent survey. The Greater Bilby population estimate has increased more than four-fold from the estimate obtained in 2020, with numbers now comparable with population peaks observed prior to the drought. This reflects the ability of this species to reproduce rapidly during favourable conditions. Burrowing Bettong numbers also increased in 2021. While numbers are still well below historical estimates, the growth observed in 2021 indicates that the population is in the process of recovering after the drought-driven decline.

Bridled Nailtail Wallabies declined to very low numbers at Scotia in 2019-20 in response to severe drought. This made obtaining an accurate population estimate difficult. Several survey techniques were trialled, including experimental thermal drone surveys. While these new techniques show some promise, strip-plot spotlighting transects were used to generate population estimates. The most recent survey results suggest that the Bridled Nailtail Wallaby population at Scotia has now begun to recover.

In response to the observed population decline, AWC developed a Population Management Plan (PMP) for the Bridled Nailtail Wallaby at Scotia (Berry et al. 2021), identifying key risks to the population and outlining how those risks will be mitigated. The PMP stipulated consolidating all remaining individuals into Stage 2. This was to limit the potential for inbreeding amongst remaining animals in different fenced areas and to capitalise on better habitat quality for the species in Stage 2. All animals in the smaller 'homestead paddock' have now been moved to Stage 2. A small number of animals persist in Stage 1 and attempts to move Stage 1 animals to Stage 2 are ongoing. In 2022, AWC is planning to supplement the Scotia Bridled Nailtail Wallaby population with animals from the only remaining remnant population of the species at Taunton National Park, QLD. The genetic management plan for the species (Weeks 2018) identified the need to supplement the Scotia population with Taunton animals given low genetic diversity at Scotia. The recent decline in population size at Scotia provides an ideal opportunity to undertake this supplementation as fewer animals are required from Taunton to achieve desired genetic outcomes.

Brush-tailed Bettongs at Scotia (and Yookamurra) declined markedly during the 2018-19 drought. Consequently, the decision was made to remove remaining animals from Scotia. This involved translocating

26 individuals from Scotia to Yookamurra in 2020, to supplement that population. In August 2021, the remaining animals at Scotia (n = 16) were translocated to Mallee Cliffs National Park as part of the reintroduction of Brush-tailed Bettongs to that site. Now that conditions have improved, AWC plans to reintroduce Brush-tailed Bettongs to Scotia in 2022 from the genetically-diverse population that we have established at Mt Gibson Wildlife Sanctuary, WA.

Extant threatened and iconic species

Of the 110 known Malleefowl mounds that were assessed for activity in 2021, 12% were active, while no active mounds were identified during the height of the drought in 2019. Improved conditions associated with two years of average rainfall appear to be facilitating Malleefowl breeding activity. Historic trends at Scotia suggest that the number of active mounds observed is influenced by annual rainfall totals. This is especially the case inside the fence where feral predators do not act to suppress Malleefowl breeding activity.

Inside the Scotia feral predator-free fenced area, 26% of monitored mounds were active, compared to 6% outside the fenced area. This suggests that feral cats and/ or foxes have a significant negative impact on Malleefowl breeding activity, and that Malleefowl at Scotia are likely to benefit from the eradication of feral predators inside the fence. Similar patterns have been observed from other fenced areas managed by AWC that support Malleefowl.

Management implications

Reintroduced mammal populations in semi-arid ecosystems are strongly influenced by prevailing climatic conditions. Improved conditions at Scotia in 2020-21 have resulted in increases in population size for reintroduced species following drought-driven declines in 2019. Management plans will be developed for each species to identify risk mitigations and associated trigger action response plans to ameliorate risks. This will allow any future population fluctuations to be carefully managed to ensure ongoing population viability.

Species management plans will also consider mitigations to address genetic risks following fluctuations in population size. There may be a need for genetic rescue/supplementation using wild populations or populations from other AWC sanctuaries.

It is also interesting to note that extant threatened species such as the Malleefowl appear to be benefitting from the removal of feral predators inside the fence. A similar outcome has been reported for extant small mammals at Scotia (Roshier et al. 2020). When considering conservation of threatened species, the importance of removing or controlling pressures associated with feral predators and herbivores is critical.

Acknowledgements

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

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

References

- BoM, Bureau of Meteorology (2022) Climate Data Online. Retrieved 8 Feb 2022
<http://www.bom.gov.au/climate/data/index.shtml>
- Berry L, Holland G, Anson J, Pierson J, Kanowski J (2021) *Bridled Nailtail Wallaby: Population Management Plan, Scotia Wildlife Sanctuary*. Australian Wildlife Conservancy, Perth.
- Carter A, Potts JM, Roshier DA (2019) Toward reliable population density estimates of partially marked populations using spatially explicit mark-resight methods. *Ecology and Evolution* 9, 2131-2141.
- Kanowski J, Hopkins MS, Marsh H, Winter JW (2001) Ecological correlates of folivore abundance in north Queensland rainforests. *Wildlife Research* 28, 1-8.
- Kanowski J, Joseph L, Kavanagh R, Fleming A (2018) 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.
- Kemp JE, Jensen R, Hall ML, Roshier DA, Kanowski J (2021) Consequences of the reintroduction of regionally extinct mammals for vegetation composition and structure at two established reintroduction sites in semi-arid Australia. *Austral Ecology* 46, 653-669.
- Kemp L, L'Hotellier F, Carter A, Roshier D (2016) *Scotia Sanctuary Small Mammal Trapping Survey Protocol*. Australian Wildlife Conservancy, Perth
- L'Hotellier F, Carter A, Kemp L, Roshier D (2016a) *Scotia Sanctuary Numbat Survey SOP*. Australian Wildlife Conservancy, Perth
- L'Hotellier F, Carter A, Kemp L, Roshier D (2016b) *Scotia Sanctuary Mammal Spotlight Survey Protocol*. Australian Wildlife Conservancy, Perth
- Roshier DA, Carter A (2021) Space use and interactions of two introduced mesopredators, European red fox and feral cat, in an arid landscape. *Ecosphere* 12, 10.1002/ecs2.3628
- Roshier DA, L'Hotellier FL, Carter A, Kemp L, Potts J, Hayward MW, Legge SM (2020) Long-term benefits and short-term costs: small vertebrate responses to predator exclusion and native mammal reintroductions in south-western New South Wales, Australia. *Wildlife Research* 47, 570-579.
- Weeks A (2018) Genetic Management Plan For The Bridled Nailtail Wallaby. CESAR, Parkville, Victoria.
- Westbrooke ME, Miller JD, Kerr M (1998) The vegetation of the Scotia 1:100 000 map sheet, western New South Wales. *Cunninghamia* 5, 665-684.
- White GC (2008) Closed population estimation models and their extensions in Program MARK. *Environmental and Ecological Statistics* 15, 89-99.

Appendix 1. Native small mammals and reptiles

Reptile species observed during the Standard Trapping Survey in 2019. Occupancy = number of sites where each reptile species was recorded (n = 48).

Scientific Name	No. Records	Occupancy (n = 48 Sites)
<i>Anilius bituberculatus</i>	6	4
<i>Brachyurops australis</i>	1	1
<i>Cryptoblepharus australis</i>	2	2
<i>Cryptoblepharus pannosus</i>	3	3
<i>Ctenophorus fordii</i>	13	10
<i>Ctenopus atlas</i>	9	6
<i>Ctenopus inornatus</i>	13	10
<i>Ctenopus regius</i>	15	11
<i>Ctenopus schomburgkii</i>	45	24
<i>Delma butleri</i>	1	1
<i>Diporiphora nobbi</i>	3	3
<i>Egernia striolata</i>	2	2
<i>Eremiascincus richardsonii</i>	34	16
<i>Gehyra versicolor</i>	24	20
<i>Heteronotia binoei</i>	14	12
<i>Lerista aericeps</i>	5	1
<i>Lerista labialis</i>	108	30
<i>Lerista punctatovittata</i>	14	12
<i>Lialis burtonis</i>	1	1
<i>Liopholis inornata</i>	1	1
<i>Lucasium damaeum</i>	8	8
<i>Menetia greyii</i>	20	14
<i>Morethia boulengeri</i>	13	10
<i>Morethia obscura</i>	1	1
<i>Nephrurus levis</i>	15	12
<i>Oedura cincta</i>	2	2
<i>Pogona vitticeps</i>	3	3
<i>Pseudonaja modesta</i>	1	1
<i>Pygopus schraderi</i>	1	1
<i>Rhynchoedura angusta</i>	17	13
<i>Strophurus intermedius</i>	2	2
<i>Varanus gouldii</i>	3	3

Native mammals recorded during trapping, camera and/ or nocturnal spotlight in 2019. Sites occupied = total number of sites where each mammal species was observed during surveys.

Common Name	Scientific Name	Numbers captured	Sites occupied	Survey Method
Southern Ningau	<i>Ningau yvonneae</i>	16	11	Trapping
Fat-tailed Dunnart	<i>Sminthopsis crassicaudata</i>	1	1	Trapping
Strip-faced Dunnart	<i>Sminthopsis macroura</i>	1	1	Trapping
Common Dunnart	<i>Sminthopsis murina</i>	18	14	Trapping

Appendix 2. Native Birds

List of native birds recorded during Standard Bird Survey in 2020

Species	Count	Species	Count
Australian Magpie	3	Mulga Parrot	7
Australian Owllet-nightjar	2	Pallid Cuckoo	1
Australian Raven	10	Pied Honeyeater	3
Australian Ringneck	3	Pink Cockatoo	1
Babbler sp.	1	Purple-backed Fairywren	2
Black-eared Cuckoo	3	Rainbow Bee-eater	3
Black-faced Cuckoo-shrike	2	Red-capped Robin	26
Black-faced Woodswallow	1	Rufous Whistler	18
Blue Bonnet	1	Singing Honeyeater	3
Brown Quail	1	Southern Scrub-robin	7
Brown Treecreeper	1	Spiny-cheeked Honeyeater	33
Brown-headed Honeyeater	2	Splendid Fairy-wren	4
Budgerigar	68	Spotted Pardalote	8
Chestnut-rumped Thornbill	15	Striated Grasswren	6
Chestnut Quail-thrush	11	Striated Pardalote	15
Cockatiel	4	Striped Honeyeater	1
Common Bronzewing	3	Stubble Quail	3
Crested Bellbird	9	Varied sitella	1
Crested Pidgeon	1	Weebill	22
Crimson Chat	6	White-breasted Woodswallow	1
Galah	1	White-browed Babbler	8
Gilberts Whistler	3	White-browed Treecreeper	8
Golden Whistler	1	White-browed Woodswallow	2
Grey Butcherbird	8	White-eared Honeyeater	6
Grey Currawong	1	White-fronted Honeyeater	19
Grey Shrike-thrush	6	White-plumed Honeyeater	1
Grey-fronted Honeyeater	1	White-winged Chough	2
Horsefield's Bronze-cuckoo	5	White-winged Triller	13
Inland Thornbill	12	Willie Wagtail	4
Jacky Winter	6	Yellow-plumed Honeyeater	26
Little Eagle	2	Yellow-throated miner	7
Masked Woodswallow	39		

Occupancy of Ecohealth indicator bird species (number of sites surveyed in brackets)

Species	2020 (n=48)	2018 (n=63)	2017 (n=48)	2015 (n=48)	2013 (n=84)
Pink Cockatoo (Major Mitchell's)	2.1%	0.0%	0.0%	2.1%	0.0%
Striated Grasswren	12.5%	7.9%	8.3%	10.4%	1.2%
Shy Heathwren	0.0%	9.5%	0.0%	2.1%	1.2%
Chestnut Quail-thrush	18.8%	4.8%	16.7%	12.5%	10.7%
Gilbert's Whistler	6.3%	11.1%	8.3%	10.4%	8.3%
Hooded Robin	0.0%	0.0%	4.2%	2.1%	1.2%
Southern Scrub-robin	10.4%	6.3%	16.7%	8.3%	1.2%

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