Bowra Wildlife Sanctuary

Ecohealth Report 2021

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 Bowra Wildlife Sanctuary (Bowra). Metrics from the program are reported in annual Ecohealth Reports and Scorecards. This is the Ecohealth Report for 2021. Values of metrics derived in this report were based on data collected during surveys carried out between 2013–2021. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In this report, results are presented from three long-term surveys conducted to report on 13 Biodiversity and 3 Threat Indicators using data collected on a periodic schedule since acquisition of the property in 2010. Standard Trapping Surveys were conducted in 2011, 2012, 2013, 2014, 2019 and 2020 (the first two were considered 'Inventory' surveys are not included in long-term analyses), Daily Bird Lists have been recorded for 12 years, and the Macropod and Feral Herbivore Survey have been conducted annually since 2015.

During the most recent Standard Trapping Surveys in 2020, a total of 24 native species (19 reptiles, three mammals and two frogs) were detected. The Stripe-faced Dunnart (*Sminthopsis macroura*) and the Fat-tailed Dunnart (*S. crassicaudata*) had the highest recorded abundance to date. The Stripe-faced Dunnart had higher occupancy in 2020 than 2019. These increases were likely driven by improved conditions following reduced grazing pressure from large herbivores and increased rainfall in 2020 after three years of drought conditions in 2017–2019. The Kultarr, which is a significant biodiversity indicator (a Key Threatened Species) for Bowra, was recorded on the camera sensors in 2019. Future targeted surveys will be designed to track status and trends of this species.

Small to medium reptile species richness and abundance per site increased from 2019 to 2020. As for small mammals, these increases were likely the result of improved rainfall in 2020. Consistent with previous years, the most abundant and widely distributed species was the Timid Slider (*Lerista timida*). The Eastern Beaked Gecko (*Rhynchoedura ormsbyi*) was recorded at lower abundance and occupancy in 2020 than in 2019. The Common Dwarf Skink (*Menetia greyii*), which occupied 54% of sites in 2014, was not detected in 2019 or 2020.

The large herbivore survey has been conducted annually in October/November since 2015. In 2021, the surveys detected Red Kangaroos (*Macropus rufus*), Eastern Grey Kangaroos (*M. giganteus*), Western Grey Kangaroos (*M. fuliginosus*) and Wallaroos (*M. robustus*). The six years of annual macropod surveys revealed that the large macropods (Red Kangaroos, and Eastern and Western Grey Kangaroos), suffered drought-related declines in 2018 and 2019 and are now increasing in numbers following increased rainfall in the region. Wallaroos and Swamp Wallabies, while always found in low numbers, have not consistently increased in density in recent years. In 2021, Red Kangaroos were increasing faster than other macropod species, with a 97% increase in 12 months.

A Daily Bird List for the sanctuary was recorded by Birds Queensland from 2010–2019 and has resumed in 2022 with the lifting of Covid-19 restrictions. These data record the observations of Bowra volunteers and visitors, whereby the highest number of a species (seen in a single flock) is recorded for each species every day. When data between 2010–2019 is investigated, all 221 confirmed species were recorded over the 10-year period. Daily records of the Major Mitchell Cockatoo (*Lophochroa leadbeateri*), Bourke's Parrot (*Neopsephotus bourkii*) and Hall's Babbler (*Pomatostomus halli*) were consistently recorded on the sanctuary. The Major Mitchell's Cockatoo is the most frequently encountered species and is observed on average 86.7% of days birded each year during the period 2010–2019. Bourke's Parrot were observed on average 53.5% of days birded a year, the highest observations occurred in 2010 when the species were recorded on 70% of days birded during that year. In contrast, the Hall's Babbler is the most infrequently observed, and is recorded on average 44.6% of days birded per year. This species has a relatively small distribution and on Bowra they favour a narrow section of Mulga.

With respect to introduced herbivores, sheep (*Ovis aries*), and cattle (*Bos taurus*) population estimates continue to remain low with very few incursions onto the sanctuary, however, goats (*Capra hircus*) were found to have increased in population size and density in the past year. The reductions in populations of large herbivores between 2015 to 2019 were driven by severe drought conditions in addition to AWC's ongoing

management, including population control and the removal of artificial water sources. The increase in large herbivore numbers, both native and introduced, observed from 2020 onwards is unsurprising, given improved rainfall during 2020 and 2021 as well as, low densities of herbivores generally over the last few years, which has allowed vegetation communities to recover. Long-term efforts to maintain fences and reduce or remove man-made surface water will continue to ensure low grazing pressure of introduced species and continual recovery of the remnant vegetation.

Contents

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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 one of a series of annual Ecohealth Reports for Bowra Wildlife Sanctuary (referred to here as Bowra) and draws on surveys conducted between 2013 and 2021 to calculate values for metrics that track the status and trend of the Ecohealth indicators. The companion Ecohealth Scorecard presents the indicators and their metrics in a summary format.

Bowra Wildlife Sanctuary

Bowra Wildlife Sanctuary ('Bowra') is a 14,700 ha property located near Cunnamulla in south-west Queensland, Australia (Figure 1). Bowra is within the traditional lands of the Kunja people. The sanctuary is situated in the semi-arid Mulga Lands bioregion and incorporates two subregions: the Warrego Plains subregion in the south-east (dominated by Poplar Box, *Eucalyptus populnea*, Cypress Pine, *Callitris glaucophylla*, and Gidgee, *Acacia cambagei*, woodlands); and the West Warrego subregion on low stony hills in the north-west (dominated by Mulga, *Acacia aneura*, woodlands). As a consequence of its location and diversity of habitats (Figure 2), Bowra supports a number of species at or near their eastern or western range limits, such as Bourke's Parrot (*Neopsephotus bourkii*; east) and Plum headed Finch (*Neochmia modesta*; west).

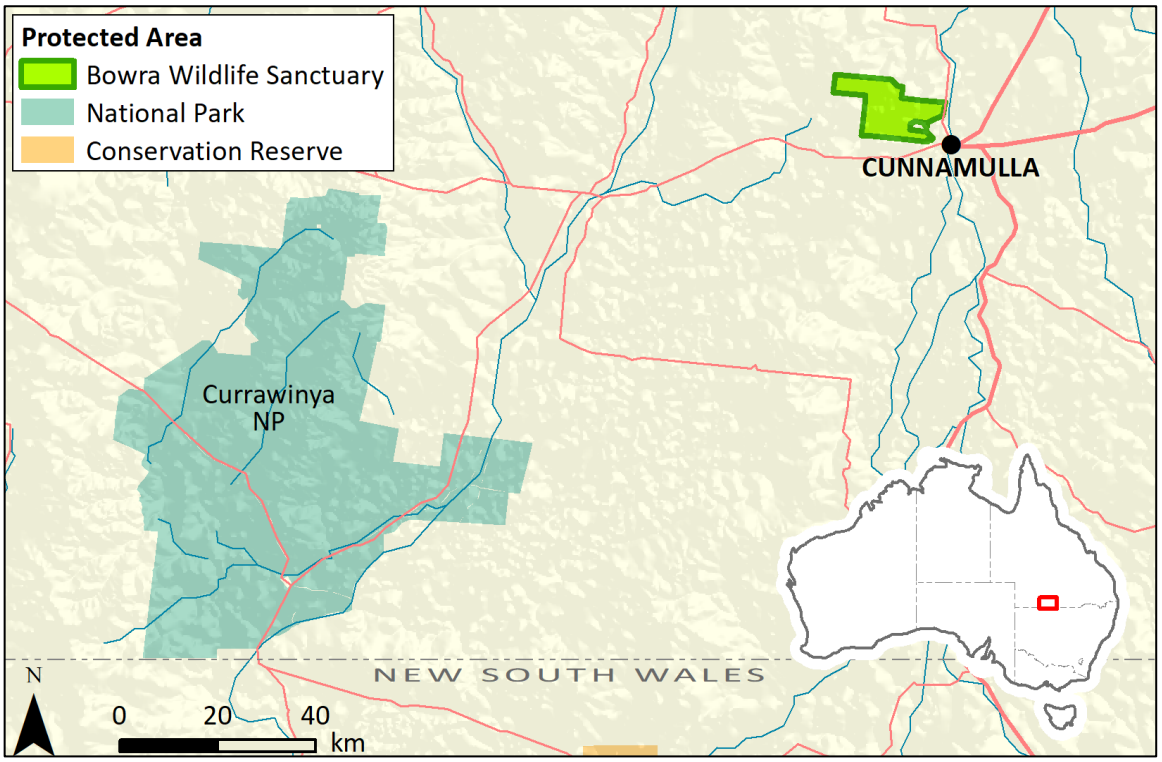

Figure 1. Location and regional context of Bowra.

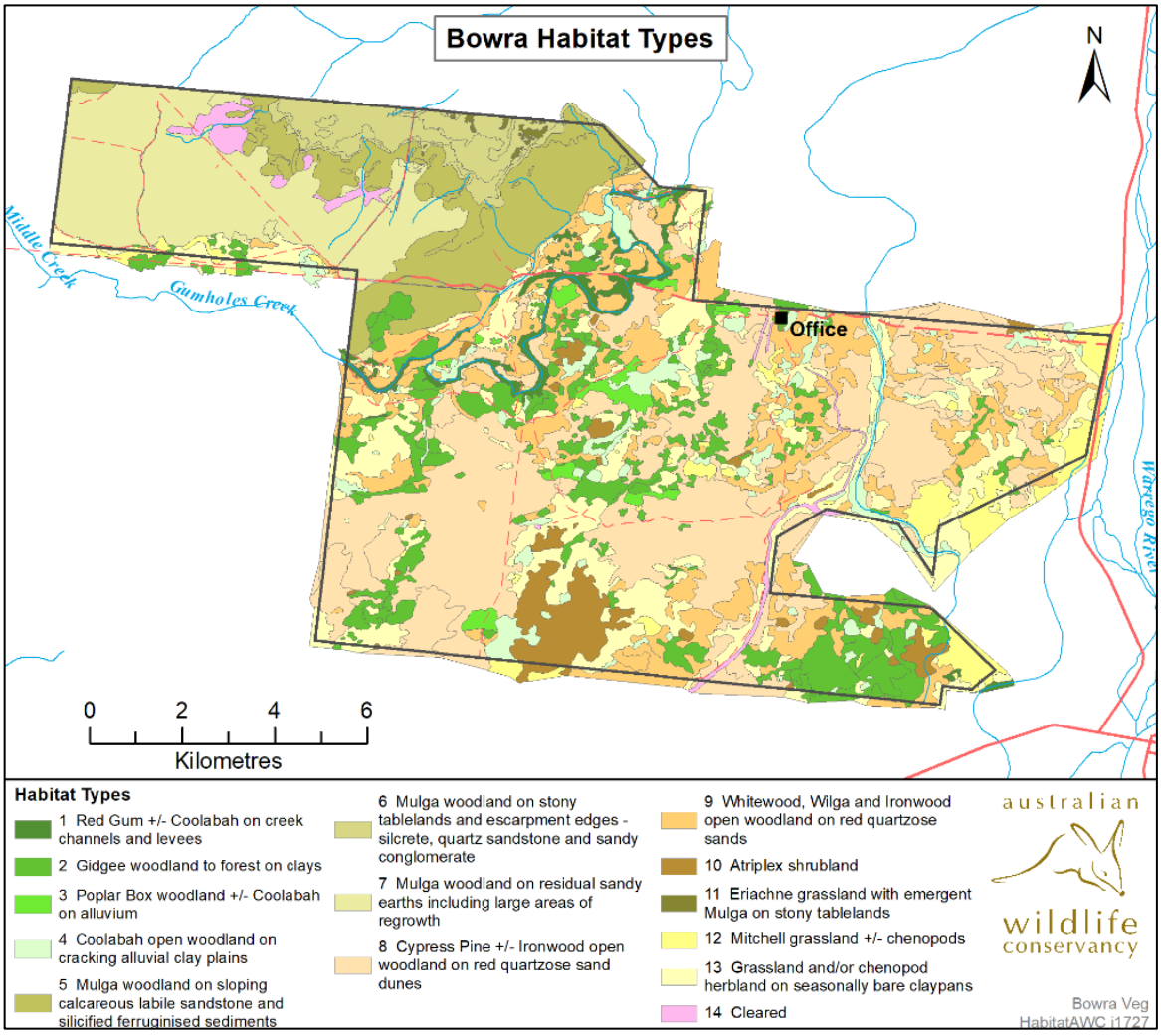

Figure 2. Main vegetation types on Bowra.

To date, 325 native species have been confirmed on Bowra (219 birds, 26 mammals, 55 reptiles, 17 frogs and 8 fish). Many of the species are reliant on the Mulga Lands bioregion for the bulk of their distribution. This includes seven threatened species, six of which are birds though only one species, the Eastern Major Mitchell Cockatoo (*Lophochroa leadbeateri leadbeateri*) is a resident on the sanctuary. Including the Major Mitchell Cockatoo, there are three additional species of high conservation value that are supported on Bowra; Kultarr (*Antechinomys laniger*), Bourke's Parrot and Hall's Babbler (*Pomatostomus halli*), all of which maintain a permanent population on the sanctuary.

Historically, Bowra was subject to considerable grazing pressure from feral herbivores (goats, *Capra hircus*; sheep, *Ovis aries*; rabbits, *Oryctolagus cuniculus*; and cattle, *Bos taurus*), as well as from high numbers of native macropods (Red Kangaroos, *Macropus rufus*; Eastern Grey Kangaroos, *M. giganteus*; and Western Grey Kangaroos, *M. fuliginosu*s). Sheep and cattle are periodically removed from Bowra by surrounding landowners in coordination with AWC. Goats are managed subject to an agreement between AWC and a local operator. Rabbits are subject to opportunistic management which includes strains of Calicivirus which pass through the area. The control of overabundant macropods by AWC commenced in 2015 and continued annually until 2017. By 2018, macropod numbers had decreased substantially, due to a combination of control management, ongoing drought and removal of artificial water sources.

Climate and weather summary

Bowra is located in a semi-arid environment that receives minimal annual rainfall. The region typically experiences hot summers and cold winters with mean maximum temperatures ranging between 35.5 °C in summer and 19.9 °C in winter (Figure 3).

Mean maximum temperatures have been above average since 2019 with 30.2 °C, 29.3 °C and 28.6 °C documented from 2017–2019 respectively, compared to the long-term average annual maximum of 28.2 °C (Bureau of Meteorology 2021a; data from Cunnamulla Post Office 1907–2020, weather station number 44026). Mean minimum temperatures from 2019 to 2021 have also been above average (Bureau of Meteorology 2021b; Figure 3).

Coupled with the extreme summer temperatures, the region experienced severe drought conditions, recording below average annual rainfall from 2017 through to 2020 (Figure 4). The average annual rainfall (1997–present) for Cunnamulla is 379 mm. The 2019 period saw half of this with only 185 mm of rain (Figure 4). Encouragingly, 2020 and 2021 had higher rainfall, with 2021 rainfall, the highest total since 2016, and surpassing the long-term average.

After years of drought, in 2020, the Cunnamulla region recorded its most consistent rainfall in four years, with regular rainfall nearly every month and above average rainfall in January, March, July, August and December totalling 269 mm annual rainfall although was still nearly 100 mm below average (Bureau of Meteorology 2021c; Figure 5). This was surpassed in 2021 with an annual total of 409 mm, over 100 mm above the average rainfall for the region.

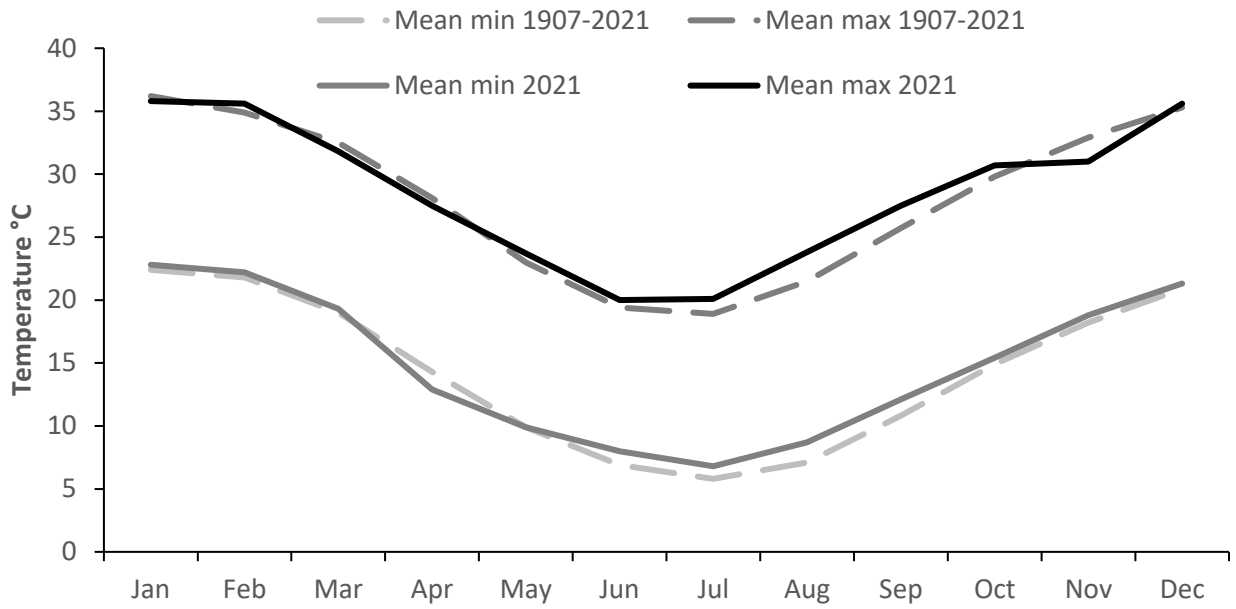

Figure 3. Mean monthly maximum and minimum temperatures at Cunnamulla in 2021, and mean (1907–2021; BOM Climate Data online station number 44026).

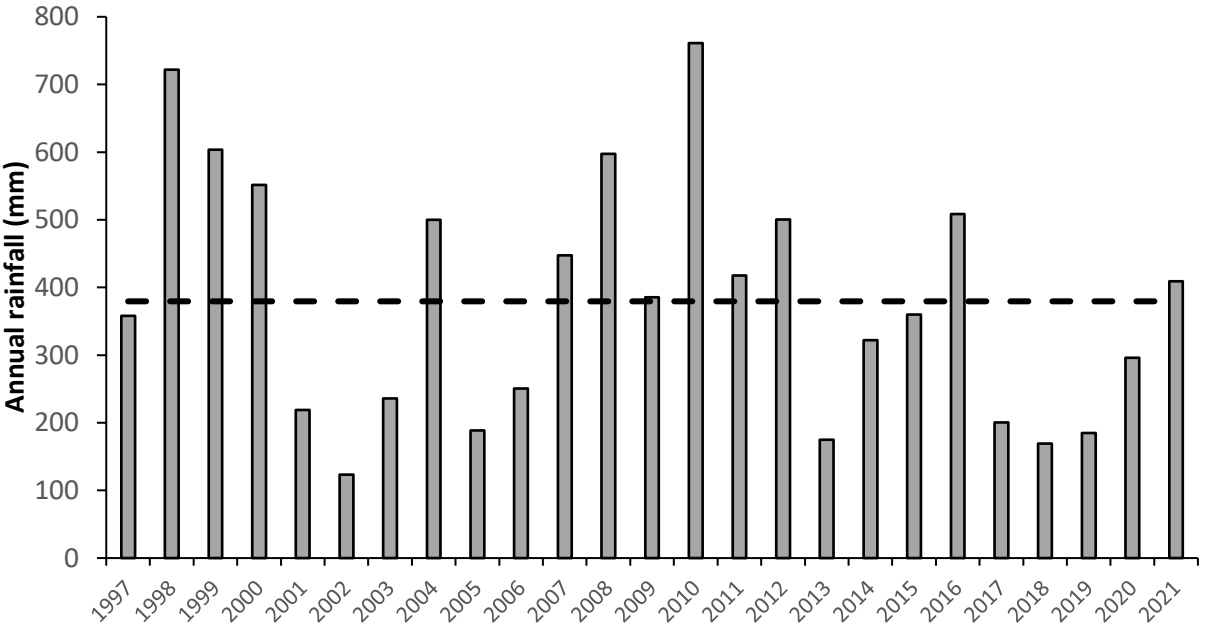

Figure 4. Annual total rainfall at Cunnamulla, 1997–2021. Dashed line is the average from 1997–2021 (BOM Climate Data online station number 44026).

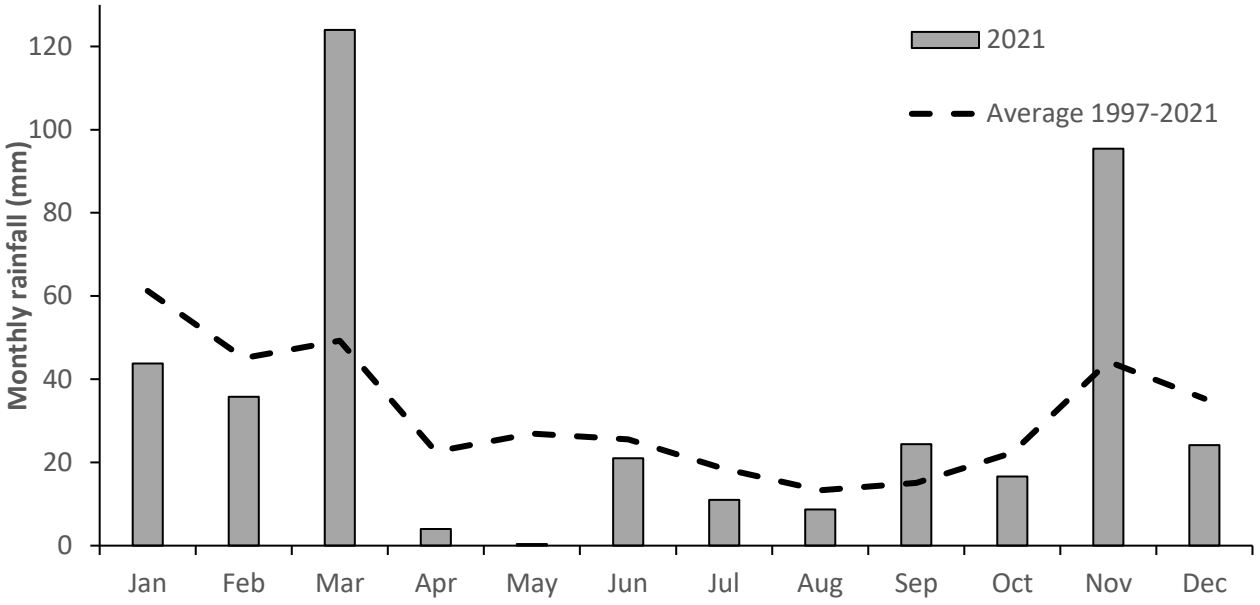

Figure 5. Monthly total rainfall in Cunnamulla 2021. Dashed line is the average monthly rainfall, 1997–2021 (BOM Climate Data online station number 44026).

Methods

Monitoring and evaluation framework

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

Key threatened and iconic vertebrates

The Ecohealth program is focused on species of high conservation value, including 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). Where relevant, reintroduced species are also in this category. AWC will aim to develop *Conservation Plans* for the extant threatened and iconic species to ensure early detection of any serious issues that arise and to trigger timely responses. These plans will specify metrics to monitor outcomes for target species against nominated performance criteria.

Vertebrate assemblages and surveillance species

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

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

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

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

Indicators and metrics

On Bowra, 23 biodiversity indicators (species and guilds) have been selected for monitoring, including four species of high conservation value (Table 1). Six (the large herbivores and birds) of these indicators were surveyed on in 2021 and an additional 13 were last surveyed in 2020; all are reported on here.

Threat metrics are selected to monitor the status and trends of introduced weeds, predators and herbivores, and fire regimes. Three threat indicators have been selected for monitoring at Bowra (Table 2); all are reported on in 2021.

Table 1. Biodiversity indicators and methods for Bowra.

Key threatened and iconic vertebrates

Indicator	Survey name	Survey method	Metric/s
Mammals			
Kultarr (*Antechinomys laniger*)	Standard Camera Surveys Targeted Kultarr Survey (TBD)	Sensor Camera	Occupancy and Abundance
Birds			
Bourke's Parrot (*Neopsephotus bourkii*)	Daily Bird Lists (Birds Queensland),	Incidental observations	Percentage days seen per annum
Hall's Babbler (*Pomatostomus halli*)	Daily Bird Lists (Birds Queensland),	Incidental observations	Percentage days seen per annum
Eastern Major Mitchell's Cockatoo (*Lophochroa leadbeateri*)	Daily Bird Lists (Birds Queensland),	Incidental observations	Percentage days seen per annum

Vertebrate assemblages and surveillance species

Indicator	Survey name	Survey method	Metric/s
Mammals			
Assemblage richness	Standard Trapping Survey, Standard Camera Survey, Macropod and Feral Herbivore Survey, Incidentals	Pitfalls, funnels, camera traps, track-based strip transects	Number of species
Small-medium mammals			
Assemblage richness	Standard Trapping Survey	Pitfalls, funnels, camera traps	Number of species
Small-medium mammal guild	Standard Trapping Survey	Pitfalls, funnels	Abundance, occupancy, richness
Fat-tailed Dunnart (*Sminthopsis crassicaudata*)	Standard Trapping Survey	Pitfalls, funnels	Abundance, occupancy
Stripe-faced Dunnart (*Sminthopsis macroura*)	Standard Trapping Survey	Pitfalls, funnels	Abundance, occupancy
Large mammals			
Assemblage richness	Macropod and Feral Herbivore Survey, Standard Camera Survey	Track-based strip transects	Number of species
Western Grey Kangaroo (*Macropus fuliginosus*) and Eastern Grey Kangaroo (*Macropus giganteus)*	Macropod and Feral Herbivore Survey	Track-based strip transects	Population estimate, density
Common Wallaroo (*Macropus robustus*)	Macropod and Feral Herbivore Survey	Track-based strip transects	Population estimate, density
Red Kangaroo (*Macropus rufus*)	Macropod and Feral Herbivore Survey	Track-based strip transects	Population estimate, density
Swamp Wallaby (*Wallabia bicolor*)	Macropod and Feral Herbivore Survey	Track-based strip transects	Population estimate, density

Indicator	Survey name	Survey method	Metric/s
Reptiles			
Assemblage richness	Standard Trapping Survey, Standard Camera Survey, Incidentals	Pitfalls, funnels	Number of species
Small-medium reptiles			
Assemblage richness	Standard Trapping Survey	Pitfalls, funnels	Number of species
Small-medium reptile guild	Standard Trapping Survey	Pitfall, funnels	Abundance, occupancy, richness
Eastern Variegated Dtella (*Gehyra versicolour*)	Standard Trapping Survey	Pitfall, funnels	Abundance, occupancy
Eastern Beaked Gecko (*Rhynchoedura ormsbyi*)	Standard Trapping Survey	Pitfall, funnels	Abundance, occupancy
Boulenger's Snake-eyed Skink (*Morethia boulengeri*)	Standard Trapping Survey	Pitfall, funnels	Abundance, occupancy
Common Dwarf Skink (*Menetia greyii*)	Standard Trapping Survey	Pitfall, funnels	Abundance, occupancy
Timid Slider (*Lerista timida*)	Standard Trapping Survey	Pitfall, funnels	Abundance, occupancy
Birds			
Assemblage richness	Daily Bird Lists (Birds Queensland), Targeted Bird Survey	Incidental observations	Number of species

Table 2. Threat indicators and metrics for Bowra.

Indicator	Survey method	Metric/s
Pest animals		
Feral Cat (*Felis catus*)	Feral Predator Survey	Density
Fox (*Vulpes vulpes*)	Feral Predator Survey	Density
Cattle (*Bos taurus*)	Macropod and Feral Herbivore Survey	Population estimate, density
Sheep (*Ovis aries*)	Macropod and Feral Herbivore Survey	Population estimate, density
Goats (*Capra hircus*)	Macropod and Feral Herbivore Survey	Population estimate, density

Survey types and history

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

For key threatened and iconic vertebrates, these include:

- Standard Trapping Survey
- Kultarr Targeted Survey (TBD)
- Daily Bird Lists (conducted by Birds Queensland)

For monitoring vertebrate assemblages and surveillance species, these include:

- Standard Trapping Survey
- Daily Bird Lists (conducted by Birds Queensland)
- Macropod and Feral Herbivore Survey
- Feral Predator Survey (TBD)

A list of surveys and associated effort is summarised in Table 3.

Two of the ecological surveys were conducted at Bowra in 2021: Macropod and Feral Herbivore Survey and Daily Bird Lists. 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 Bowra reported upon in this report.

Survey name	Effort (2021)	Description	Previous surveys
Standard Trapping Survey	0	22 monitoring sites with pitfall and funnel traps. Stratified to include a range of geography and major vegetation types (Mulga, alluvium, stony tablelands). Two cameras were deployed at each site and left in situ for 14 days.	2020 – 22 sites, 1,318 trap nights, 616 camera trap nights 2019 – 22 sites, 1,320 live trap nights, 616 camera trap nights 2014 – 22 sites, 2,640 live trap nights, 264 camera trap nights 2013 – 20 sites, 1,800 live trap nights, 240 camera trap nights
Macropod and Feral Herbivore Survey	147 km	7 transects of varying length, stratified by major habitat types which are accessible by road.	Annually, 2015–21
Daily Bird List	Variable	Daily bird call data, whereby the highest documented number of a species is recorded for the day	Daily, 2011–2019

Survey design and methods

Standard Trapping Survey

Live trapping

The Standard Trapping Survey consists of live trapping (pitfall and funnel trapping) at 22 survey sites (Figure 6). A long-term Ecohealth survey design was established in 2019 where site selection was stratified by vegetation and soil type (Figure 6). While methods were consistent between the 2019 and 2020 surveys, the number and location of monitoring sites and the number of traps at each site varied between 2013 and 2019. Of the 22 sites surveyed in 2020, 16 had been surveyed in all prior years.

Each of the 22 monitoring sites contained two pitfall arrays. A single array comprised four pitfall traps approximately 600 mm deep with a 250 mm diameter, and six funnel traps, connected by a 30 cm high drift fence (dampcourse). The pitfall traps were installed in 2019 and are deeper than the 20 L buckets used in previous years, making it more difficult for small mammals to escape. The drift fence was erected in a “T” shape (broken into a 20 m section and 10 m section: Figure 7 and 8). Pitfall traps were set near the ends of each section of fence. Pairs of funnel traps were placed on each side of the fence in the centre of each section between pitfalls. Funnel traps were covered in reflective insulation to prevent heat and rain exposure.

Traps were open for three consecutive nights. Traps were checked during the first three hours of sunlight in the morning and again in the last three hours of light in the afternoon. Captured animals were removed from the traps and held in calico bags or clear plastic sandwich bags. Captured animals were identified to species level and small mammals and reptiles were marked with a paint pen to assist in identifying recaptured animals. Morphometric measurements were taken for identification purposes if required.

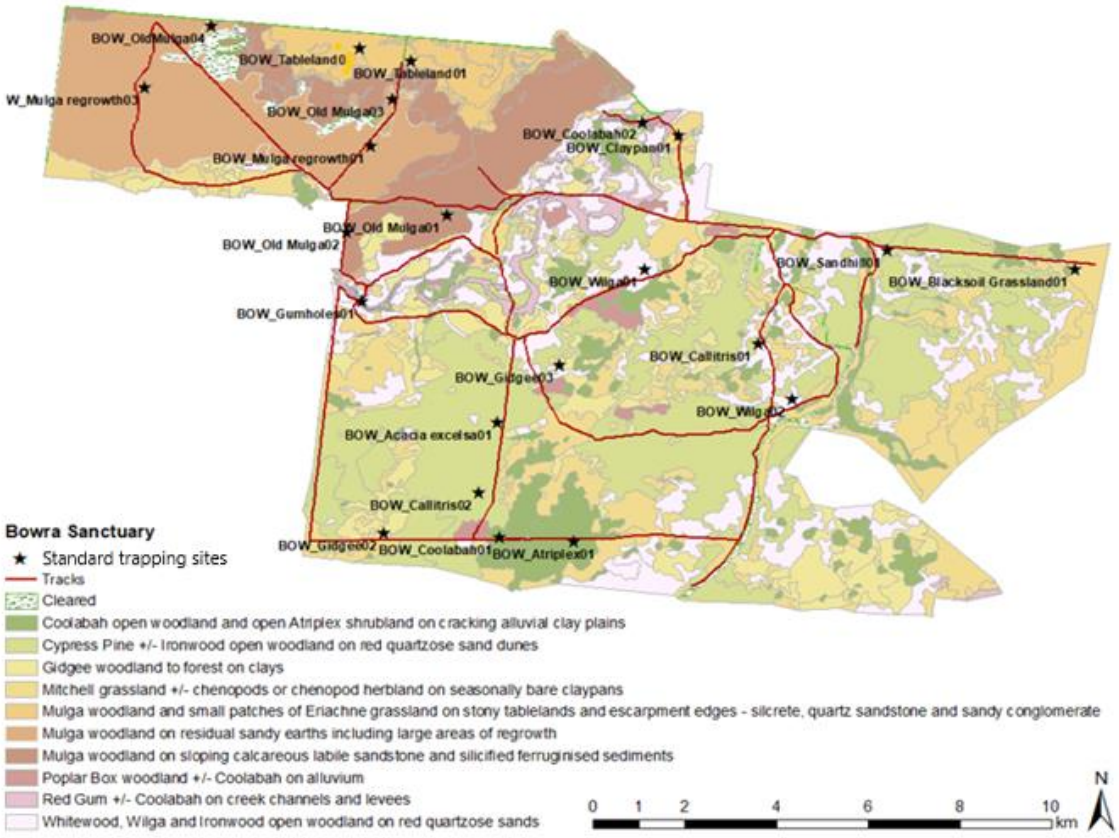

Figure 6. Location of 22 standard monitoring sites on Bowra within representative vegetation types.

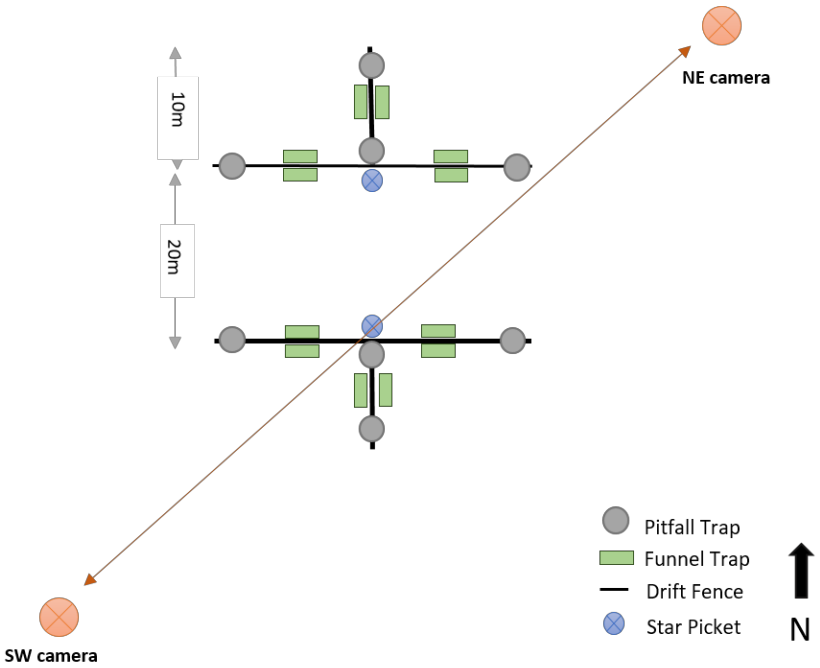

Figure 7. Standard Trapping Survey site design.

Figure 8. Volunteer Anders Zimny working to erect a drift fence at an old Mulga site. Emily Rush/AWC.

Camera trapping

During the 2019 and 2020 Standard Trapping Survey two Reconyx Hyperfire PC850 Whiteflash motion sensor camera traps were placed at each of the 22 Standard Trapping Survey sites (Figure 6), replacing the 20 Elliott traps that were previously deployed at each site. A number of reasons supported this change in method including: the relatively low capture rates of small mammals in Elliott traps in previous surveys; high ambient temperatures over October and November which increases the likelihood of trap deaths; and little to no ground cover at Bowra which results in little shade for the traps. Additionally, there are very few small mammal species at Bowra, increasing the likelihood of identification of individuals captured on camera traps.

One camera was placed to the north-east of one (out of the two) randomly chosen 'T' sites and one camera was placed south-west of the same 'T'. Each camera was located 70 metres from the centre of the selected 'T' (Figure 7). Both cameras were set to a height of 0.3 m to the top of the camera (0.2 m to the lens), angled to face a raised container containing universal bait (rolled oats, peanut butter, sardines and vanilla essence). Cameras were left in situ for 14 days.

Camera data were downloaded and processed using the newly established Artificial Intelligence (AI) software (Microsoft Azure and Postman). Once the AI component was completed, data were uploaded into the program 'Timelapse', and animals were identified to species level where possible. A camera trap 'event' is defined as a detection of a species within one 24-hour period.

Macropod and Feral Herbivore Survey

The Macropod and Feral Herbivore Survey is 49 km of track-based strip transects that were established in 2015 (Figure 9). The transects were driven three times per survey (147 km total). Transects were stratified by Regional Ecosystem (Queensland Herbarium 2014) and represent (as far as possible within the track network) the major ecosystems on Bowra. This survey is conducted annually.

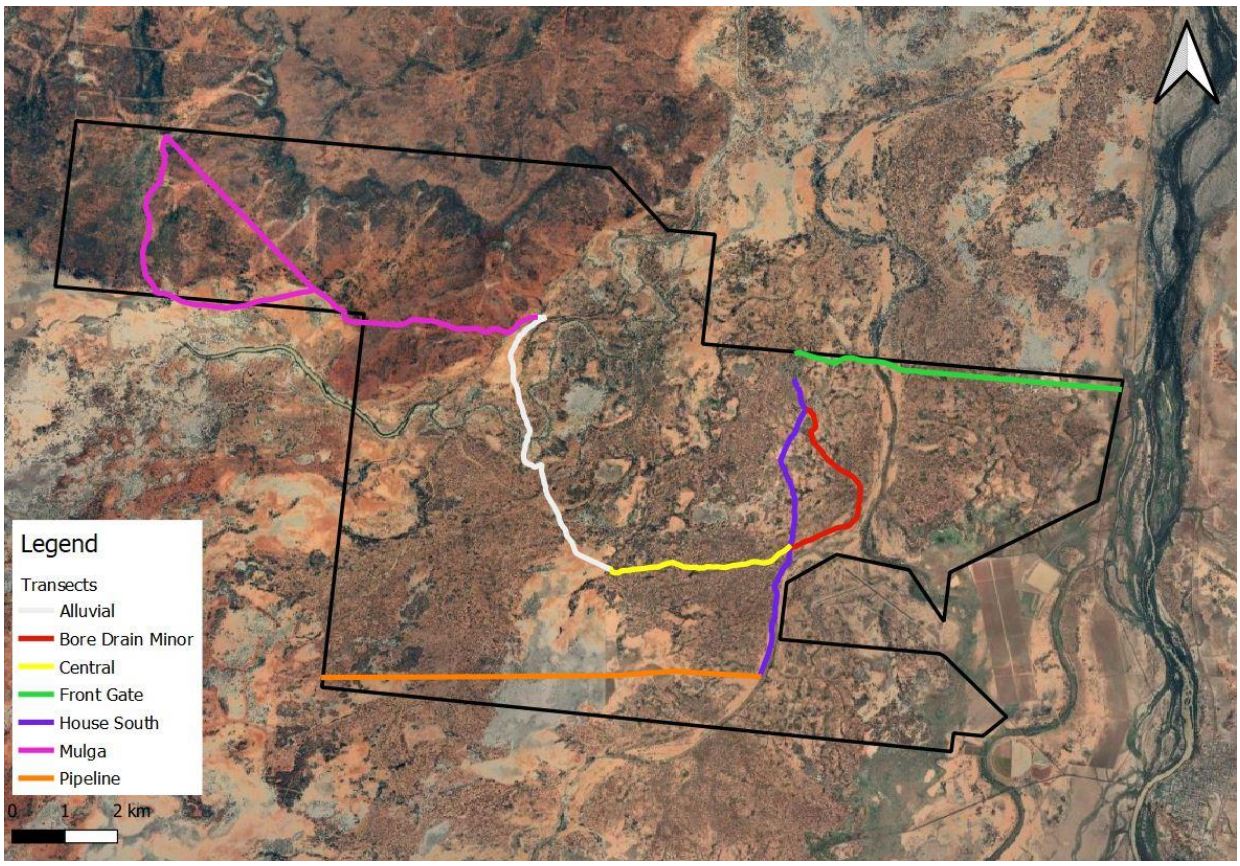

Figure 9. Survey strip transects to monitor native and introduced large herbivores across Bowra.

The Macropod and Feral Herbivore Survey was conducted by two people in the back of a utility vehicle driven slowly along pre-determined transects. This team comprised one scribe and one observer who searched both sides of the road. The vehicle travelled at a maximum speed of 20 km/h. During a pilot survey, macropods were active between approximately 5:00 am to 8:00 am, and 4:00 pm to 7:00 pm. All surveys were therefore conducted during these periods as temperatures were milder (between approx. 19°C and 32°C). Daytime transects were conducted in preference to night-time (spotlighting) to enable easier species identification. Each transect was surveyed three times.

The observer signalled to the driver to halt the vehicle with each sighting of a large herbivore (macropod, cattle, sheep, and goat). The distance to every animal at first sight, or to the centre of each group of animals, was measured in a 90 degree angle to the vehicle using a rangefinder. Animals were identified to species level with the exception of the grey kangaroos. Eastern Grey and Western Grey kangaroos were grouped together as 'grey kangaroos' due to the difficulty of identifying these species in the field.

Daily Bird Lists

Bowra has a high number of visitors and is staffed by Birds Queensland (BQ) volunteers year-round. Since BQ have been managing the visitation at Bowra they have kept daily bird lists, through a system called 'Bird Call', which utilises the volunteer and visitors' daily observations. This data has been recorded in the same manner, every day (excluding Covid-19 periods), since 2010. Participants vary in skill and number throughout the year, however, BQ volunteers are experienced with birds and identification, and they assess and vet the data as it comes through. Since 2014, daily bird lists have been generated for every month in the year, however, in earlier years (2011 to 2013) this data was collected only for a subset of months, which varied by year.

Each evening between 18:00–19:00, BQ volunteers hold 'Bird Call', which is open to all visitors at Bowra. During Bird Call, BQ volunteers systematically go through each species that occurs on Bowra and document the highest number of individuals recorded in a single sighting. For example, one visitor may have seen 10 Grey-crowned Babblers together in a single group, but another visitor will have seen 12 Grey-crowned Babblers together – in this instance 12 is recorded on the data sheet.

In 2020 and 2021, Covid-19 restrictions severely impacted on this dataset, as the sanctuary was closed to the public for much of the time. Given this, analysis in this Ecohealth report is from 2011–2019.

Analysis methods

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

Table 4. Metrics and associated calculations.

Indicator	Metric	Survey data sources	Description	Analysis summary/calculation
Assemblage richness	Number of species	All surveys and incidental records	A measure of intactness for the whole sanctuary	The number of species detected on the sanctuary within the last 1–10 years is compared to the number of species listed as 'confirmed', 'very likely' or 'likely' on the sanctuary species list.
Small-medium mammals guild Small-medium reptile guild	Average richness	Standard Live Trapping	Average number of species across sites	Species richness (average number of species per site) was calculated for guilds. This is calculated by summing the number of species detected per site (total richness per site) and averaging it across the total number of sites.
Various	Abundance	Standard Live Trapping	Abundance of all species	Abundance is calculated as the total number of individuals of all species within the guild divided by the total number of trap nights. Abundance = (number of total individuals/ trap nights x 100) Here, trap nights are only included where a trap type targets the indicator appropriately. For example, funnel trap nights are excluded for small to medium sized mammals.
Various	Occupancy	Standard Live Trapping	Occupancy of all species	Occupancy is calculated by the number of sites all small mammal species are detected at by the total number of sites. (Occupancy: number of sites detected/ total number of sites).
Large native and feral herbivores	Population estimate	Macropod and Feral Herbivore Survey	Estimate of total number of individuals in the population based upon strip transects	Strip-plot methodology (as per Kanowski et al. 2001). Transect surveys where animals are recorded within a variable strip reflecting vegetation change. Widths are recorded by an observer. Observations used to calculate density within the strip area are then extrapolated, by multiplying the density with the total area surveyed (142.2 km^2; Kemp et al. 2015).
Large native and feral herbivores	Density	Macropod and Feral Herbivore Survey	Estimate of number of individuals per km^2 based upon strip plot transects	For each habitat, counts of individuals of each species within strip transects were used to estimate density. Animals recorded outside the allocated strip width for each section were removed from calculations. Average density with standard error was calculated across

Indicator	Metric	Survey data sources	Description	Analysis summary/calculation
				the three repeat surveys of all transects within the two main habitat types. The average density of each species on Bowra was then derived from the habitat-specific densities, weighted by the relative area of each habitat.
Birds				
Various	Activity	Daily Bird Lists (Birds Queensland)	Proportion of days a species was observed in a given year	For each year x: (Sum the # of days a species was observed in year x)/ total number of days birded in year x] *100 Average this value across years

Results

Biodiversity indicators

Key threatened and iconic vertebrates

Kultarr

In 2019, the Kultarr was recorded for the first time at Bowra since AWC acquisition. A single individual was captured on a camera trap during the Standard Trapping Survey; however, the species were not detected again in 2020 despite surveys occurring at the same site.

Eastern Major Mitchell's Cockatoo, Bourke's Parrot and Hall's Babbler

Records of the Eastern Major Mitchell's Cockatoo, Bourke's Parrot and Hall's Babbler have been collected on Bowra from 2010 to 2019 (Figure 10). Each of the three species have been recorded on the sanctuary every year since surveys began in 2010. The Major Mitchell's Cockatoo is the most frequently encountered of the indicator bird species, in 2020 it was observed on 97.2% of days birded above its long-term average of 86.7% of days birded a year (2010–2019). In 2020, Bourke's Parrot were observed on 61.9% of days birded, which is above their long-term average, 53.5% of days birded a year during the same period. Bourke's Parrot had the highest observations occur in 2010 when the species were recorded on 70% of days birded in a year. In contrast, the Hall's Babbler is the most infrequently observed indicator bird species. In 2020, it was recorded on 41% of days birded, which is slightly below its long-term average of 44.6% of days birded per year (2010–2019). This species has a relatively small distribution and on Bowra they favour a narrow section of Mulga. Observations for Hall's Babbler were at their lowest in 2018, when they were recorded on only 31.6% of days birded in the year compared to their highest detections in 2010 at 61.6% of days birded.

It should be noted that visitation to Bowra has varied over the years. Typically, the sanctuary is open to visitors from March to October. However, BQ have had volunteers in residence year-round and they continued the daily bird list in the absence of visitors. In 2019 a decision was made by AWC to close the sanctuary to all visitors at certain periods for land management operations. This closure typically takes place over the summer months, when temperatures are extreme and unsuitable for unguided visitors. Hence, the number of observers varies annually and there are days when the bird list does not take place.

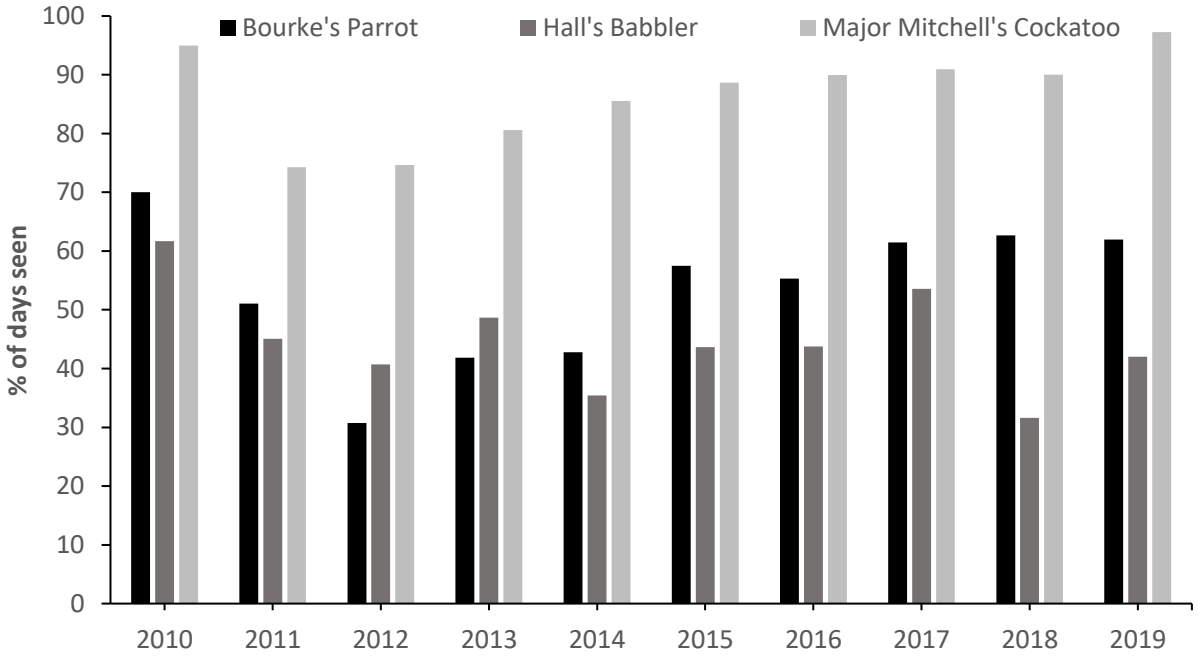

Figure 10. Percentage of days seen each year for iconic bird species, Bourke's Parrot, Hall's Babbler and Major Mitchell's Cockatoo from 2010–2019.

Vertebrate assemblages and surveillance species

Mammals

In 2020, nine of the 26 mammal species known or likely to occur on Bowra were recorded. These were the five macropod species: Eastern and Western Grey Kangaroo, Common Wallaroo (*Macropus robustus*), Red Kangaroo and Swamp Wallaby (*Wallabia bicolor*), as well as three small mammals: Stripe-faced Dunnart (*Sminthopsis macroura*), Fat-tailed Dunnart (*S. crassicaudata*) the Narrow-nosed Planigale (*Planigale tenuirostris*). Many of the missing species were micro-bats, which require specialised survey techniques such as harp trapping and acoustic monitoring, as well as some medium mammals such as Rakali (water rat; *Hydromys chrysogaster*) and Common Brush-tail Possums (*Trichosurus vulpecula*) which are recorded infrequently on the sanctuary.

Small-medium mammals

Three of six species known or likely to occur in this assemblage were recorded in 2020. Missing species were Giles Planigale (*Planigale gilesi*), Kultarr and Central Short-tailed Mouse (*Leggadina forresti*). Each of these have only been recorded once on the sanctuary (2014, 2019 and 2020 respectively) and may occur in very low densities or only after prolonged periods of productive years (i.e., following sustained rainfall).

Individual small-medium mammal species indicators

Three small, native mammal species were captured during the 2020 Standard Trapping Survey. Of these, two are Ecohealth indicator species: the Stripe-faced Dunnart and the Fat-tailed Dunnart. The third species, captured once in 2020, was the Narrow-nosed Planigale, part of the small mammal guild (Figure 11). This was the fourth Narrow-nosed Planigale captured at Bowra and the first record of the species since 2013.

Figure 11. Narrow-nosed planigale captured in 2020. Anders Zimny/AWC.

Of the two indicator species, the Stripe-faced Dunnart had the highest abundance and occupancy (Table 5). This was the highest abundance of this species recorded in any survey to date and a 103% increase since 2019. The Fat-tailed Dunnart was captured less frequently and only at 3 sites (Table 5; Figure 11).

Table 5. Individual small-medium mammal species metrics 2013–2020. A = abundance per 100 trap nights; O = occupancy (proportion of sites occupied).

	2013		2014		2019		2020	
Indicator species	**A**	**O**	**A**	**O**	**A**	**O**	**A**	**O**
Fat-tailed Dunnart	0	0	0	0	0.76	0.14	0.94	0.14
Stripe-faced Dunnart	0	0	0.57	0.14	1.33	0.32	2.65	0.41

Small-medium mammal guild

Although native small mammal captures are typically low at Bowra, the average species richness (number of species per site) increased annually from 2013 to 2020 (Table 6). In contrast, the proportion of sites occupied remained stable (Table 6). The abundance of the small mammal guild decreased between 2013 and 2019. This improved in 2020, when abundance increased by 82% from 2019, to 3.79 individuals per 100 trap nights (Table 6).

Table 6. Small-medium mammal guild metrics 2013-2020. Abundance = abundance per 100 trap nights; occupancy = occupancy (proportion of sites occupied); richness = average number of species per site.

Metric	2013	2014	2019	2020
Abundance	5.00	3.03	2.08	3.79
Occupancy	0.45	0.50	0.45	0.45
Richness	0.10 ± 0.07	0.23 ± 0.11	0.36 ± 0.10	0.59 ± 0.17

Some caution is needed in comparing the above metrics over the 2013–2020 period in light of the variation in the Standard Trapping Survey sites. Nonetheless, the fluctuations in these metrics suggest that small mammal populations on Bowra were influenced by rainfall patterns over this timeframe. While Bowra experienced below average annual rainfall in 2013 (175 mm in 2013; average of 372 mm), this followed an above average year in 2012 (500 mm), which is likely to have led to the high small mammal abundance observed during the 2013 survey. The survey in October 2019 followed below average rainfall in 2017 (200 mm), 2018 (169 mm),

and 2019 (185 mm), which is reflected in the low abundance of small mammals in 2019. The increased and consistent rainfall in 2020 (296 mm) likely improved food resources and ground cover, resulting in the increase in abundance of small mammals including the two dunnart indicator species. The same is evident in the introduced house mouse (*Mus musculus*) captures in 2020 when 105 individuals were caught, in comparison to just 1 individual in 2019.

Figure 12. Juvenile Fat-tailed Dunnart captured at an old Mulga site. Gina Zimny/AWC.

Large herbivores

In 2021, all but one of the macropods known to occupy Bowra was documented during the surveys. The missing species was the Swamp Wallaby, which does have permanent populations on the property, however, occur in much lower densities than the other species.

In 2021, the upward trends that began in 2020 continued for some species. Red Kangaroo density increased from to 3.9/km^2 (± 2.17) in 2020 to 7.7/km^2 (± 0.86) in 2021 (Figure 13). While grey kangaroos increased marginally from 0.5/km^2 (± 0.24) to 0.6/km^2 (± 0.61) over the same period. In contrast, Common Wallaroo density decreased from 1.5/km^2 (± 4.52) in 2020 to 0.6/ km^2 (± 1.86) in 2021. Swamp Wallabies are irregularly detected each year; they were recorded at a density of 0.09/km^2 (± 0.13) in 2020 but were not detected in 2021. This is not unusual as Swamp Wallabies generally occur in low densities on the sanctuary and occupy only a small area of habitat. It is likely they were simply not encountered in 2021.

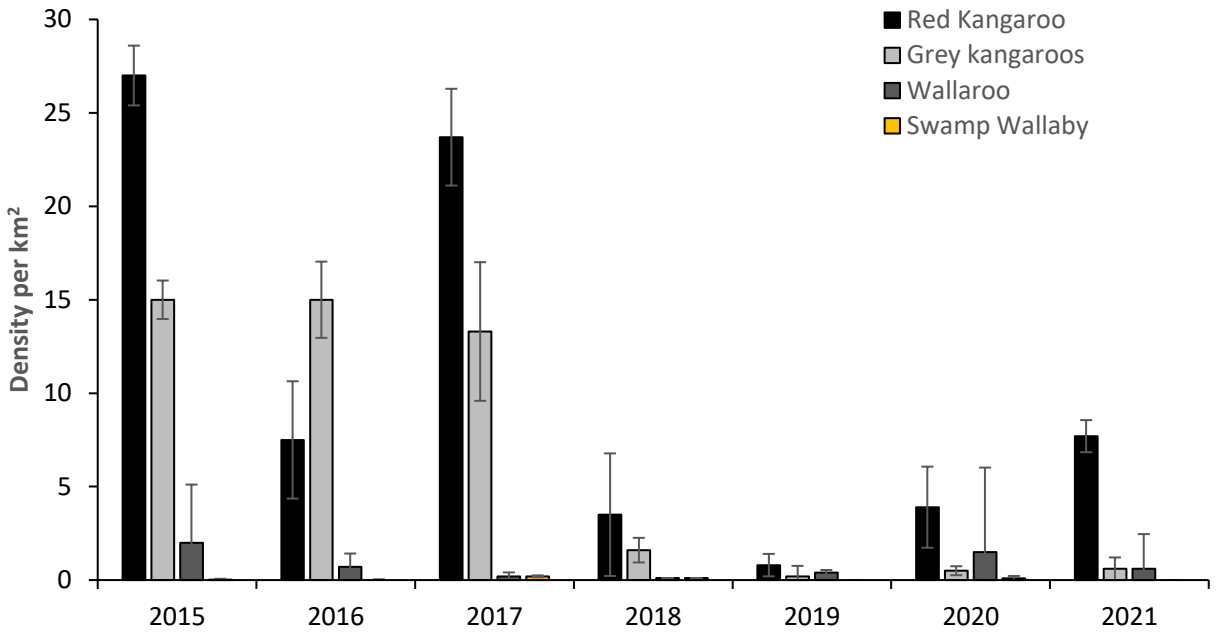

Figure 13. Macropod density per km² from the annual surveys 2015–2021.

In 2021, the survey recorded a 49.5% increase from 2020 with 1,278 individuals estimated for the sanctuary (89 grey kangaroos, 91 Common Wallaroos, 1,098 Red Kangaroos and nil Swamp Wallabies). In 2020, there were an estimated 855 macropods in total on Bowra (comprising 76 grey kangaroos, 210 Common Wallaroos, 556 Red Kangaroos and 13 Swamp Wallabies). Results from 2021 show a substantial increase from the 185 recorded in 2019 but is still a significant reduction (79.8%) since surveys began in 2015, where 6,322 macropods were estimated to occur. Substantial population declines for large native herbivores from 2015 to 2019 (Figure 14) were due in part to both the control of macropods in 2015–2017, as well as ongoing drought conditions in the region until 2019. The increase in population size recorded in 2020–2021 is likely due to the improved vegetation growth and water availability following rainfall throughout 2020 and 2021.

Interestingly, Red Kangaroo populations have recovered substantially faster than those of grey kangaroos on Bowra. From 2020 to 2021, the Red Kangaroo population increased by 97%, while grey kangaroos increased by only 17%. This is likely the result of several factors including biological differences between the two species. Grey kangaroos were more heavily impacted by the drought than other macropods, decreasing by 98% from 2017–2019, prior to the drought breaking. This is largely due to their feeding habit being restricted to grazing only. Meanwhile, Red Kangaroos and Common Wallaroos alike will both graze and browse, greatly increasing their ability to access resources during adverse climatic conditions. Additionally, grey kangaroos have been documented to reach sexual maturity at a slower rate than Red Kangaroos, making population recovery slower than other species (Mjadwesch 2011).

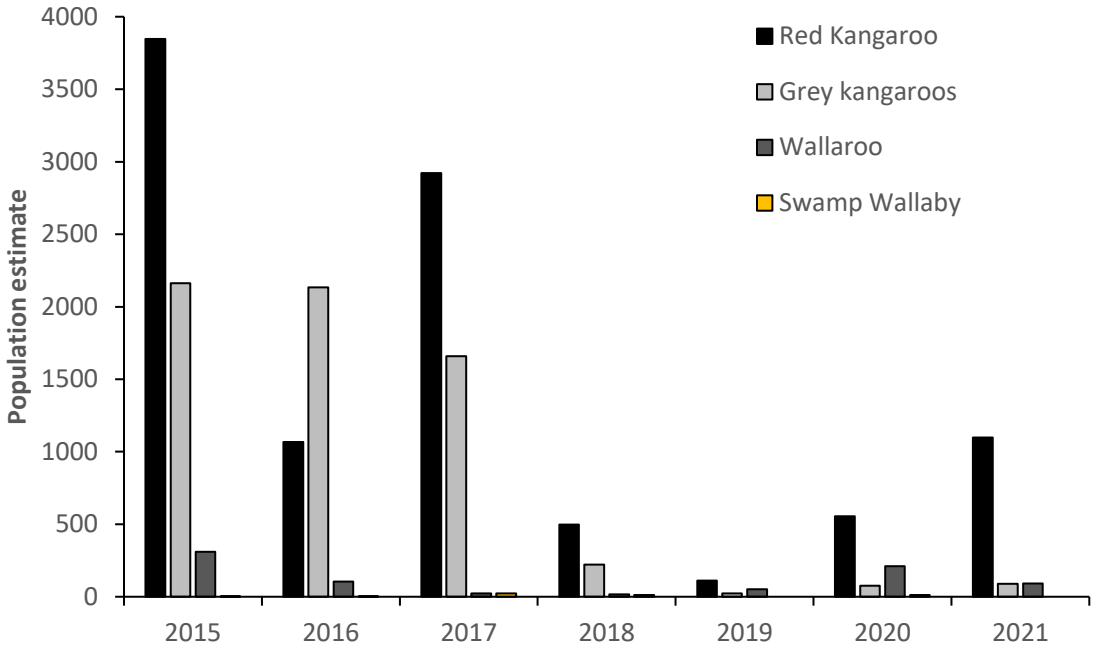

Figure 14. Population estimates of macropods at Bowra from 2015 to 2021.

Reptiles

There were 18 species of reptile recorded in 2020, from 62 known or likely to occur on Bowra. Many species that were not encountered are snakes, which are less likely to enter the standard traps (e.g., pitfalls and funnels) and many skink species that are either arboreal, fossorial or occupy different habitats than those of our trap sites. Reptile captures are dependent on many factors, and as such may require additional survey techniques such as active searches (both day and night) to increase the likelihood of encountering additional species.

Small-medium reptiles

There were 18 species of small to medium reptile recorded in 2020, from 45 known or likely to occur (excluding large snakes and varanids and turtles). This was an increase from 2019 where 14 species were captured. Semi-arid zones fluctuate in condition with rainfall, which affects density and distribution of species. During dry and hot conditions many species are in such low numbers that they are difficult to pick up in routine surveys. Other reasons that contribute to many of the species not being detected in these years include their cryptic nature or low "trappability" (likelihood of entering traps etc) and may require targeted search methods to document them appropriately).

Individual small-medium reptile species indicators

Four of the five reptile indicator species were captured in 2020; the exception was the Common Dwarf Skink (*Menetia greyii*; Table 7). In accordance with previous surveys, the Timid Slider (*Lerista timida*) had the greatest abundance and the highest occupancy (Table 7). In previous years, the Common Dwarf Skink and Boulenger's Snake-eyed Skink (*Morethia boulengeri*) also had high abundance and occupancy, however the Common Dwarf Skink has not been captured since 2014, when it occupied over half of the sites. Boulenger's Snake-eyed Skink had its lowest abundance and occupancy in 2019, however in 2020 the species' abundance increased by 50%. The Eastern Variegated Dtella (*Gehyra versicolour*) appears to be relatively stable in abundance and occupancy. However, Eastern Beaked Gecko (*Rhynchoedura ormsbyi*) abundance decreased by 58% from 2019 to 2020, and occupancy decreased from 2019 to 2020 (Table 7).

It is difficult to draw clear inferences from the fluctuations in these metrics given the variation in Standard Trapping Survey site locations prior to 2019. Nonetheless, the relatively low occupancy and abundance of the Eastern Beaked Gecko in 2020 and the absence of the Common Dwarf Skink from all sites surveyed since 2014 is potentially concerning. Future surveys will be carried out to clarify the status of these two indicator species on Bowra and the likely influence of extrinsic factors such as rainfall.

Small-medium reptile guild

Average species richness and occupancy were generally similar between the four surveys for the small to medium reptile guild. Average species richness increased by 15% from 2019 to 2020, with the highest richness recorded in 2014. Occupancy increased from 2013 to 2014 and 2019 but decreased in 2020 (Table 7). The abundance per 100 trap nights of the small reptile guild has fluctuated through time, peaking in 2014 (Table 8).

Table 7. Individual small-medium reptile species metrics 2013–2020. A = abundance per 100 trap nights; O = occupancy (proportion of sites occupied).

	2013		2014		2019		2020	
Indicator species	**A**	**O**	**A**	**O**	**A**	**O**	**A**	**O**
Eastern Variegated Dtella*	-	-	1.14	0.50	1.14	0.27	0.91	0.41
Eastern Beaked Gecko	0.50	0.10	0.98	0.41	1.44	0.32	0.60	0.23
Boulenger's Snake-eyed Skink	0.83	0.20	1.81	0.68	0.30	0.09	0.60	0.09
Timid Slider	1.67	0.35	3.86	0.73	1.97	0.50	2.88	0.50
Common Dwarf Skink	0.83	0.25	2.20	0.54	0	0	0	0

**The 2013 data were excluded from analyses due to taxonomic changes to the Gehyra gecko family, which altered G. variegata to G. versicolor in 2014.*

Table 8. Small-medium reptile guild metrics 2013–2020. Abundance = abundance per 100 trap nights; occupancy = occupancy (proportion of sites occupied); richness = average number of species per site.

Metric	2013	2014	2019	2020
Abundance	7.17	14.6	7.74	8.34
Occupancy	0.75	0.95	0.95	0.82
Richness	3.00 ± 0.41	5.08 ± 0.47	2.73 ± 0.31	3.16 ± 0.27

As with the small mammal data, the high abundance of reptiles in 2014 may reflect improved conditions due to higher rainfall, while the comparably lower abundance in 2019 followed three years of below average rainfall. The slightly higher species richness and abundance of this guild in 2020 may be related to higher rainfall during 2020, although site occupancy decreased over this period.

There are other interacting factors that could also drive fluctuations in reptile occupancy and abundance, including grazing pressure and predation. Studies investigating grazing pressures on reptile assemblages have been largely unsuccessful due to confounding environmental, vegetation and climatic factors (Castellano and Valone 2006; Read and Cunningham 2010). In some cases, lizard abundance was found to be higher in ungrazed areas, however individual species responded differently to this pressure (Castellano and Valone 2006; Read and Cunningham 2010). It is possible that the Common Dwarf Skink favours grazed areas; its peak abundance and occupancy occurred when macropods and feral herbivores were at their highest on the property. Further surveys would be required to explore this possibility.

Birds

The Daily Bird Lists document a stable level of avian species diversity from 2010–2019 (Figure 15). All 221 species confirmed for the sanctuary were recorded between 2010–2019. When assessed across years, the highest level of diversity was recorded in 2014 when 195 species were recorded from the 221 species that are confirmed to occur on the sanctuary (88.2% of species). Comparatively, the lowest species diversity occurred in 2010 with 166 species observed (75.1%). Species diversity remained stable from 2017 through to 2019, despite the closure of open bore drains on Bowra (in 2017) and a period of significant drought, which resulted in both rivers that dissect the sanctuary to dry out completely in 2018.

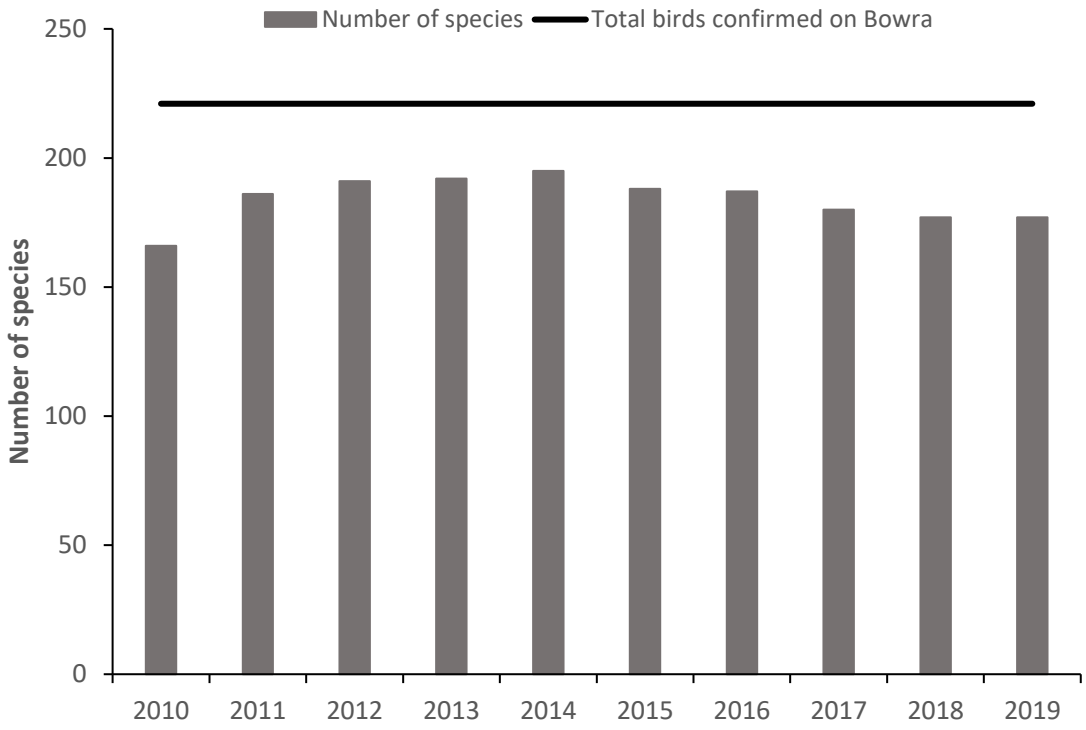

Figure 15. Total number of avian species recorded on Bowra from 2010–2019.

Threat indicators

Feral predators

Despite ongoing targeted control efforts, more feral cats (*Felis catus*) and foxes (*Vulpes vulpes*) were incidentally detected on camera traps of the Standard Trapping Survey and observed by the Sanctuary Manager in 2020 than in 2019 (possibly driven by the increase in small mammal populations over that time). Targeted surveys would be required to clarify the status of both the feral and native (e.g., varanid) predator populations and their influence on native species assemblages at Bowra.

Feral herbivores

In 2021, goats were recorded at a density of 3.4 animals per km^2, a substantial increase from 2020 where they were in densities of 0.9 animals per km^2 (Figure 16). This was the highest density recorded since 2015 (5.0/km^2 ± 3.63). There has not been a muster since 2019 due to Covid-19 pandemic resource disruptions in 2020 and 2021. Overall, there has been a substantial reduction in goat density on Bowra over the years and a muster is targeted to go ahead in 2022.

A mob of 15 sheep were recorded during surveys in 2021, however, they fell outside of the strip width during analysis and were not encountered again. This is the third year in a row where sheep densities have remained at zero animals, a contrast to 2018 when they were recorded at 2.5/km^2 ± 2.33. Due to the herding nature of goats and sheep, there is large variability in their detection resulting in relatively large standard errors associated with the density metrics (Figure 16). For instance, across the 21 transects in 2020, goats were only detected within the strip-widths twice but tended to occur in larger groups than macropods.

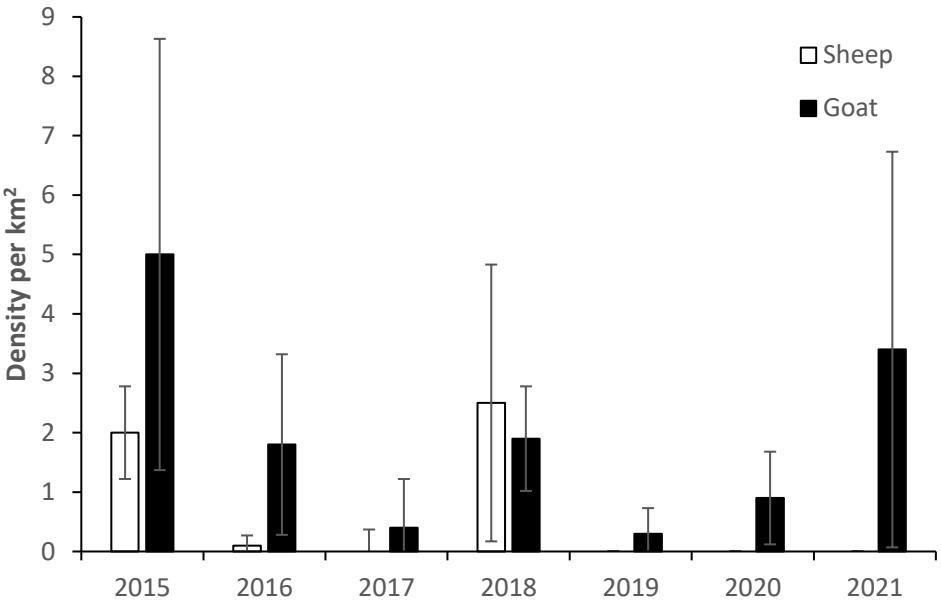

Figure 16. Density per km^2 of large feral herbivores from the annual surveys 2015–2020.

Cattle have been infrequently recorded during the herbivore surveys since 2015, as such they have been excluded from the analysis in this report due to the low to no densities recorded from year to year. Cattle that are encountered by staff and visitors are promptly reported to the Sanctuary Manager who makes arrangements with the neighbour to have them removed. Operations are in place to improve the external fencing on Bowra over the next few years, which will reduce the incursions made by neighbouring stock.

The estimated total number of introduced herbivores on Bowra was reduced from 1,001 in 2015 to 483 in 2021 (Figure 17). While caution should be taken when interpreting the results from year to year, it is clear that there has been an overall population decline in sheep since 2015 and the trend in goat numbers was reducing over time until a large number in 2021. In November 2018, the first on-site Sanctuary Managers commenced, and undertook an intensive management program including feral animal control. Subsequently, the number of feral herbivores decreased markedly. The increase in feral goat numbers between 2020 and 2021 was unsurprising given improved ground vegetation and water availability following higher rainfall over the past two years. The increase in goat incursions may also be attributed to a neighbouring property where goats are now actively farmed, which has increased the number of animals in the surrounding area. As previously noted, operations are in place to improve the boundary fencing on Bowra over the next few years, which will reduce the incursions made by neighbouring stock.

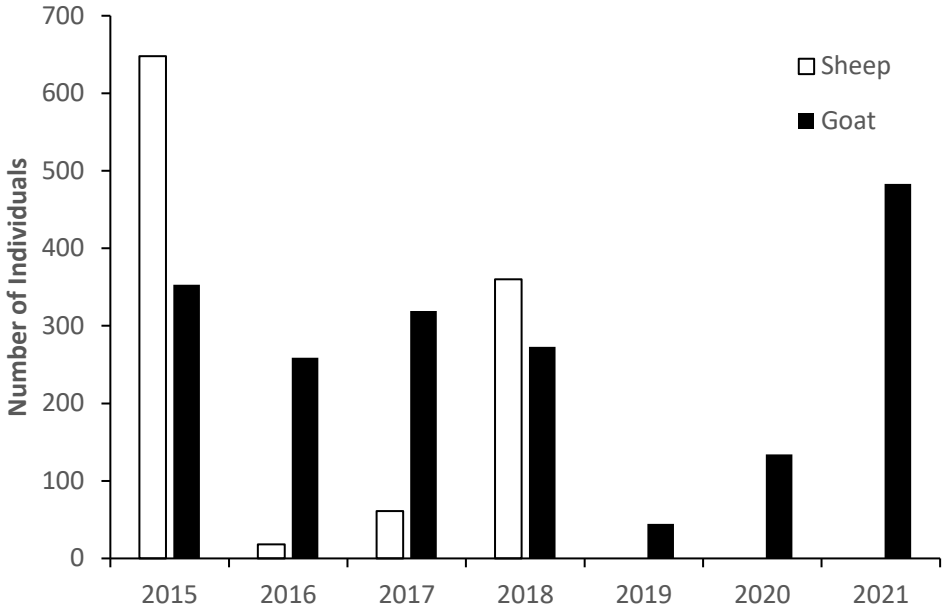

Figure 17. Population estimates of large feral herbivores at Bowra from 2015 to 2021.

Discussion

Native mammals and reptiles in arid and semi-arid regions have highly fluctuating populations driven predominantly by rainfall events. Rainfall drives interactions and results in “pulse” events which are variable in time and duration and often short lived (1–2 years). However, the resources they generate cause population “booms” in small mammals through bottom-up processes; increased vegetation provides resources for invertebrates, which in turn provide increased food and ground cover for small mammals, which then provide prey for predators (Letnic and Dickman 2006). The “boom” was evident in house mouse captures in 2020 when 105 individuals were caught, in comparison to just 1 individual in 2019. Native species also benefited, with both Stripe-faced and Fat-tailed Dunnarts having the highest abundance recorded in any survey. While rodent irruptions correspond directly with increased rainfall and the resources it brings, this pattern is not necessarily reflected in dasyurid population dynamics. Long-term research shows that dasyurids benefit more from the vegetation cover brought on by rainfall events than from food resources (Greenville et al. 2012).

Within these substantial boom and bust cycles, changes in land-use and sustained conservation land management activities can result in positive changes in numbers and diversity. It is likely that the relatively higher abundances of small mammals and reptiles observed in 2020 (with the exception of the Common Dwarf Skink and the Eastern Beaked Gecko) can be attributed to the increased rainfall and decreased grazing pressure (associated with the active removal of feral herbivores over recent years) compared to previous years. Prior to acquisition by AWC and up until 2018, Bowra was heavily grazed by introduced herbivores (sheep and goats), as well as overabundant native macropods. This would likely have greatly reduced ground cover vegetation, even in years of good rainfall. Following 2018, macropod numbers were reduced from three years of management and drought, and feral herbivore numbers had declined due to destocking by the on-site Sanctuary Manager. The removal of grazing pressure likely allowed vegetation to recover following decades of damage, and may explain why 2020 had the highest number of dasyurid captures to date, despite it following only a marginally better year of rainfall.

Macropod numbers remain substantially lower than 2015 levels, when over 6,000 were estimated to occur on Bowra. Several years of drought and macropod control have driven these numbers down to more ecologically suitable densities, while the increases observed since 2019 are a result of increased rainfall and the subsequent vegetation growth. With the La Nina weather event predicted to continue into 2022 it is expected that Bowra and the surrounding region will receive above average rainfall for another year. This will aid in continuing the recovery of vegetation communities and promote the recovery or ‘boom’ of native species,

including macropods. Red Kangaroos have documented significant annual increases in population since 2019 to 2021, with a 97% increase documented in the last year alone. Although an increase in goats were detected in 2021, feral herbivore numbers remain low compared to numbers estimated in 2015 (a combined estimate of 1,001 sheep and goats). AWC sanctuary managers are on-ground to continue de-stocking efforts and replace deteriorating fences, which will aid in reducing feral herbivore incursions. Future repeated surveys will allow the influence of extrinsic factors such as rainfall and grazing pressure to be further examined in relation to the Biodiversity and Threat indicators on Bowra.

Despite variable climatic conditions avian diversity has remained stable at Bowra since surveys began in 2010, with an average of 83.2% of all species documented annually. Interruptions to the visitor program at Bowra were caused by the Covid-19 pandemic in 2020, which resulted in a period of almost 2 years where the daily bird surveys were not done regularly. Surveys have resumed in 2022 and will be analysed as part of next years' Ecohealth report.

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- Andrew Howe

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- Mark and Tess McLaren (AWC Sanctuary Managers)
- Alexander Watson (NE Regional Ecologist)

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