Bowra Wildlife Sanctuary

Ecohealth Report 2020

australian wildlife conservancy

Summary

Australian Wildlife Conservancy (AWC) has implemented an Ecological Health Monitoring Program to measure changes in the status and trend of conservation assets, and threats to those assets, across Bowra Wildlife Sanctuary (Bowra). Metrics from the program are reported in annual Ecohealth Reports and Scorecards. This is the Ecohealth Report for 2020. Metrics derived in this report were based on data collected during surveys carried out in 2013-2020. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In implementing the Ecohealth program in 2020, AWC conducted 1,318 live trap nights and 147 km of macropod and introduced herbivore transects. A total of 24 native species (19 reptiles, three mammals and two frogs) were caught in pitfall and funnel traps during the Standard Trapping Survey. 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.

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 factors driving fluctuations in reptile abundance and occupancy at Bowra will become clearer following repeated surveys.

In 2020, there was a slight increase in the estimated population size of large macropods on Bowra (469 in 2020, compared to 185 in 2019). The estimated population size of feral goats (*Capra hircus*) also increased from 44 in 2019 to 167 in 2020. However, these increases followed five years of substantial population declines: in 2015, population sizes were estimated at > 6,000 macropods and 1,000 introduced large herbivores. No sheep (*Ovis aries*) were detected in 2020. The reductions in populations of large herbivores between 2015 to 2019 are a consequence of AWC's management actions, including population control, the removal of artificial water sources, and severe drought conditions. The small increase in large herbivore numbers observed in 2020 is unsurprising, given improved rainfall during 2020 and increased goat incursions from neighbouring properties. Continued efforts to maintain fences and reduce artifical water sources will ensure low grazing pressure from introduced species and continued recovery of the remnant vegetation on Bowra.

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Introduction

Australian Wildlife Conservancy (AWC) owns, manages, or works in partnerships across 30 properties in Australia, covering almost 6.5 million hectares, to implement our mission: *the effective conservation of Australian wildlife and their habitats*. AWC relies on information provided by an integrated program of monitoring and research to measure progress in meeting its mission and to improve conservation management. AWC's Ecohealth Monitoring Program has been designed to measure and report on the status and trends of species, ecological processes and threats on each of these properties (Kanowski et al. 2018). The program focuses on selected 'indicator' species, guilds, processes and threats, using metrics derived from data collected through a series of purpose-designed surveys.

The structure of the Ecohealth Program on each AWC property is as follows. Based on the guidance provided by AWC's over-arching program framework, above, Ecohealth Monitoring Plans are developed, describing the conservation values or assets of each property, and threats to these assets; and setting out the monitoring program that will be used to track the status and trend of selected indicators of these conservation assets and threats. Annual survey plans and schedules are developed to implement these plans. The outcomes of these surveys are presented in annual Ecohealth Reports and summary Ecohealth Scorecards.

This document, the Bowra Ecohealth Report 2020, draws on surveys conducted between 2013 and 2020 to calculate values for metrics that track the status and trend of the Ecohealth indicators. The companion Bowra Ecohealth Scorecard 2020 presents these 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*).

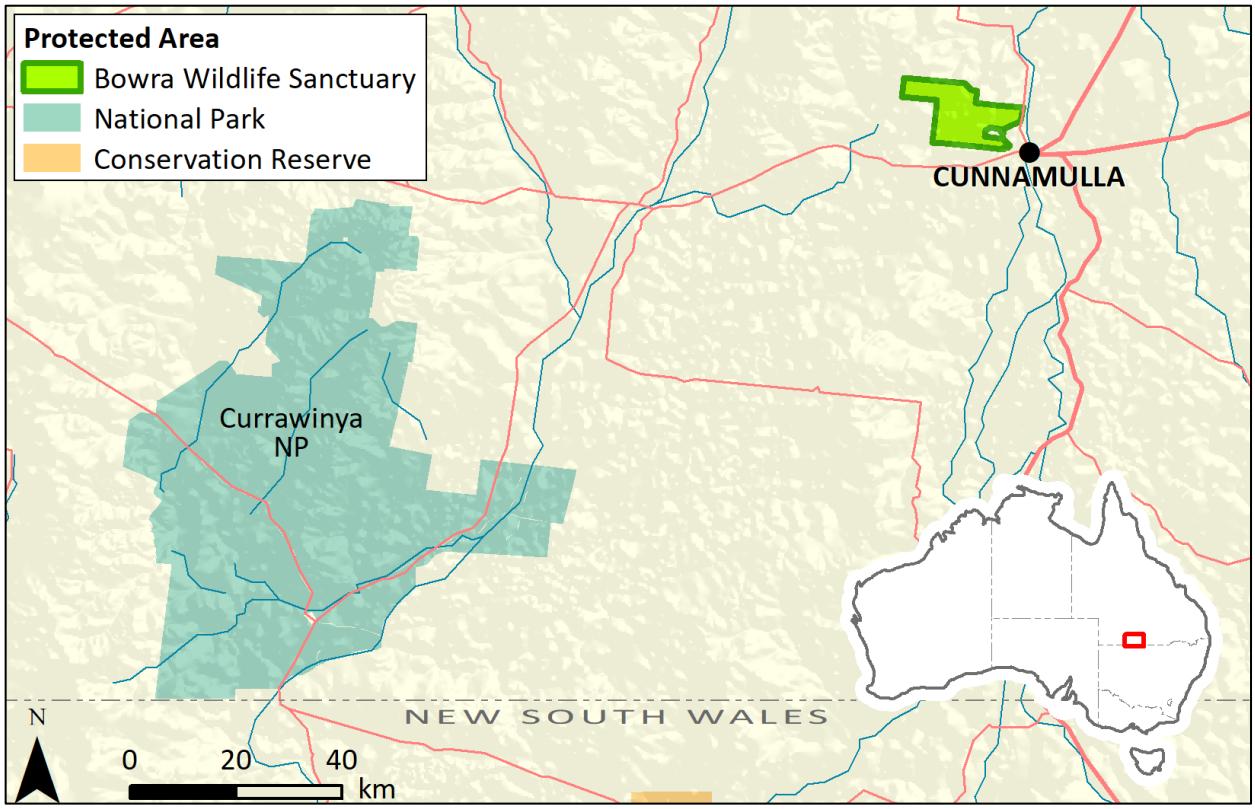

Figure 1. Location and regional context of Bowra

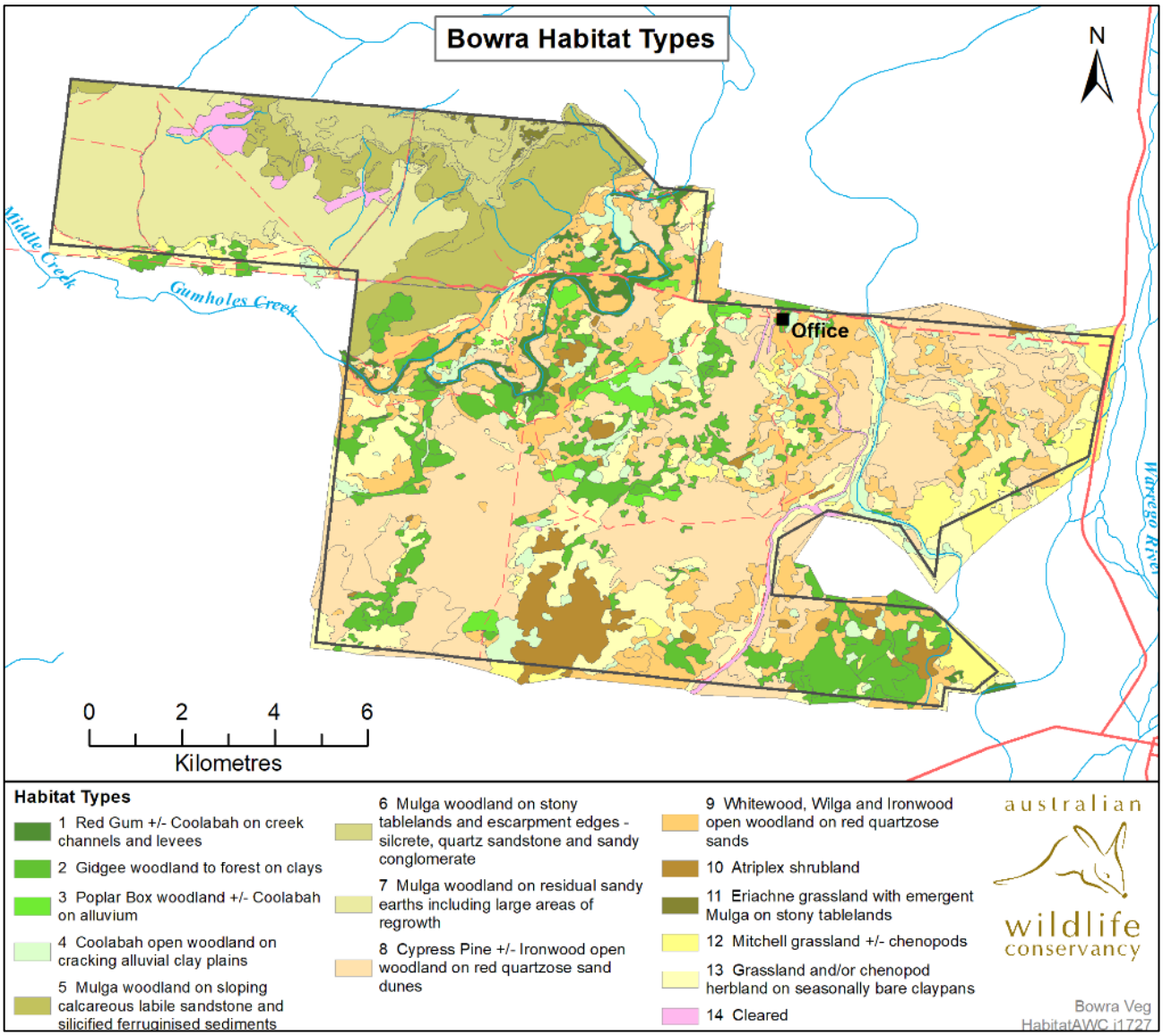

Figure 2. Main vegetation types on Bowra

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 (*Macropus giganteus*) and Western Grey Kangaroos (*Macropus fuliginosus*)). Sheep and cattle are 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. At that point, continued management of macropod populations was deemed unnecessary.

To date, 325 native species have been confirmed on Bowra (219 birds, 26 mammals, 55 reptiles, 17 frogs and 8 fish). Many of these species are reliant on the Mulga Lands bioregion for the bulk of their distribution.

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 35.4 °C in summer and 19.8 °C in winter (Figure 3).

Between 2017 and 2019, mean maximum temperatures were well above average: 30.4 °C, 30.3 °C and 30.2 °C in 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). Bowra

experienced an extremely hot summer in 2020. In December 2020, a new temperature record was set with a maximum temperature of 46.2 °C (Figure 3). Mean minimum temperatures from 2017 to 2020 were also well above average (Bureau of Meteorology 2021b; Figure 3).

Coupled with the extreme summer temperatures, the region has experienced severe drought conditions, recording below average annual rainfall from 2017 through to 2020. The average annual rainfall (1879-present) for Cunnamulla is 372 mm. The 2019 period saw half of this with only 185 mm of rain (Figure 4). Encouragingly, 2020 saw 296 mm of rain, the highest total since 2016, though still marginal compared to other years.

After years of drought, in April of 2019 Bowra's ephemeral wetlands, dams and the major river were refreshed during the first significant rainfall event for the region since 2016. Over three days, 94 mm of rain fell (Figure 4). This was 67 mm above the monthly April average (27 mm). This event was a one off, coinciding with Cyclone Trevor, which made landfall in the Gulf of Carpentaria. The remainder of 2019 continued with negligible amounts of rain. In 2020 the 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 (Figure 4). This consistent rainfall was the motivation behind conducting the Standard Trapping Survey ahead of the Ecohealth Monitoring Plan schedule, which had originally scheduled the next survey for 2022.

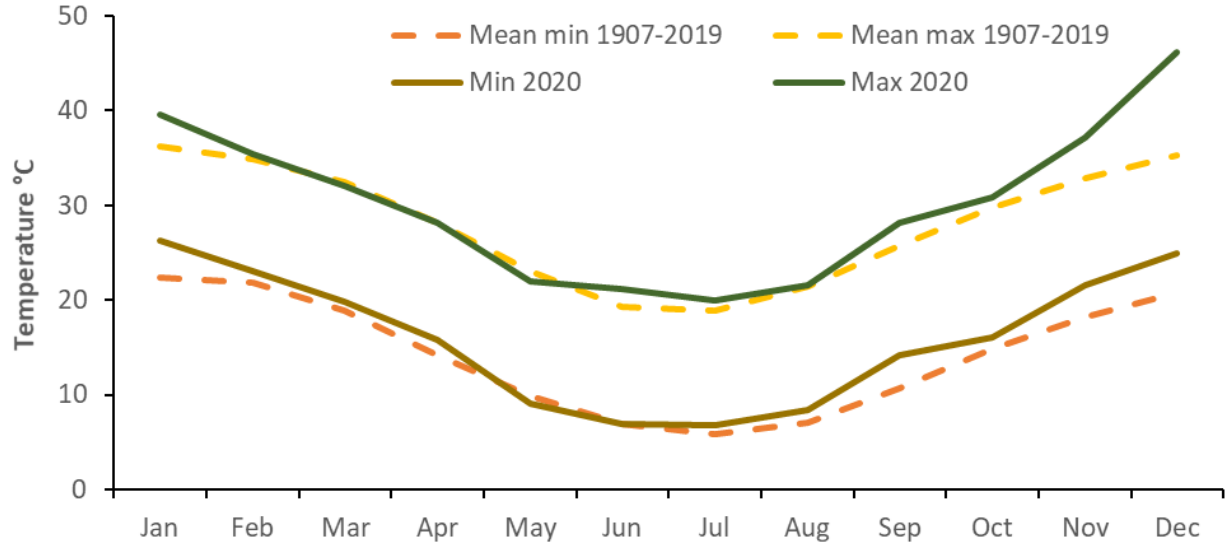

Figure 3. Mean maximum and minimum temperatures at Cunnamulla in 2020, and mean (1907-2019). Data acquired from Bureau of Meteorology (2021a, 2021b), Cunnamulla Post Office, weather station number 44026.

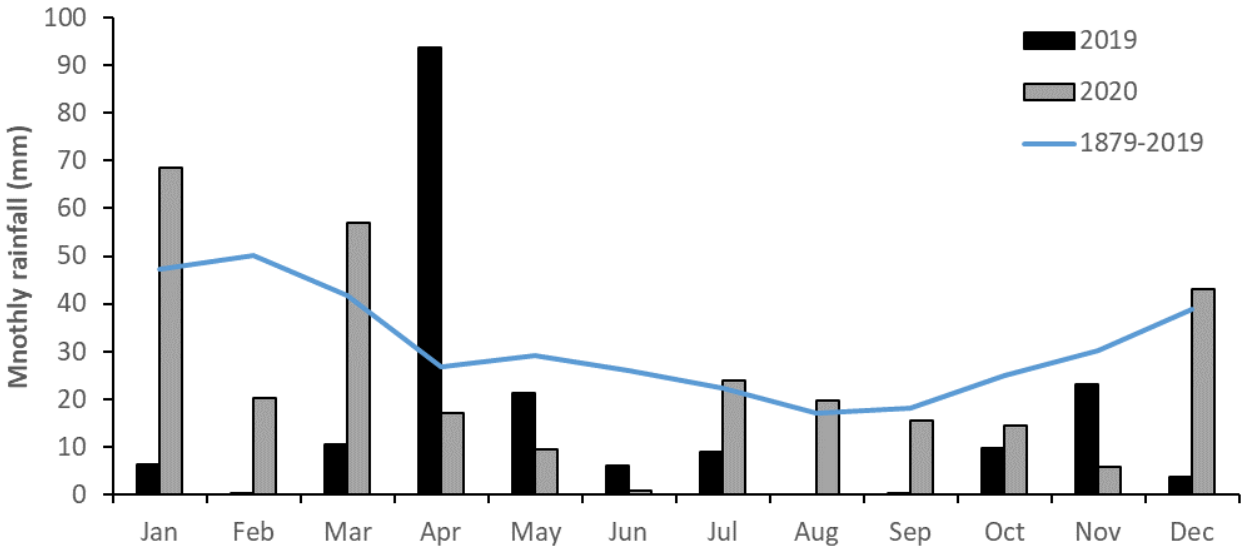

Figure 4. Monthly rainfall in Cunnamulla 2019 and 2020, compared with the mean 1879-2019. Data acquired from Bureau of Meteorology (2021c), Cunnamulla Post Office, weather station number 44026.

Methods

Indicators and metrics

Bowra's Ecohealth Monitoring Program has been designed to measure and report on the status and trends of species, ecological processes and threats on the sanctuary. The program focuses on selected biodiversity and threat indicators, using metrics derived from data collected through a series of purpose-designed surveys A selection of species or guilds were chosen as biodiversity indicators which fit into one or more of the following categories: (1) declining and/or threatened species or guilds, (2) strong drivers of ecosystem function, or (3) are a member of the full range of taxa (to enable ongoing surveillance monitoring of a range of taxonomic groups to provide early warning of any unexpected declines). In 2020, 13 biodiversity indictors (species and guilds) are reported on; the rationale for their selection is recorded for each indicator in Table 1. Threat metrics are selected to ensure monitoring the status and trends of introduced predators and herbivores, and weeds. In 2020, 3 threat metrics are reported on (Table 2).

Table 1. Biodiversity indicators reported on in 2020. Rationale for selection: T = threatened or declining; D = strong driver of ecosystem function; S = surveillance monitoring. Metric definitions: abundance = number of detections per 100 trap nights; occupancy = proportion of sites where species or guild recorded (naïve occupancy); richness = average number of species in guild captured per site; population estimate = estimated number of individuals on sanctuary; density = individuals per km^2.

Indicator	Rationale			Survey method	Metric/s
	T	D	S		
Mammals					
Small-medium mammals					
Fat-tailed Dunnart *Sminthopsis crassicaudata*			*	Standard Trapping Survey	Abundance, occupancy
Stripe-faced Dunnart *Sminthopsis macroura*			*	Standard Trapping Survey	Abunbdance, occupancy
Small-medium mammal guild			*	Standard Trapping Survey	Abundance, occupancy, richness
Large herbivores					
Western Grey Kangaroo *Macropus fuliginosus* and Eastern Grey Kangaroo *Macropus giganteus*		*	*	Macropod and Feral Herbivore Survey	Population estimate, density
Common Wallaroo *Macropus robustus*		*	*	Macropod and Feral Herbivore Survey	Population estimate, density
Red Kangaroo *Macropus rufus*		*	*	Macropod and Feral Herbivore Survey	Population estimate, density
Swamp Wallaby *Wallabia bicolor*		*	*	Macropod and Feral Herbivore Survey	Population estimate, density
Reptiles					
Small-medium reptiles					
Tree Dtella *Gehyra versicolour*			*	Standard Trapping Survey	Abundance, occupancy
Eastern Beaked Gecko *Rhynchoedura ormsbyi*			*	Standard Trapping Survey	Abundance, occupancy
Boulenger's Snake-eyed Skink *Morethia boulengeri*			*	Standard Trapping Survey	Abundance, occupancy
Common Dwarf Skink *Menetia greyii*			*	Standard Trapping Survey	Abundance, occupancy
Timid Slider *Lerista timida*			*	Standard Trapping Survey	Abundance, occupancy
Small-medium reptile guild			*	Standard Trapping Survey	Abundance, occupancy, richness

Table 2. Threat indicators reported on in 2020. Metrics: population estimate = estimated number of individuals on sanctuary; density = individuals per km^2.

Indicator	Rationale	Survey method	Metric/s
Cattle *Bos taurus*	Erosion, soil impaction, overgrazing, weed dispersal, reduction in ground cover	Macropod and Feral Herbivore Survey	Population estimate, density
Sheep *Ovis aries*	Erosion, soil impaction, overgrazing, weed dispersal, reduction in ground cover	Macropod and Feral Herbivore Survey	Population estimate, density
Goats *Capra hircus*	Erosion, soil impaction, overgrazing, weed dispersal, reduction in ground cover	Macropod and Feral Herbivore Survey	Population estimate, density

Survey type and history

To report on the 14 Biodiversity and 3 Threat Indicators of 2020, 2 types of surveys were undertaken in 2020:

- Standard Trapping Survey
- Macropod and Feral Herbivore Survey

Metrics derived in this report were based on data collected during surveys carried out in 2013-2020. Since the acquisition of Bowra by AWC, six fauna monitoring surveys have been conducted (2011, 2012, 2013, 2014, 2019 and 2020). The 2011 and 2012 surveys were largely for the purpose of inventory, so only data obtained since 2013 (Kemp et al. 2013; Mulder et al. 2014) were presented in this report. 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. Total survey effort for the 2020 Ecohealth surveys is summarised in Table 3.

Table 3. Survey effort for Ecohealth Monitoring Plan surveys on Bowra in 2020

Survey name	Effort 2020	Description	Previous surveys
Standard Trapping Survey	1,318 trap nights	22 monitoring sites with pitfall and funnel traps. Stratified to include a range of geography and major vegetation types (Mulga, alluvium, stony tablelands).	2011 - 19 sites 2012 - 16 sites 2013 - 20 sites 2014 - 22 sites 2019 - 22 sites 2020 - 22 sites
Macropod and Feral Herbivore Survey	147 km	7 transects of varying length, stratified by major habitat types which are accessible by road.	Annually, 2015-20

Survey design and methods

Standard Trapping Survey

The Standard Trapping Survey consists of live trapping (pitfall and funnel trapping) at 22 survey sites (Figure 5). A long-term Ecohealth survey design was established in 2019 where site selection was stratified by vegetation and soil type (Figure 5). A table of the 22 sites, including GPS coordinates and a description of habitat type, is in Appendix 1.

Each of the 22 monitoring sites contained two pitfall arrays. A single array comprised four Rotomould buckets approximately 600 mm deep with a 250 mm diameter, and six funnel traps, connected by a 30 cm high drift fence (dampcourse). The rotomould pitfall buckets 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 6 and 7). 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.

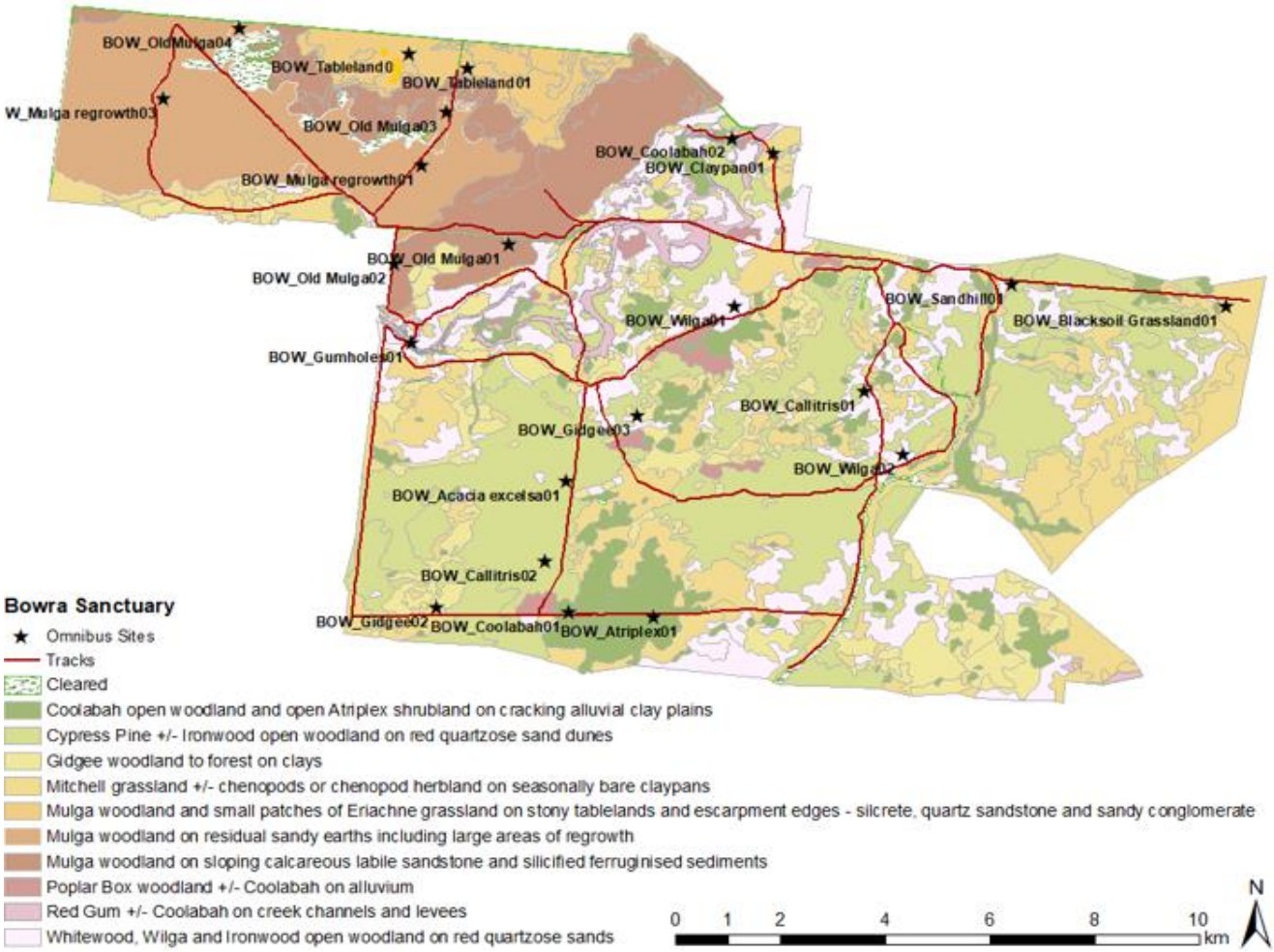

Figure 5. Location of 22 fauna monitoring sites on Bowra within representative vegetation types

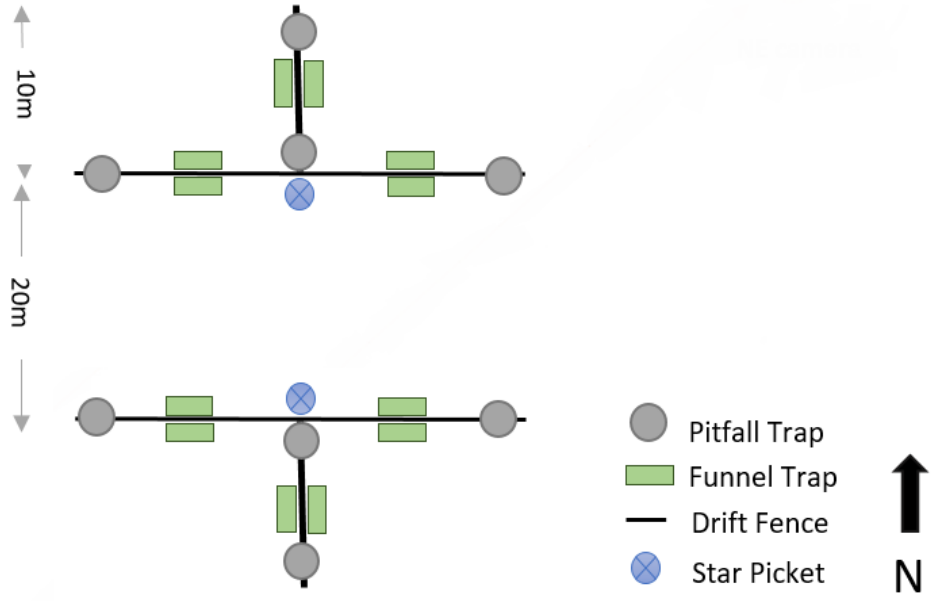

Figure 6. Standard Trapping Survey site design

Figure 7. Volunteer Anders Zimny working to erect a drift fence at an old Mulga site. Emily Rush/AWC

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 8). 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 (Appendix 1). This survey is conducted annually.

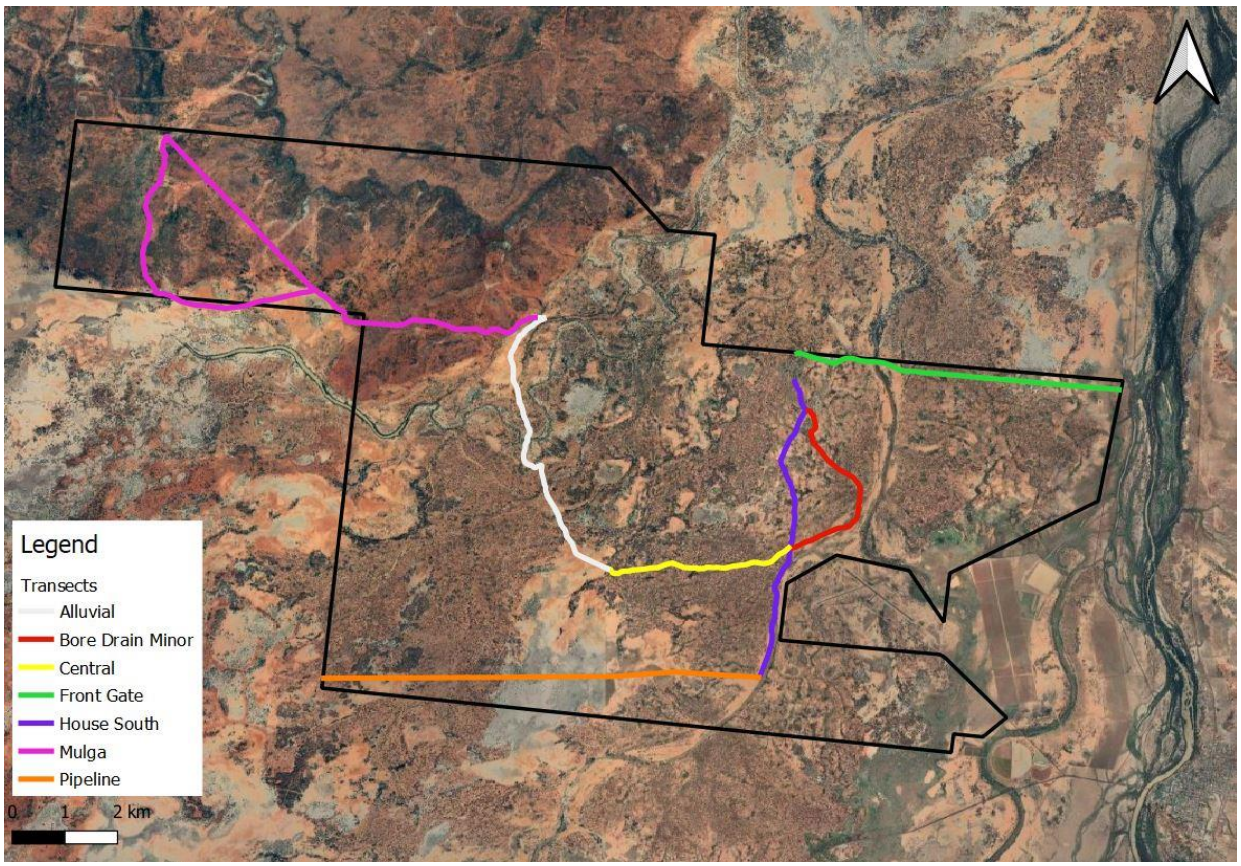

Figure 8. Survey strip transects to monitor native and introduced large herbivores across Bowra

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 traveled 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.

Analysis methods

Small-medium mammal indicators and guild

The data from the Standard Trapping Survey (pitfall) were used to derive metrics for the small-medium mammal indicator species and guild. The metrics calculated for the indicator species and guild were abundance (number of individuals/ trap nights x 100) and occupancy (naïve occupancy: number of sites detected/ total number of sites). Species richness (average number of species per site) was calculated for the guild.

Large herbivores

The data from the Macropod and Feral Herbivore Survey were used to calculate the large herbivores metrics. Mean density of the large herbivore indicator species was calculated for each of the two major habitat types on Bowra: "Mulga-dominated ecosystems on stony red soil" and "all other ecosystems on a mixture of alluvial soils ranging from clays to sands". 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 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. An estimate of the population size of each species on Bowra was derived by multiplying the density with the total area surveyed (142.2 km^2; Kemp et al. 2015).

Small-medium reptile indicators and guild

The data from the Standard Trapping Survey (pitfall and funnel traps) were used to derive metrics for the small-medium reptile indicator species and guild. The metrics calculated for the indicator species and guild were abundance (number of individuals/ trap nights x 100) and occupancy (naïve occupancy: number of sites detected/ total number of sites). Species richness (average number of species per site) was calculated for the guild.

Threats

Average density and population size of the three threat indicator species (cattle, goat and sheep) were calculated as described above for "large herbivores". Goat and sheep density and population size estimates have been undertaken since 2015; cattle were included in these surveys and associated calculations from 2019 onwards.

Results

Biodiversity indicators

Small-medium mammals

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 (*Planigale tenuirostris*), part of the small mammal guild (Figure 9). This was the fourth Narrow-nosed Planigale captured at Bowra and the first record of the species since 2013.

Figure 9. Narrow-nosed planigale (*P. tenuirostris*) captured in 2020. Anders Zimny/AWC

Of the two indicator species, the Stripe-faced Dunnart had the highest abundance and occupancy (Table 4). 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 4; Figure 10).

Table 4. Individual small-medium mammal species metrics 2013-2020. A = abundance per 100 trap nights; O = naïve 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 5). In contrast, the proprtion of sites occupied remained stable (Table 5). 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 5).

Table 5. Small-medium mammal guild metrics 2013-2020. Abundance = abundance per 100 trap nights; occupancy = naïve 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 to the suite of 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.

Arid and semi-arid regions of Australia are characterized by irratic rainfall events that produce “boom” and “bust” dynamics in its biota (Morton et al. 2011). 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 (Table 4; Figure 10). 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).

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 (culling) 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 could explain why 2020 had the highest number of dasyurid captures to date, despite it following only a marginally better year of rainfall.

Figure 10. Juvenile Fat-tailed Dunnart (*S. crassicaudata*) captured at an old Mulga site. Gina Zimny/AWC

Large herbivores

Between 2015 and 2019, macropod density declined substantially for all species (Figure 11). This changed in 2020, with a slight increase recorded for each species since 2019. Red Kangaroo density increased from 0.8/ km^2 in 2019 to 1.6/ km^2 in 2020, while grey kangaroos increased from 0.2/ km^2 to 0.6/ km^2. Wallaroo density increased from 0.4/ km^2 in 2019 to 0.72/ km^2 in 2020. Swamp Wallabies were not detected during the 2019 transects but were recorded at a density of 0.12/ km^2 in 2020 (Figure 11).

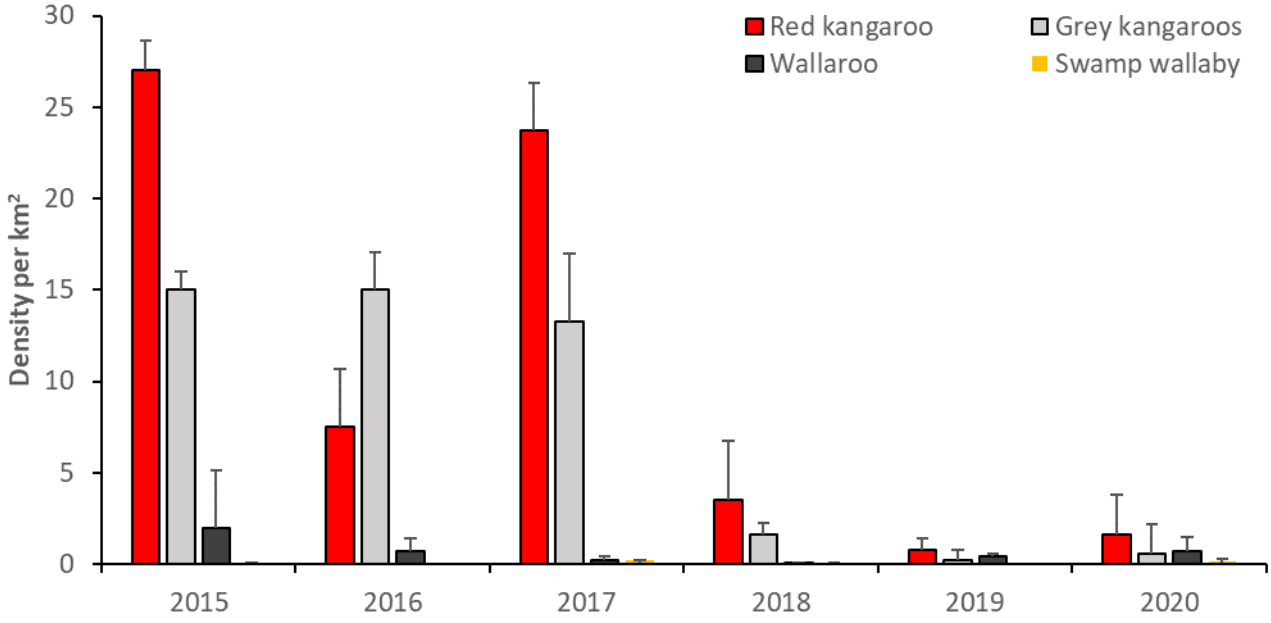

Figure 11. Density per km^2 of macropods from the annual surveys 2015-2020

In 2020, there were an estimated 469 macropods in total on Bowra (comprising an estimated 78 grey kangaroos, 61 Wallaroos, 228 Red Kangaroos and 102 Swamp Wallabies). This is an increase from the 185 recorded in 2019, but a 93% reduction since 2015 when 6,320 macropods were estimated to occur on the sanctuary. Overall, population declines for large native herbivores have been substantial from 2015 to 2019 (Figure 12). This is likely due to the ongoing drought conditions, as well as the control of macropods in 2015-2017. The increase in population size in 2020 is unsurprising given the improved vegetation growth and water availability following increased rainfall throughout 2020. Macropod numbers in semi-arid Queensland fluctuate in response to prevailing rainfall with a 1-3 year lag (Queensland Government 2019).

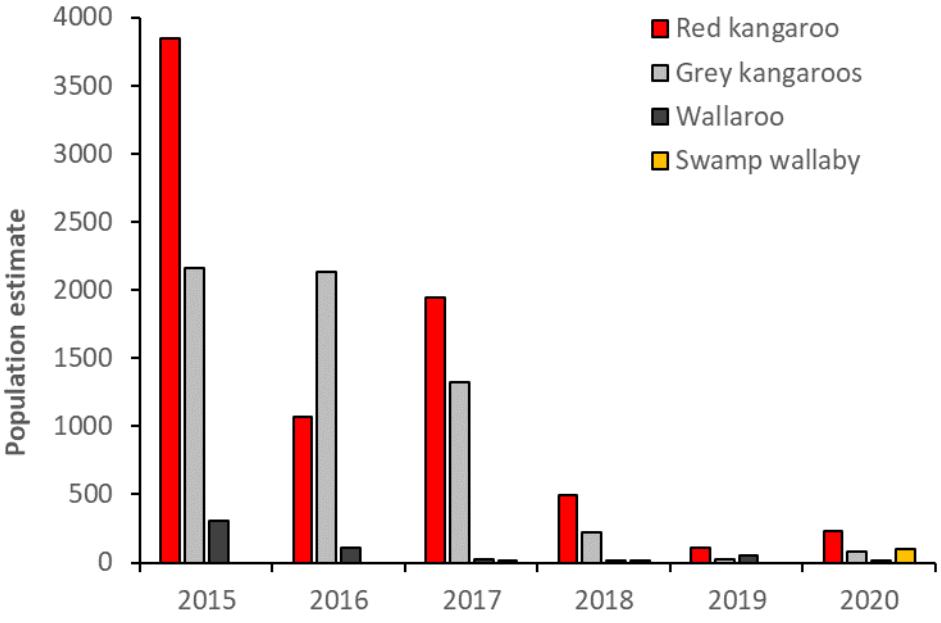

Figure 12. Population estimates of macropods at Bowra from 2015 to 2020

Reptiles

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 6). In accordance with previous surveys, the Timid Slider (*Lerista timida*) had the greatest abundance and the highest occupancy (Table 6). 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 Tree Dtella (*Gehyra versicolor*) 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 6).

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 (Table 7). 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 7).

Table 6. Individual small-medium reptile species metrics 2013-2020. A = abundance per 100 trap nights; O = naïve occupancy (proportion of sites occupied).

	2013		2014		2019		2020	
Indicator species	**A**	**O**	**A**	**O**	**A**	**O**	**A**	**O**
Tree Dtella* *Gehyra versicolor*	-	-	1.14	0.50	1.14	0.27	0.91	0.41
Eastern Beaked Gecko *Rhynchoedura ormsbyi*	0.50	0.10	0.98	0.41	1.44	0.32	0.60	0.23
Boulenger's Snake-eyed Skink *Morethia boulengeri*	0.83	0.20	1.81	0.68	0.30	0.09	0.60	0.09
Timid Slider *Lerista timida*	1.67	0.35	3.86	0.73	1.97	0.50	2.88	0.50
Common Dwarf Skink *Menetia greyii*	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 7. Small-medium reptile guild metrics 2013-2020. Abundance = abundance per 100 trap nights; occupancy = naïve 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. 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.

Despite ongoing targeted control efforts, more feral cats (*Felis catus*) and foxes (*Vulpes vulpes*) were incidentally detected on camera traps 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 reptile assemblages at Bowra.

Threat indicators

Feral herbivores

In 2020, goats were recorded at a density of 1.2 animals per km^2 (Figure 13). This was an increase from 2019, when goats were recorded at 0.3 animals per km^2. Overall, there has been a substantial reduction in goat density on Bowra since 2015, when they were recorded at 5 animals per km^2. Sheep were not recorded in 2020. Due to the herding nature of goats and sheep, there is vast variability in their occurrence during the sampling procedure, hence the relatively large standard errors associated with the density metrics in Figure 13. 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.

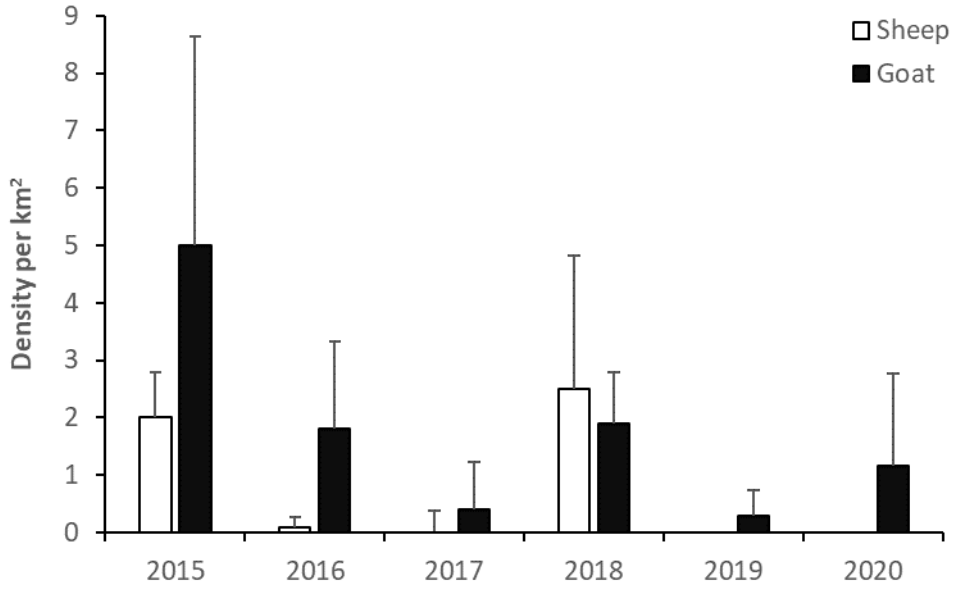

Figure 13. Density per km^2 of large feral herbivores from the annual surveys 2015-2020

No cattle were recorded during surveys in 2019 or 2020, resulting in an estimated density of zero for both years. Ten cattle that had breached the western fence line were observed incidentally. These were promptly reported to the Sanctuary Manager who notified the neighbours. Cattle are generally recorded in very low numbers on Bowra, as most neighbouring properties farm sheep.

The estimated total number of introduced herbivores on Bowra dropped from 1,001 in 2015 to 167 in 2020 (Figure 14). While caution should be taken when interpreting the results of these species from year to year, it is clear that there has been an overall population decline since 2015. 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 2019 and 2020 was unsurprising, given the increased ground vegetation and water availability following higher rainfall in 2020. The increase in goats is also the result of incursions from neighbouring properties in 2020, including from a site where goats are now farmed (pers comm. J Barton, Sanctuary Manager).

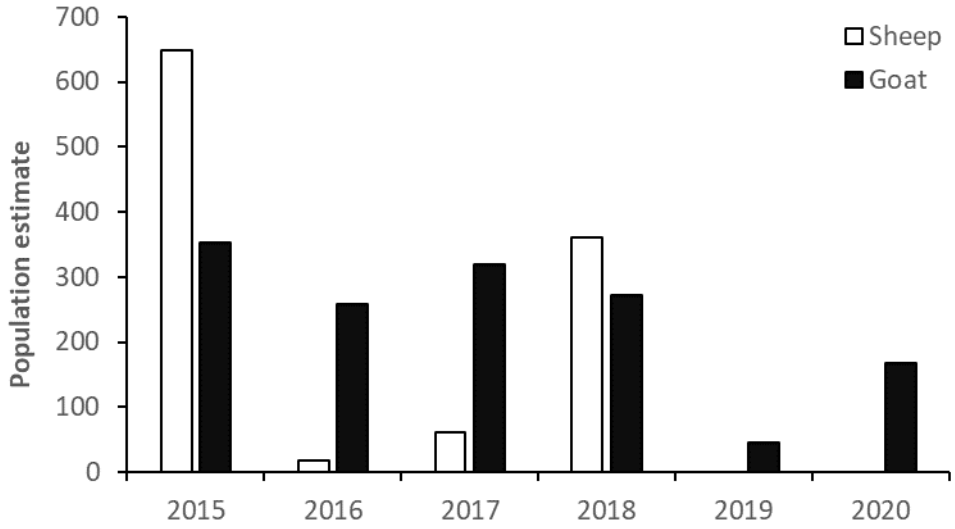

Figure 14. Population estimates of large feral herbivores at Bowra from 2015 to 2020

Discussion

Native mammals and reptiles in arid and semi-arid regions have highly fluctuating populations driven predominantly by rainfall events. 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.

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 likely driven these numbers down, while the slight increases observed between 2019 and 2020 may be a result of increased rainfall. Although goats were detected in 2020 (an estimated population of 167), feral herbivore numbers remain low compared to numbers estimated in 2015 (a combined estimate of 1,001 sheep and goats). 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.

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AWC staff participating in survey:

- Emily Rush
- Andrew Howe

Volunteers:

- Gina Zimny
- Anders Zimny
- Maddison Stuart
- Daniela Matheus-Holland
- Brian Coulter
- Majella, Siobhan, Taylah and Mia Rush

Survey support:

- John and Melinda Barton (AWC Sanctuary Managers)
- Alexander Watson (NE Regional Ecologist)

Staff and volunteers during the Bowra 2020 Standard Trapping Survey. From L – R: Gina Zimny, Emily Rush, John Barton, Melinda Barton, Anders Zimny, Maddison Stuart, Andy Howe and Daniela Matheus-Holland.

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Appendix 1: Survey design

Table 8. Name, location and description of 22 Standard Trapping Survey sites

Site code	Habitat description	Latitude	Longitude
AcaciaExcelsa01	Cypress Pine +/- Ironwood open woodland on red quartzose sand dunes	-28.0241	145.55598
Atriplex01	Coolabah open woodland and open Atriplex	-28.04804	145.57095
Blacksoil Grassland01	Mitchell grassland +/- chenopods herbland and seasonal bare daypans	-27.9933	145.66922
Callitris01	Cypress Pine +/- Ironwood open woodland on red quartzose sand dunes	-28.00814	145.6072
Callitris02	Cypress Pine +/- Ironwood open woodland on red quartzose sand dunes	-28.0382	145.5522
Claypan01	Mitchell grassland +/- chenopods herbland an seasonal bare claypans	-27.9663	145.5914
Coolabah01	Coolabah open woodland and open Atriplex shrubland on cracking alluvial clay plains	-28.0473	145.5563
Coolabah02	Red Gum +/- Coolabah on creek channels and levees	-27.9637	145.5844
Gidgee02	Gidgee woodland to forest on clays	-28.0463	145.5336
Gidgee03	Gidgee woodland to forest on clays	-28.0125	145.5681
Gumholes01	Red Gum +/- Coolabah on creek channels and levees	-27.9997	145.5292
MulgaRegrowth01	Mulga woodland on residual sandy earths including large areas of regrowth	-27.9684	145.5310
MulgaRegrowth03	Mulga woodland on residual sandy earths including large areas of regrowth	-27.9565	145.4866
OldMulga01	Mulga woodland and small patches of Eriachne grassland on stony tablelands and escarpment edges – silcrete, quartz sandstone and sandy conglomerate	-27.9823	145.5461
OldMulga02	Mulga woodland and small patches of Eriachne grassland on stony tablelands and escarpment edges – silcrete, quartz sandstone and sandy conglomerate	-27.9857	145.5263
OldMulga03	Mulga woodland and small patches of Eriachne grassland on stony tablelands and escarpment edges – silcrete, quartz sandstone and sandy conglomerate	-27.9589	145.5352
OldMulga04	Mulga woodland and small patches of Eriachne grassland on stony tablelands and escarpment edges – silcrete, quartz sandstone and sandy conglomerate	-27.9442	145.4998
Sandhill01	Cypress Pine +/- Ironwood open woodland on red quartzose sand dunes	-27.9893	145.6325
Tableland01	Mulga woodland and small patches of Eriachne grassland on stony tablelands and escarpment edges – silcrete, quartz sandstone and sandy conglomerate	-27.9512	145.5389
Tableland02	Mulga woodland and small patches of Eriachne grassland on stony tablelands and escarpment edges – silcrete, quartz sandstone and sandy conglomerate	-27.9522	145.5317
Wilga01	Whitewood, Wilga and Ironwood open woodland on cacking alluvial clay plains	-27.9931	145.5848
Wilga02	Whitewood, Wilga and Ironwood open woodland on cacking alluvial clay plains	-28.0193	145.6138

Appendix 2: Live trapping

Table 9. Species caught during the 2020 Standard Trapping Survey

Scientific Name	Common Name
Cryptoblepharus australis	Inland Snake-eyed Skink
Ctenophorus nuchalis	Central Netted Dragon
Ctenotus ingrami	Unspotted Yellow-sided Ctenotus
Ctenotus regius	Pale-rumped Ctenotus
Ctenotus schomburgkii	Barred Wedgesnout Ctenotus
Ctenotus strauchii	Eastern Barred Wedgesnout Ctenotus
Diplodactylus ameyi	Eastern Deserts Fat-tailed Gecko
Eremiascincus richardsonii	Broad-banded Sand-swimmer
Gehyra versicolor	Eastern Variegated Dtella
Heteronotia binoei	Bynoe's Prickly Gecko
Lerista punctatovittata	Eastern Robust Slider
Lerista timida	Timid Slider
Litoria rubella	Desert Tree Frog
Morethia boulengeri	South-eastern Morethia Skink
Mus musculus	House Mouse
Notaden bennettii	Crucifix Toad
Oedura cincta	Inland Marbled Velvet Gecko
Planigale tenuirostris	Narrow-nosed Planigale
Pogona barbata	Bearded Dragon
Rhynchoedura ormsbyi	Eastern Beaked Gecko
Sminthopsis crassicaudata	Fat-tailed Dunnart
Sminthopsis macroura	Stripe-faced Dunnart
Strophurus williamsi	Eastern Spiny-tailed Gecko
Suta suta	Curl Snake
Tympanocryptis sp.	Tympanocryptis sp.