

Charnley River-Artesian Range Wildlife Sanctuary Ecohealth Report 2020



Summary

Australian Wildlife Conservancy (AWC) has conducted an Ecological Health Monitoring program across Charnley River – Artesian Range (CRAR) Sanctuary to measure the changes in ecological health. Values and metrics presented in this 2020 Ecohealth Report and the accompanying Ecohealth Scorecard were based on data collected during field Ecohealth Surveys carried out in 2020, with reference to surveys undertaken in previous years on CRAR. Extensive Ecohealth surveying in 2019 and 2020 was largely focused on eastern Charnley, with limited surveys taking place in the Artesian Range – a rugged and ecologically distinct bioregion. The first comprehensive and standardised Ecohealth survey in the Artesian Range (to be undertaken every two years) will be completed in 2021.

During the 2020 reporting period, Ecohealth survey effort included small-medium mammal and reptile live-trapping (4,080 live-trap nights), bird surveys (68), vegetation and habitat structure surveys (34), camera trap surveys in eastern Charnley rocky areas and the Artesian Range (6,160 camera trap nights), spotlighting and more targeted observational surveys (50), and aerial surveys of weeds and feral animals (573 km).

Below-average rainfall during the 2019-20 wet season (904 mm), following one of the driest wet seasons on record in 2018-19 (514 mm), was likely a key driver of survey results in 2020. In particular, live-trapped small-medium mammals were much less abundant in 2019 and 2020, than in previous surveys conducted in 2016 and 2017. The overall abundance of live-trapped reptiles (skinks and dragons) also declined in 2020 from 2019 levels. Conversely, one species of small-medium mammal (the Long-tailed Planigale) was trapped in greater numbers in 2020 than previously, and there was a considerable increase in the abundance of small-medium mammals inhabiting rocky areas, notably rodents and rock-wallabies, in 2020 than in 2019. The Northern Quoll, which is especially susceptible to the introduced cane toad, was detected at all camera sites in the Artesian Range, as well as a number of rocky areas in eastern Charnley. However, Northern Quoll abundance on Charnley was lower in 2020 than in 2019 – potentially reflecting the longer establishment of the cane toad in eastern Charnley, and/or resource abundance fluctuations associated with recent failed and below average wet seasons.

This report also presents data on a number of threats that affect conservation of biodiversity on Charnley River – Artesian Range, including information on the distribution and abundance of feral cats, feral herbivores and weeds. Fire-scar analysis shows that the extent of wildfire and all other metrics relating to fire management continued to improve on Charnley River – Artesian Range in 2020, compared with baseline (pre-AWC) conditions.

Further data collection over the next few years will be important for better understanding the response of wildlife on Charnley River – Artesian Range to changing environmental conditions, with a particular focus on the impact of the recent arrival of the cane toad on the diverse fauna of the north-west Kimberley.

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Cover photographs: A gorge in the Artesian Range in the Kimberley, WA. Joe Porter/AWC

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 that are 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, Ecohealth Monitoring Plans are developed describing the conservation values or assets of each property, and threats to these assets. In addition, the Ecohealth Plans set 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.

The 2020 Ecohealth Report is the second in the series of annual Ecohealth Reports for Charnley River – Artesian Range Wildlife Sanctuary (CRAR). It reports the results of Ecohealth Surveys undertaken in 2020 and summarises up-to-date information on status and trends of the Ecohealth indicators. The accompanying 2020 Ecohealth Scorecard presents the most up to date values for the indicators and their metrics.

Charnley River – Artesian Range Wildlife Sanctuary

Conservation-oriented fire management on CRAR commenced in 2007-8 under AWC's regional 'Ecofire' program. In 2010, AWC began managing a 139,000 ha section of the Artesian Range, located on Charnley River pastoral lease, with the remainder of the range then under the control of the WA Department of Environment and Conservation (the 'DEC triangle': 37,000 ha) added to AWC's management in 2011. In 2015, AWC's extended its management to the remainder of the Charnley River pastoral lease, to establish the 'Charnley River – Artesian Range Wildlife Sanctuary'. In 2017, AWC relinquished management of the DEC triangle, and entered into a partnership with Australian Capital Equity (ACE, owners of Mt House Station) for the sustainable management of cattle (*Bos taurus*) on eastern parts of the pastoral lease. The total area of CRAR is now just over 300,000 ha (Figures 1 and 2).

The sanctuary straddles the transition from the lower rainfall (below 1000 mm annually) and less-rugged Central Kimberley to the higher rainfall (above 1000 mm annually) and generally more rugged North-West Kimberley bioregions. It encompasses both relatively intact, high conservation value ecosystems, as well as ecosystems with potential for improvement under conservation land management and effective control of threats. At present, the sanctuary is confirmed or considered likely to support 64 species of mammals, 219 species of birds, 138 species of reptiles, 37 species of amphibian, of which a total of 13 species are listed as threatened at the national or state level. At least 387 species of plants have been recorded on CRAR. As some parts of the sanctuary are yet to be surveyed, these numbers may increase over coming years.

The Ecohealth Monitoring Program for CRAR is divided into two parts – 'Artesian', focused on the north-western part of the sanctuary; and 'Charnley', focused on the eastern part. This is due to the considerable differences in ecological communities, threat pressures, management issues, conservation goals, and access logistics in the two areas, as described below.

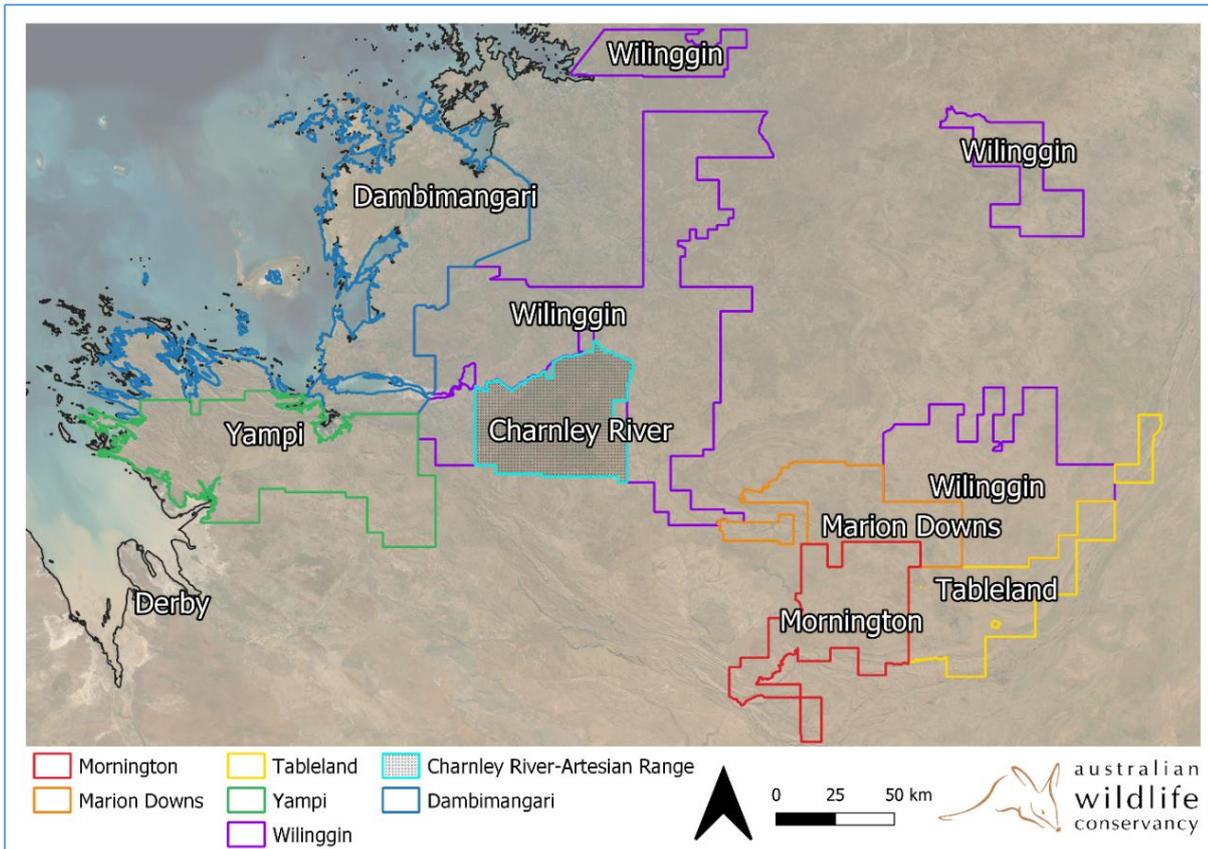


Figure 1. Location of Charnley River – Artesian Range Wildlife Sanctuary ('Charnley River') in the Kimberley, WA, with reference to other AWC sanctuaries and partnership areas in the region.

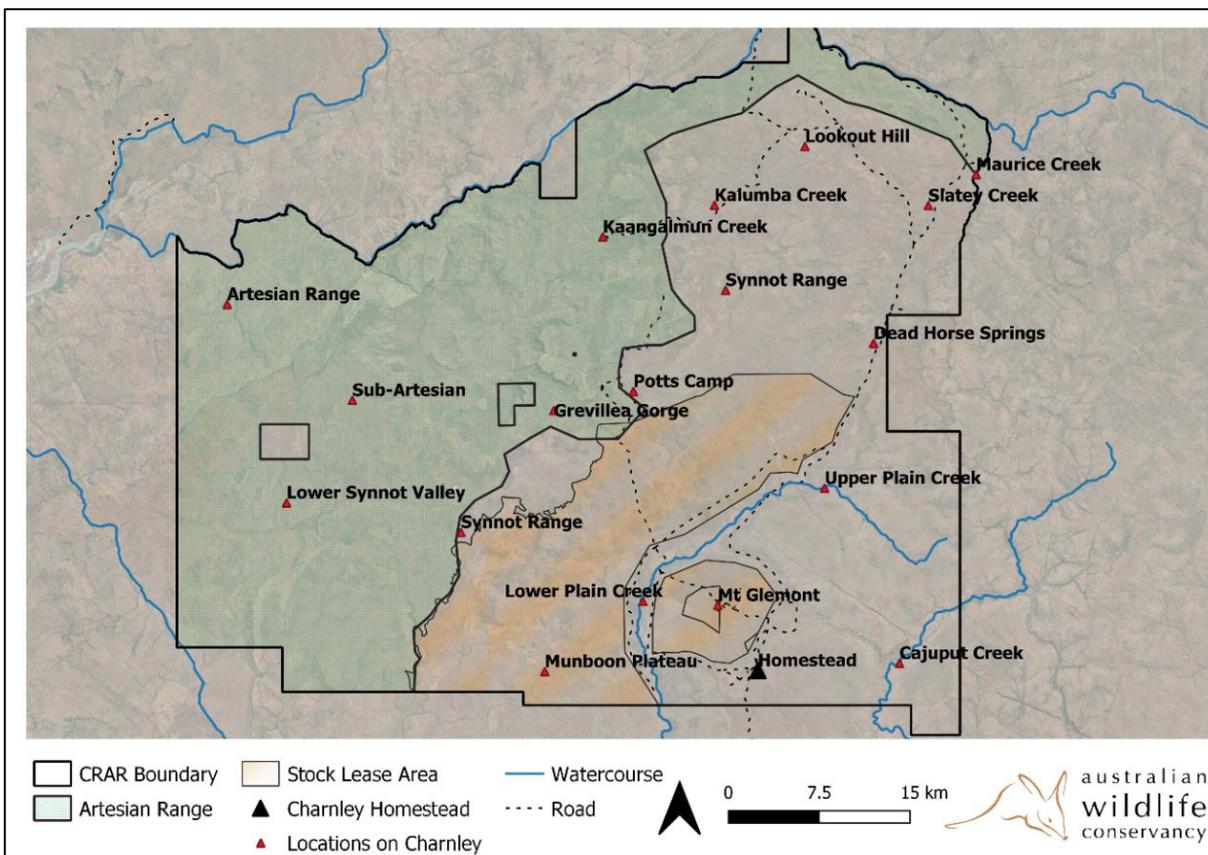


Figure 2. A map depicting the various areas on Charnley River – Artesian Range Wildlife Sanctuary. 'Artesian' section, shaded green; 'Eastern Charnley' section, no shading, except for the Mt House Station (ACE) stocked sub-lease area, shaded orange.

Artesian Range

The north-western, Artesian Range section of CRAR Sanctuary (hereafter, 'Artesian') is a remote and rugged landscape with little to no access except via helicopter. The landscape is dominated by spinifex-covered sandstone ranges dissected by gorges, many of which support rainforest pockets in fire-protected locations. It can be thought of as relatively ecologically 'intact' landscape, with very few feral herbivores, feral cats or weeds detected within the region (Legge et al. 2013), although the introduced cane toad (*Rhinella marina*) has recently invaded the area. Consequently, most of the threatened and endemic species that have disappeared from the central Kimberley, including eastern Charnley, have persisted in the Artesian Range. Management for the conservation of these species is largely focused on improving fire regimes, by creating and maintaining a mosaic of vegetation ages and continuing to protect important refuges.

AWC has been conducting inventory surveys and ecological research in the Artesian Range since 2012 (Legge et al. 2013; Hohnen 2015, Hohnen et al. 2015, 2016b, 2016a). In 2019, AWC established arrays of remote cameras to monitor Northern Quoll populations in response to the invasion of cane toads in the Artesian Range. Standardised Ecohealth surveys of a range of indicator species are to be conducted in the Artesian Range from 2021 onwards.

Charnley

The south-eastern (hereafter, 'eastern Charnley') section of CRAR is dominated by savanna woodland communities on a complex of sandstone, volcanic and alluvial soils. Extensive areas of eastern Charnley have been subject to impacts from cattle, feral pigs (*Sus scrofa*), feral cats (*Felis catus*), and frequent wildfires prior to active management by AWC; there is also a substantial grader grass (*Themeda quadrivalvis*) infestation in this section. With the exception of some small, isolated rugged refugial areas, such as Mt Glemont, the Munboon Plateau escarpment, and gorges in the Synnot Range (Figure 2), most of Eastern Charnley currently does not support the diversity of wildlife species restricted to the Artesian Range and other parts of the north-west Kimberley.

Management in eastern Charnley is heavily focused on actively minimising threats from feral animals, weeds and wildfire. Outside the Mt House Station (ACE) sub-leased area with a managed cattle herd, the remaining part of eastern Charnley is being actively destocked, with fences constructed and a muster conducted in 2019, and ongoing culling since 2020. The conservation goal is to restore ecological health in this area to allow threatened and endemic species of the north-west Kimberley to expand their populations into this area.

While biologically diverse, many of the woodland communities on Charnley have been adversely affected historically by destructive wildfire regimes and relatively large numbers of feral herbivores and feral cats.

Climate summary

The 2019-2020 Kimberley wet season was slightly below average (947 mm, 1968-2019), with 904 mm total rainfall recorded from July 2019-June 2020 at Charnley Homestead (Figure 3). Nevertheless, this was still considerably more rainfall than the previous year which experienced the driest 'wet season' since 1976, with only 514 mm. The 2019-2020 wet season was characterised by a late onset (December was the first month with >20 mm) and inconsistent and patchy storms until a large monsoonal low in February (354 mm). Additionally, unusually persistent localised storm events continued into May 2020, resulting in 59 mm being recorded, much higher than the 1968-2019 average for May of 18 mm. The end of 2020 saw a more typical onset to the 2020-2021 wet season, with 84 mm recorded in November. This was followed by one of the wettest Decembers on record for Charnley Homestead (329 mm). This rainfall was due to large and persistent monsoonal lows triggered by a regional climatic shift to La Niña conditions.

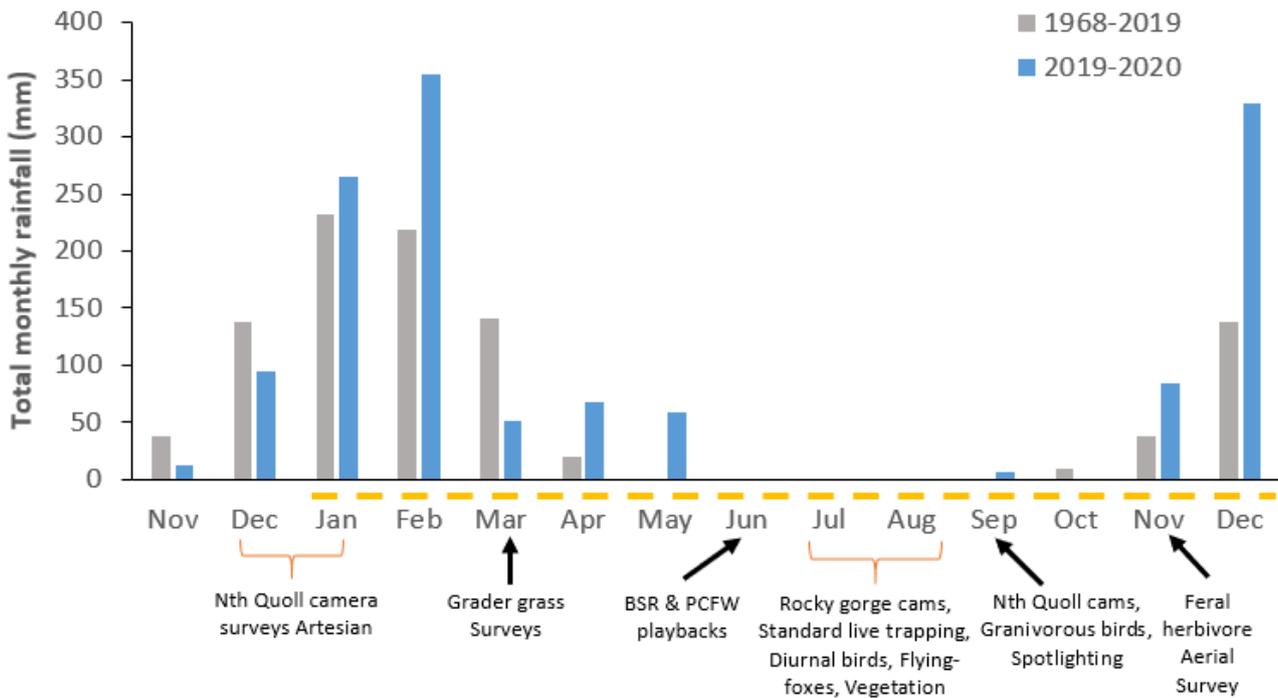


Figure 3. Monthly rainfall (mm), July 2019-December 2020 (blue), compared with historic (1968-2019, grey) median monthly rainfall. Data from the Charnley Homestead rain gauge, located at -16.72 S, 125.46 E (note: data for October 2020 missing). Timing of Ecohealth surveys indicated below graph. Orange dashed line represents 2020 Ecohealth reporting period.

Methods

Indicators and metrics

CRAR’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).

There are 41 biodiversity indicators (species and guilds) the rationale for their selection is recorded for each indicator in Table 1. In this report, the methods and results are presented for 34 of these indicators for which surveys were carried out in 2020. Threat metrics are selected to ensure monitoring the status and trends of introduced weeds, predators and herbivores and changed fire regimes (where appropriate). There are 9 threat metrics (Table 2) of which 8 are reported on in this report based upon 2020 surveys.

Table 1. Biodiversity indicators for Ecohealth Monitoring Program for Charnley River-Artesian Range Wildlife Sanctuary. Rationale for selection: T = threatened or declining; D = driver of ecosystem function; S = surveillance monitoring. Metric definitions: Abundance = number of detections/100 trap nights or survey or total raw count for Flying Foxes; Occupancy = proportion of sites recorded (occupancy); Density = number of individuals per unit area (e.g. m/ km searched); Richness = mean number of species/site.

Indicator	Rationale			Survey method	Metric/s
	T	D	S		
Mammals					
Small to medium-sized mammals					
Northern Quoll (<i>Dasyurus hallucatus</i>)	*	*	*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Northern Brown (<i>Isoodon macrourus</i>) and Golden Bandicoots (<i>Isoodon auratus</i>)	*	*	*	Cameras, cage traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Ningbing False Antechinus (<i>Pseudantechinus ningbing</i>)			*	Cameras (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Lakeland Down's Mouse (<i>Leggadina lakedownensis</i>)			*	Pitfall traps (Standard Live Trapping Survey)	Abundance, Occupancy
Long-tailed Planigale (<i>Planingale ingrami</i>)			*	Pitfall traps (Standard Live Trapping Survey)	Abundance, Occupancy
Echidna (<i>Tachyglossus aculeatus</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR array)	Abundance, Occupancy
Kimberley Rock-rat (<i>Zyomys woodwardi</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Monjon (<i>Petrogale burbidgei</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Common Rock-Rat (<i>Zyomys argurus</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Small to medium-sized mammal guild (dasyurids, rodents) – Charnley. Habitat based guilds: Riparian, Woodland, Blacksoil, Sandseep	*	*	*	Cage traps, Elliot traps, pitfall traps (Standard Live Trapping Survey)	Abundance, Richness
Small to medium-sized mammal - Rocky guild (dasyurids, rodents)	*		*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Richness
Large herbivores					
Large macropod guild			*	Camera traps (Waterhole Camera Array)	Abundance, Richness. Not surveyed 2020
Short-eared Rock wallaby (<i>Petrogale brachyotis</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Predators					
Dingo (<i>Canis lupis dingo</i>)		*		Camera traps (Rocky Area Camera Array, Predator Array)	Abundance, Occupancy
Arboreal mammals					
Golden-backed Tree-rat (<i>Mesembriomys macrurus</i>)	*			Camera traps (Artesian SECR Camera Array)	Abundance, Occupancy

Indicator	Rationale			Survey method	Metric/s
	T	D	S		
Savanna Glider (<i>Petaurus ariel</i>)			*	Spotlight transects	Abundance, Occupancy
Rock Ringtail Possum (<i>Petropseudes dahli</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Brushtail Possum (<i>Trichosurus vulpecula</i>)	*		*	Camera traps (Possum Array, Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Wyulda (<i>Wyulda squamicaudata</i>)			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Bats					
Microbat guild			*	Methods under development	Not surveyed 2020
Flying foxes			*	Roost mapping, point counts	Abundance
Reptiles					
Small-medium-sized reptiles					
Endemic gecko guild			*	Methods under development	Not surveyed 2020
Skink and dragon guild			*	Pitfall traps, funnel traps (Standard Live Trapping Survey)	Abundance, Richness
Gecko and flap-footed lizard guild			*	Pitfall traps, funnel traps (Standard Live Trapping Survey)	Abundance, Richness
Other reptiles					
Yellow Spotted Monitor (<i>Varanus panoptes</i>)	*			Camera traps (Varanid Array, Artesian SECR Camera Array)	Abundance, Occupancy
Freshwater Crocodiles (<i>Crocodylus johnsoni</i>)			*	Freshwater Crocodile Aerial Surveys and Spotlighting Surveys	Density. Not surveyed 2020
Water monitor guild			*	Camera traps (Varanid Array)	Abundance, Occupancy
Rock monitor guild			*	Camera traps (Rocky Area Camera Array, Artesian SECR Camera Array)	Abundance, Occupancy
Birds					
Savanna bird guild			*	Diurnal Bird Survey	Abundance, Richness
Buff-sided Robin (<i>Poecilodryas cerviniventris</i>)			*	Targeted playback surveys	Abundance, Occupancy
Purple-crowned Fairywren (<i>Malurus coronatus</i>)	*			Targeted playback surveys	Abundance, Occupancy
Black Grasswren (<i>Amytornis housei</i>)			*	Targeted playback surveys, cameras (Artesian SECR Camera Array)	Abundance, Occupancy
Granivorous birds					
Gouldian Finch (<i>Erythrura gouldiae</i>)	*			Granivorous Bird Targeted Survey (Waterhole Camera Array, Waterhole Surveys)	Abundance, Occupancy
Brown Quail (<i>Coturnix ypsilophora</i>)			*	Granivorous Bird Targeted Survey (Waterhole Camera Array, Waterhole Surveys)	Abundance, Occupancy
Nocturnal birds					

Indicator	Rationale			Survey method	Metric/s
	T	D	S		
Nocturnal bird guild			*	Method in development	Not surveyed 2020
Frogs					
Frog guild			*	Method in development	Not surveyed 2020
Vegetation					
Tree/canopy cover		*	*	Vegetation Structure Survey	% cover
Vegetation/shrub ground cover		*	*	Vegetation Structure Survey	% cover
Leaf litter extent		*		Vegetation Structure Survey	% cover
Ground cover extent		*		Vegetation Structure Survey	% cover
Woody debris		*		Vegetation Structure Survey	Density

Table 2. Threat indicators for Ecohealth Monitoring Program for Charnley-Artesian Wildlife Sanctuary. Metric definitions: Population density = number of individuals/unit area (ha); activity = number of records/survey; occupancy = proportion of sites recorded.

Indicator	Rationale	Survey method	Metric/s
Feral predators			
Cat (<i>Felis catus</i>)	Major threat to wildlife	Cameras (Rocky Area Camera Array, Predator Array, other relevant surveys on CRAR)	Abundance, Occupancy
Feral herbivores			
Cattle (<i>Bos taurus</i>)	Threat to wildlife, vegetation	Feral Herbivore Aerial Survey	Density
Horse (<i>Equus caballus</i>)	Threat to wildlife, vegetation	Feral Herbivore Aerial Survey	Density
Donkey (<i>Equus asinus</i>)	Threat to wildlife, vegetation	Feral Herbivore Aerial Survey	Density
Pig (<i>Sus scrofa</i>)	Threat to wildlife, vegetation	Camera (Waterhole Camera Array, other relevant surveys)	Occupancy, Abundance
Other threats			
Cane toads (<i>Rhinella marina</i>)	Threat to wildlife	Camera tapping (Rocky Area Camera Array, Artesian SECR Camera Array, other relevant surveys on CRAR)	Extent of infestation (categorised by distribution)
Weeds			
Grader grass (<i>Themeda quadrivalvis</i>)	Weed of National Significance	Grader Grass Aerial Survey (and vegetation surveys on CRAR)	Extent of infestation (categorised by distribution)
Other weeds	Threat to vegetation, changes to fire regime	Methods under development	Extent of infestation (categorised by distribution)
Fire			
Suite of ecologically-relevant metrics, calculated for (i) all fire; and (ii) late-season wildfire	Key driver of vegetation dynamics, structure and composition, habitat attributes	Remote sensing, ground traverse	Extent Time since fire Distance to unburnt (mean)

Survey types and history

To report on the Biodiversity and Threat Indicators, AWC survey teams conduct a variety of surveys over a period of 1-5 years. On CRAR, AWC first conducted Standard Live Trapping Surveys in 2012. Other components of the CRAR Ecohealth monitoring and threat monitoring program have been added in subsequent years. The surveys conducted in 2020 were:

- Standard Live Trapping (Charnley);
- Rocky Area Camera Array (Charnley);
- Artesian SECR Camera Array (Artesian);
- Spotlighting Surveys;
- Flying-fox Targeted Survey;
- Diurnal Bird Surveys (Charnley);
- Buff-sided Robin and Purple-crowned Fairywren Targeted Surveys;
- Granivorous Birds Targeted Surveys;
- Vegetation Structure (Charnley);
- Feral Herbivore Aerial Survey; and
- Grader Grass Aerial Survey.

Survey effort and history are outlined in Table 3. The methodology is described, and results of these surveys are reported on in this document.

Table 3. Survey effort for Ecohealth indicator surveys conducted on CRAR in 2020. Live-trapping and camera effort measured in trap nights (TN), transects are measured in distance (km); other surveys = total counts.

Survey	2020 Effort	Description (2020 surveys)	Previous Surveys
Standard Live Trapping (Charnley)	34 surveys, 4,080 (TN)	34 trapping sites surveyed with pitfall, Elliot, cage and funnel traps, stratified across four habitat categories	2020 – 34 sites, 2019 – 34 sites, 2017 – 26 sites, 2016 – 18 sites, 2015 – 5 sites, 2014 – 9 sites, 2012 – 12 sites
Rocky Area Camera Array (Charnley)	2,800 (TN)	20 sites, 5 cameras per site (n = 100) spaced 150-200 m apart for 28 nights each	2020 – 100 camera, 14 sites 2019 – 72 cameras, 14 sites
Artesian SECR Camera Array (Artesian)	3,360 (TN)	8 sites: 6 sites with 12 cameras per site, 2 intensive sites with 24 cameras, typically deployed in 3 x 4 grid with cameras 200m apart (total n = 120) for 28 nights each	2020 – 120 camera, 10 sites 2019 – 170 cameras, 10 sites
Spotlighting Surveys	3 surveys	Spotlighting riparian areas – each survey approximately 1 hr, along a 1-2 km transect	2020 – 3 surveys 2019 – 7 surveys
Flying-fox Targeted Survey	7 surveys	Count surveys occurred at 3 known roosting sites	2020 – 7 surveys 2019 – 9 surveys
Diurnal Bird Surveys (Charnley)	68 surveys	2-ha 20 min surveys at Standard Live Trapping sites on two mornings (total of 22 hr 40 min)	2020 – 34 sites, 68 surveys 2019 – 34 sites, 90 surveys
Buff-sided Robin and Purple-crowned Fairywren Surveys	3 surveys	Playback surveys at 3 sites, each with 6 playback points along a 1km transect	2020 – 3 surveys
Granivorous Birds Targeted Surveys	37 surveys	37 waterholes across 10 locations surveyed for 2 hrs per waterhole (total of 74 hours)	2020 – 37 waterholes across 10 locations, 74 hours 2019 – 23 waterholes across 5 locations, 46 hours
Vegetation Structure (Charnley)	34 surveys	300 point-measurements of ground and canopy cover surveyed at the 34 Standard Live Trapping sites	2020 – 34 sites 2019 – 34 sites
Feral Herbivore Aerial Survey	413 km	413 km aerial survey	Surveyed annually since 2016
Grader grass Aerial Survey	160 km	160 km aerial survey	2020 – 160 km aerial survey 2016 – Partially surveyed by road

Survey design and methods

In 2020, Ecohealth surveys for CRAR consisted of Standard Live Trapping Surveys for small mammals and reptiles (in conjunction with Diurnal Bird Surveys and Vegetation Structure Surveys), as well as a series of camera arrays, aerial, spotlighting, and targeted surveys (Table 3). These surveys attempt to cover the major vertebrate groups across the major vegetation types found on CRAR, while also providing geographic representation and replication.

Surveys conducted in 2019 but not 2020 were the Varanid Camera Surveys, Predator Camera Surveys, Possum Camera Surveys (trial methods in 2019 under review), and Freshwater Crocodile Aerial Surveys.

A brief description of survey design and methodology is given below for surveys conducted in 2020. Methodology may have changed slightly year to year through refinement and suggestions from the DBCA ethics committee. For a full list of survey effort refer to Table 3.

Standard Live Trapping (Charnley)

In eastern Charnley, the Standard Live Trapping survey is restricted to landscapes suitable for pitfall traps. In 2020, from late-July to late-August, 34 sites were sampled across four main habitat categories: Blacksoil (n = 6), Riparian (n = 10), Sandseep (n = 5) and Woodland (n = 13) (Table 4; Figure 4). As much as practicable, sites have been spread out across eastern Charnley. This survey in its standardised form was conducted in 2019 and 2020, with future survey frequency under review.

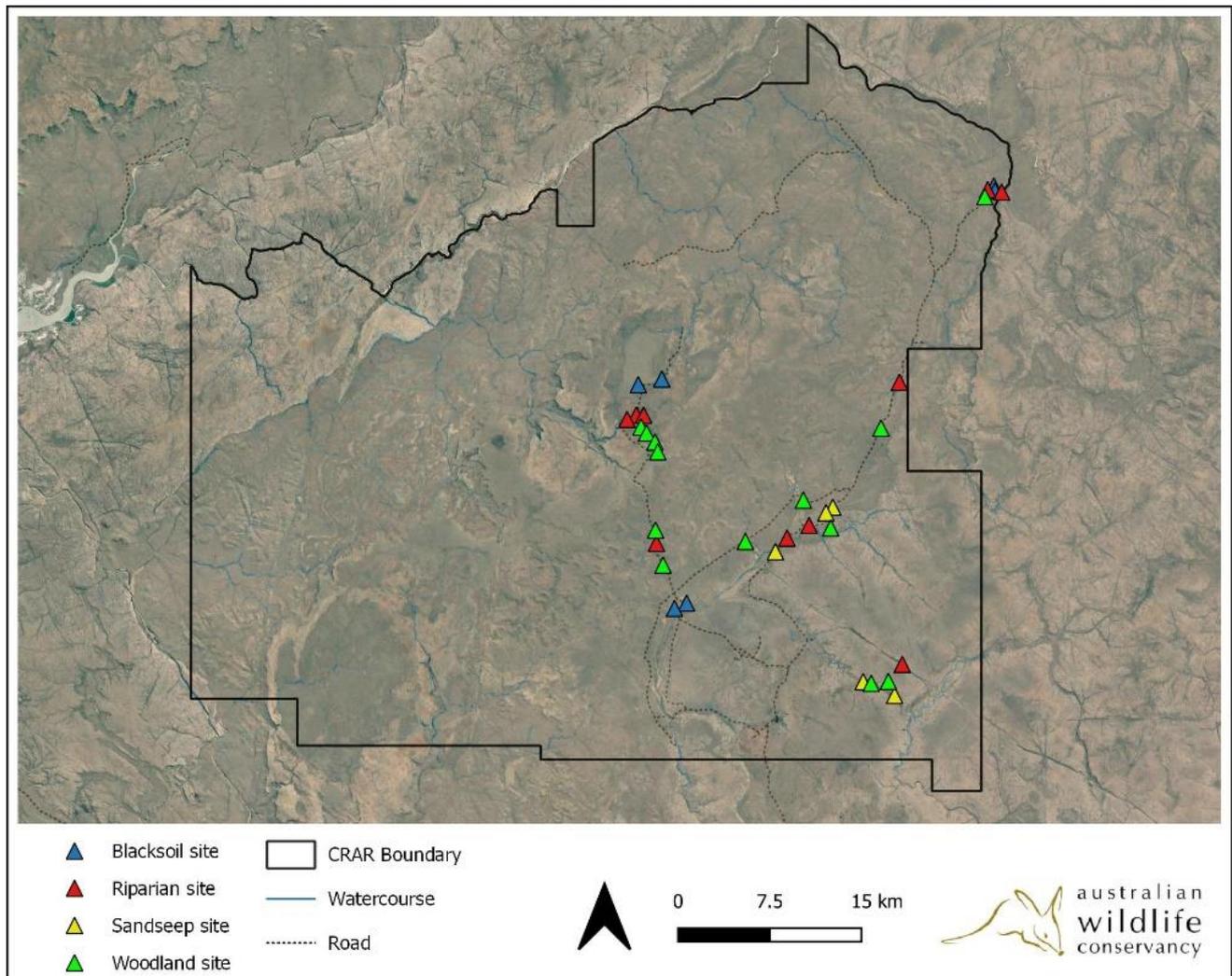


Figure 4. Location of 34 Standard Live Trapping sites across the four habitat types on eastern Charnley. Blacksoil (n = 6) - blue, Riparian (n = 10) - red, Sandseep (n = 5) - yellow and Woodland (n = 13) – green.

Each Standard Live Trapping site consists of a 50 m x 50 m plot containing 20 Elliot traps, 4 cage traps, and 4 x 20 m drift fences, each containing 2 pitfall traps and 2 funnel traps (Figure 5). The exception are sites in riparian areas, where a linear site arrangement (20 m x 80 m) has been employed, see Figure 5).

Traps were opened for three nights and days. Elliott and cage traps were baited with the bait of peanut butter, oat mix and mackerel, and only opened overnight (dusk till dawn). Funnel and pitfall traps were left open continuously. Sites were checked twice each day, morning and evening.

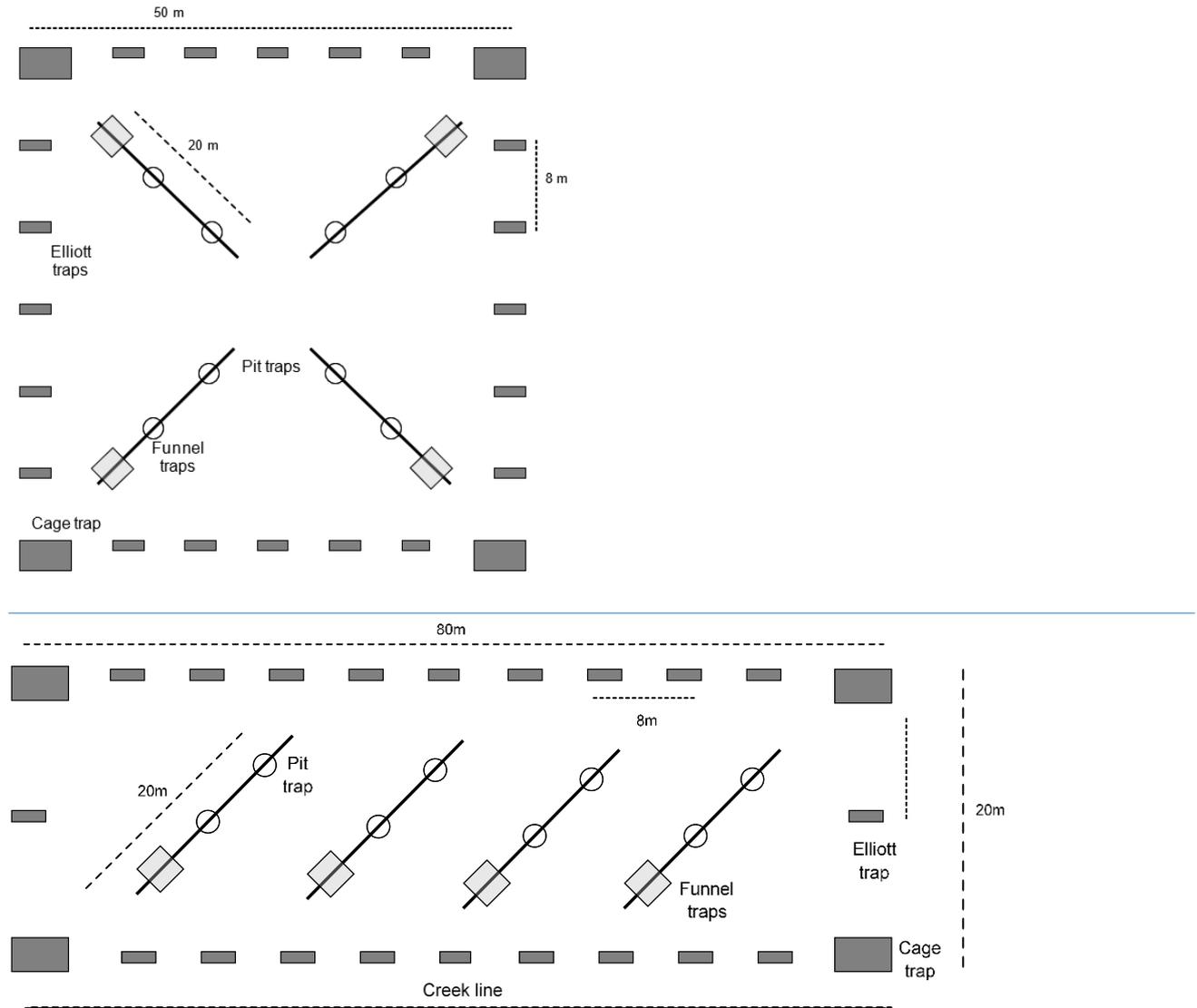


Figure 5. Site schematic for Standard Live Trapping sites (top) and Riparian habitat sites (bottom). Each site is 50 x 50 m (20 x 80 m for Riparian), with 4 cage traps, 20 Elliott traps, 8 pitfall traps and 8 funnel traps.

Table 4. Description of Standard Live Trapping site stratification ('habitat') categories in eastern Charnley.

Category	Description	No. of sites in 2020
Blacksoil	Volcanic-derived blacksoil grasslands with few/no trees on cracking clay soils. Typically dominated by perennial grasses and specialised forbs and shrubs such as <i>Vachellia suberosa</i> .	6
Riparian	Riparian vegetation along waterways on alluvium soils. Typically, with <i>Melaleuca/Lophostemon/Ficus/Terminalia</i> overstorey, <i>Pandanus/Sesbania</i> midstorey and often with dense grassy ground layer.	10
Sandseep	Periodically inundated sandy soils at the base of sandstone ranges. Typically dominated by <i>Grevillea/Acacia/Banksia</i> overstorey and matted <i>Chrysopogon/ Triodia</i> ground layer.	5
Woodland	Tropical savanna woodlands with a Eucalyptus-dominated tree layer and a grassy understorey. Woodland soils vary from skeletal rocky soils, red and grey clays, to sandy alluvial valleys. May be simple with <i>Eucalyptus tectifera</i> overstorey and <i>Sehima nervosum</i> ground layer, or complex with <i>Eucalyptus miniata/Corymbia</i> overstorey, a wide range of fruiting mid-storey trees and a diverse ground layer.	13
Total		34

Camera Surveys

Remote sensor camera arrays (typically Reconyx PC850 Hyperfire Pro white flash), are intended as broad-spectrum surveys. A large camera array will typically detect enough off-target species, especially rare species, to be useful for monitoring a variety of indicator species. All camera arrays on CRAR are designed to survey the major habitats and taxa that are not well surveyed by Standard Live Trapping surveys (e.g. rocky habitats, creek beds, roads, waterholes, and refugial pockets). In 2020, camera surveys were conducted of Rocky Areas on Charnley and SECR Camera Arrays on Artesian (Table 3, and below). Other camera surveys – of varanids, predators, possums and at waterholes – were not conducted in 2020.

Rocky Area Camera Array (Charnley)

Rocky gorges and escarpments occur over a large area of the Kimberley, including the Artesian Range and parts of Charnley. These areas provide important habitat for many species - their topographical complexity provides protection from feral cats (Hohnen et al. 2016a), and they tend to have a more patchy and less intense wildfire regime than other landscapes in the Kimberley (Bradley et al. 1987). Rocky habitats therefore function as important refugia for many species, some of which are rocky habitat specialists (e.g. rock-rats, rock-wallabies), while others are more abundant in these habitats (Hohnen et al. 2016a).

A history of extensive wildfire on many parts of Charnley has likely led to the decline of large, hollow-bearing trees and fleshy-fruited trees, which are important components of habitat for several arboreal mammal species. Rocky areas often provide some refuge from wildfire, and – with the exception of the Savanna Glider – it is often in these refuges that arboreal mammals on CRAR are most likely to be found.

A suite of indicators including small-medium sized mammals, reptiles, and threats were targeted in 20 Rocky Area Camera Array trap sites across CRAR between late July and early September 2020 (Figure 6). Five cameras were deployed at each site (totalling 100 cameras) for 28 nights, totalling 2,800 trap nights. All cameras were spaced approximately 150-200 m apart within each site and set 1.5 m above the ground facing downwards at a 45° angle towards a universal bait (NWET 2019). Cameras were set to the standard NW specifications – five images per trigger, Rapidfire™ mode, no delay between triggers, and high sensitivity.

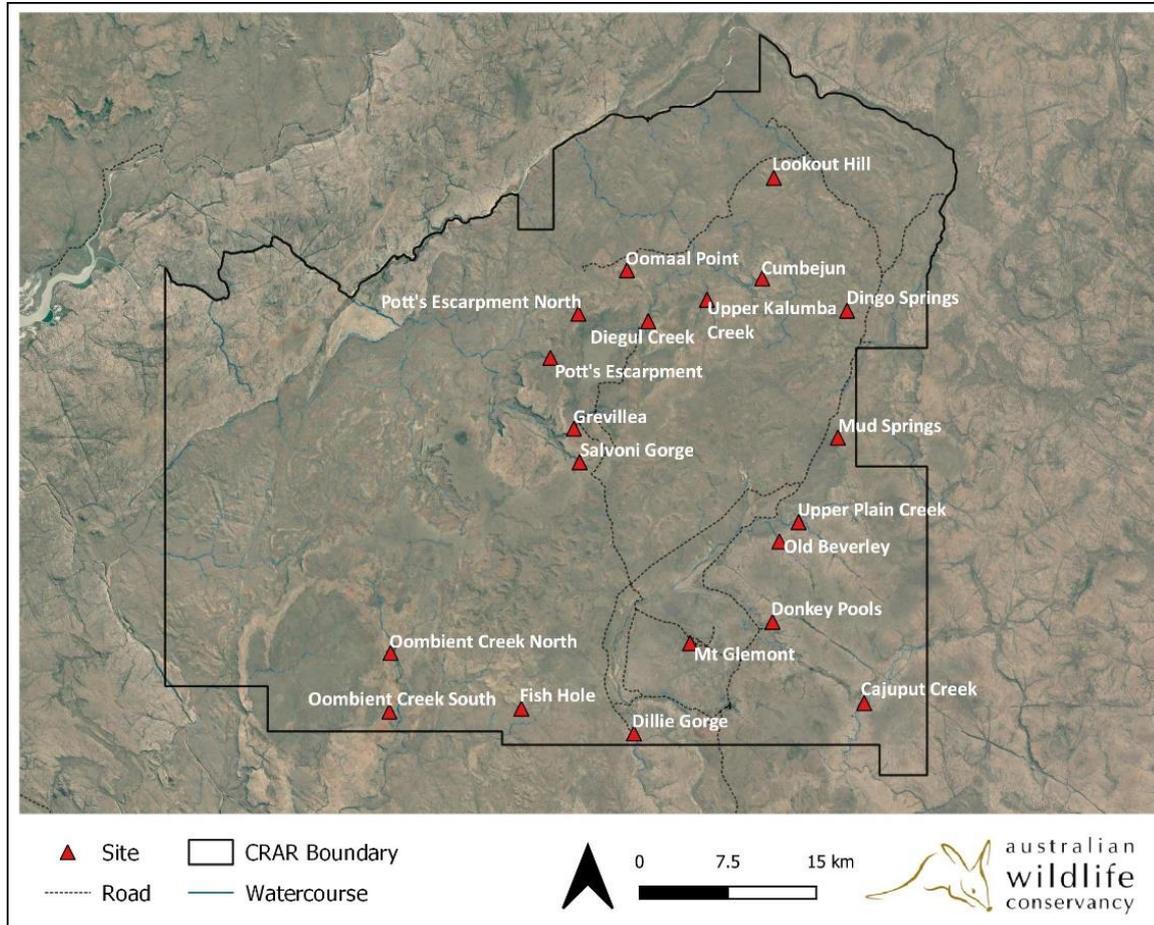


Figure 6. Location of the 20 Rocky Area Camera Array sites surveyed in July-September 2020.

Artesian SECR Camera Array (Artesian)

For several years, Northern Quolls have been monitored at sites across the Artesian Range and Sub-Artesian Range (chosen to represent a range of habitat types; Figure 7), using Camera Arrays from which population density can be estimated using a Spatially Explicit Capture-Recapture (SECR) approach. In 2020, six of the eight sites surveyed had 12 cameras deployed. The remaining two 'intensive' sites were surveyed with a cluster of 24 cameras - these were situated at the Artesian Hut (CTA Hut -Test site), and South Intensive (Intensive Sth - Control site), 3 km to the south. All eight sites were surveyed between December 2019 and January 2020 over 28 trap nights. While targeting Northern Quolls, these arrays also provide data on the suite of small-medium mammals present in the area. Note these arrays use more cameras than those used to survey small-medium mammals in rocky areas on Charnley (12-24 cameras on Artesian, compared with 5 camera traps per site on Charnley, as above). This difference in methodology should be considered when comparing results obtained from the two sections of CRAR.

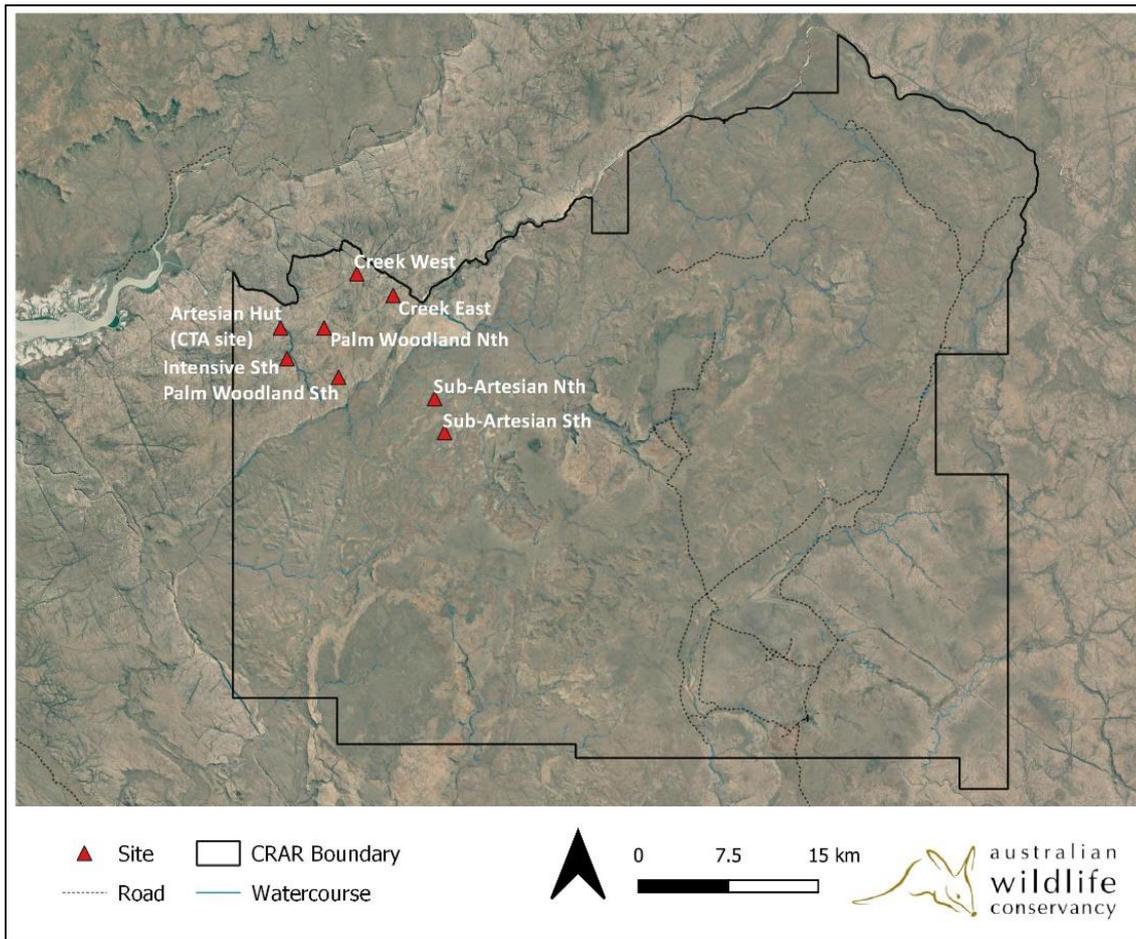


Figure 7. Map of the 8 Artesian SECR Camera Array sites across the Artesian Range surveyed during the 2019 – 2020 (December – January) wet season. Sites consisted of 12 or 24 camera arrays – totalling 120 cameras across 8 sites, each deployed for 28 trap nights.

Spotlighting Surveys

Spotlighting Surveys involved an active search along a linear transect by 1-2 observers, within a few hours after sunset in suitable conditions. A survey took 1-2 hours and covered 1-2 km of transect. During this time, a spotlight was used to survey the ground, water (when present), tree trunks and canopy for Ecohealth indicator species. Spotlight surveys were undertaken at three sites in September 2020. Spotlight surveys typically take place annually on an opportunistic basis.

Flying-fox Targeted Survey

Flying-fox Targeted Surveys comprised of roost counts at known roost locations. Where possible, counts were repeated several times or independently by several observers to aid estimate accuracy. It is extremely difficult to accurately count flying-fox roosts, and numbers should be considered best estimates only. In 2020, Diegul

Creek Pool, the Homestead, and Kalumba Creek, were surveyed for Flying-foxes twice, four times, and once, respectively, from May to September 2020. This survey was also conducted in 2019.

Diurnal Bird Surveys

In 2020, Diurnal Bird Surveys were conducted at the 34 Standard Live Trapping Survey sites (Figure 4). Each Standard Live Trapping site was surveyed for two mornings. Surveys were conducted in favourable weather during the dawn chorus and consist of a 20-minute observation of a 2-ha area around the survey site. Sites were surveyed by a single observer, with a different observer used the following morning to reduce observer bias. Four observers in total conducted the surveys. A total of 68 Diurnal Bird Surveys (34 sites x two surveys/site) were conducted in July-August in 2020.

Buff-sided Robin and Purple-crowned Fairywren Targeted Surveys

Buff-sided Robin and Purple-crowned Fairywren Targeted Surveys were conducted along a single transects (~1 km) at 3 sites (Munboon escarpment, Upper Plain Creek, and Maurice Creek) in July 2020. Call playback was conducted at set points along each transect. Observers played bird calls twice, followed by a 2 minute quiet period (active listening). There were six playback points, spaced ~200 m apart through suitable riparian habitat. Observers recorded the number of Buff-sided Robins or Purple-crowned Fairywrens that were seen or heard at each point.

Granivorous Bird Targeted Surveys

Granivorous (grain-eating) Bird Targeted Surveys (targeting finches and quails) were conducted in September 2020. Two-hour point observational surveys were undertaken at 37 waterholes, situated across 10 sites of eastern Charnley (Figure 8). Site selection was conducted via a visual walking assessment of a 5 km stretch of 10 watercourses during which time all waterholes encountered were marked on a GPS and scored based upon their suitability for finches (i.e. fringing vegetation, stagnant water, small-pebbled edges, etc.). The most suitable sites were then selected for survey. A single waterhole survey took place between 5:30-7:30 am, beginning just before sunrise, and involved counting the number of birds seen and noting how many individuals of each species were observed drinking water, with the primary focus on granivorous birds. These targeted surveys were conducted in the late dry season (September) as water is less widespread and available throughout the landscape, and granivorous birds rely more heavily on extant surface water.

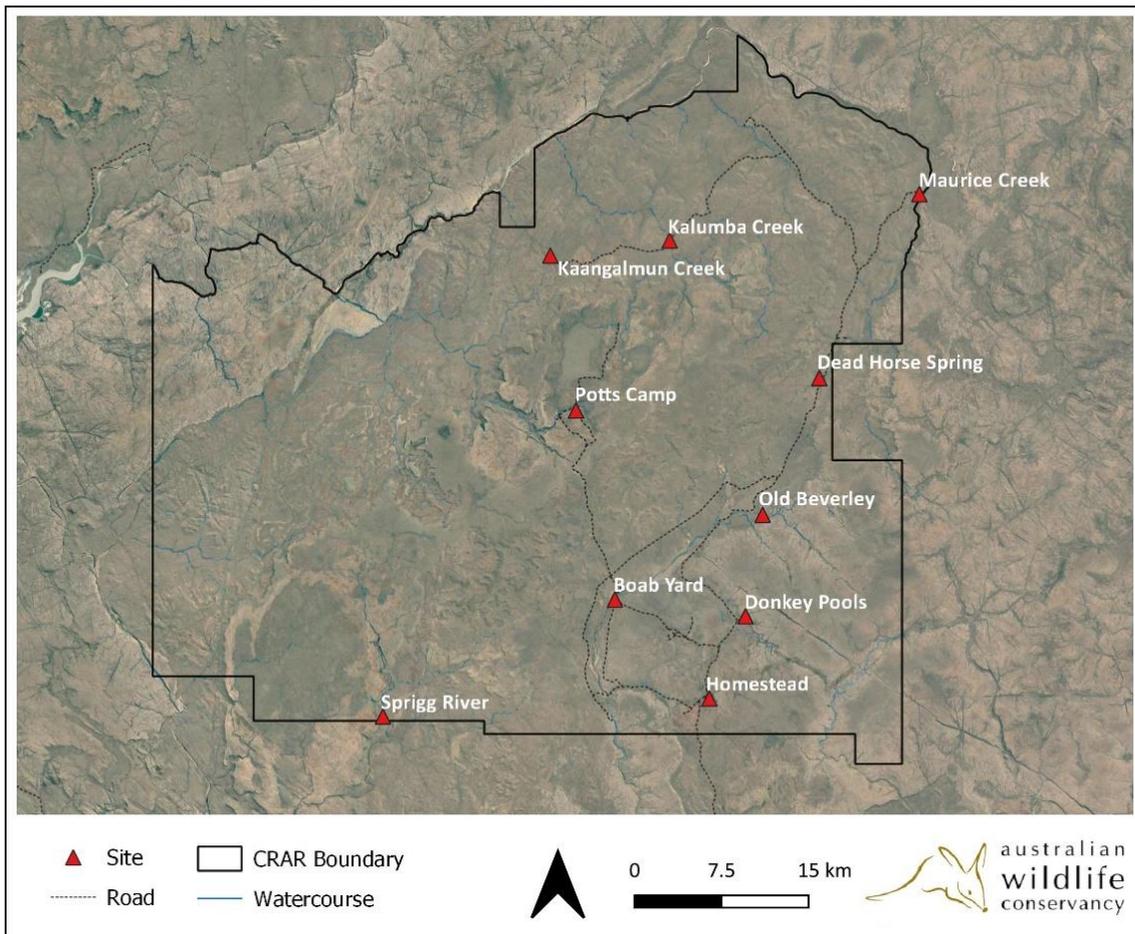


Figure 8. Map of the 10 Granivorous Bird Targeted Survey sites surveyed in September 2020. A total of 37 waterholes were surveyed for granivorous birds across these 10 sites.

Vegetation Structure Surveys

A Vegetation Structure Survey was carried out concurrently with the Standard Live Trapping Surveys conducted at the 34 Standard Live Trapping Survey sites (Figure 4). Three 100 m transects were set up within the specified habitat. At each 1 m point (300 measurement points for each site), the type and height of ground cover was recorded, the type and height of canopy cover (with plants identified to genus) directly overhead recorded for 1.8-6 m and >6 m. Woody debris (>2.5 cm) was recorded continuously along each 100 m transect. A site score was estimated for fire and cattle impact.

Feral Herbivore Aerial Survey

To monitor large feral herbivores (cattle, horses, donkeys) the feral herbivore survey (413 km) was flown on 9 November 2020, shortly before the feral herbivore/pig cull and prior to significant rain on CRAR (Figure 9). The same flight path is flown each year at approximately 100 m off the ground at 100 km/hr and covers landscapes of varied pastoral productivity and habitat. Four helicopter crew members (including one pilot) observed and recorded all cattle, horses and donkeys seen, and noted whether they were inside or outside a 45° angle from vertical (this gives an 'inside' transect width of 200 m).

In reviewing the data collected by the survey, approximately 75% of cattle observed were within the 45° angle observation area (100 m from the helicopter), indicating a steep drop-off in detection beyond that distance, and suggesting that constraining records to the 200 m wide 'inside' transect was appropriate.

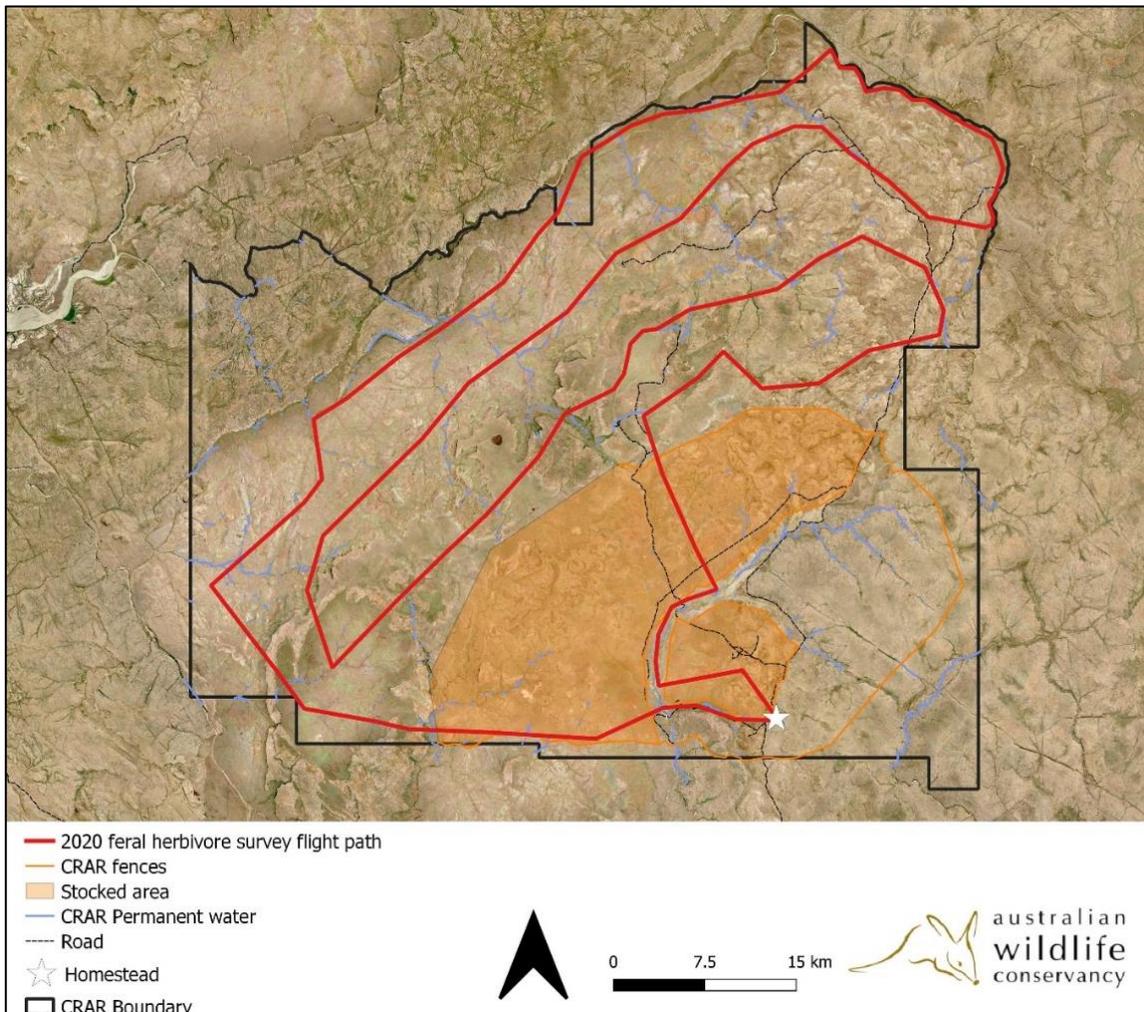


Figure 9. Map of the 2020 standardised Feral Herbivore Aerial Survey on CRAR.

Grader Grass Aerial Survey

The grader grass aerial survey (160 km) was flown on 13 March 2020, involving three observers flying low over roadways and fence lines to map out the distribution of grader grass infestations across CRAR.

Analysis

The following methods were used to calculate metrics for Ecohealth indicators:

Abundance: the number of detections (captures for live traps, independent ‘visits’ or detections for camera traps) per 100 trap nights (or per survey/site in some instances, e.g. bird surveys). 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, and cage and Elliot traps are excluded for small reptiles.

Richness: the average number of species detected per sampling site (trap site, camera, or survey site). In situations where a species could not be identified to species level (e.g. “*Cryptoblepharus sp.*”, or “*Cryptoblepharus metallicus/ruber*”), it is assumed that it does not represent a separate species when congeners have already been counted for the purposes of calculating richness.

Occupancy: Occupancy figures presented in the 2020 Ecohealth report are based on the proportion of (appropriate) survey sites occupied by a given species.

Density: is calculated as the number of detections per unit distance or area.

Results

Biodiversity indicators

Mammals

Small-medium mammals

Lowland trapped small-medium mammal guild (Charnley)

In 2020, a total of six small mammal species were captured across all 34 Standard Live Trapping sites. On most habitat types, species richness and abundance in 2020 were similar to numbers recorded in the 2019 survey, but below numbers recorded in 2016 and 2017 (Figures 10 and 11).

The steep decline of trap-revealed small mammal richness and abundance between 2017 and 2019, and the stabilisation from 2019 to 2020, tracks the amount of rainfall on the property. The 2018/19 wet season on CRAR was extremely dry, whereas the 2019/20 wet season was just below average. The variation in small mammal richness and abundance with rainfall is presumably driven by the availability of resources (i.e., there is more food in wetter years than in drought) and by predation (small mammals are much more exposed to feral cats when ground cover is sparse than when cover is dense (MacGregor et al. 2015). Interestingly, most small mammals trapped in the CRAR surveys in 2019 and 2020 were caught in the Potts Camp area (Figure 2). Potts Camp has several springs which hold water through dry times and patches of mesic vegetation; impacts from wildfire and cattle are also relatively low in this area. For these reasons, the availability of resources and the extent of ground cover can be expected to greater around Potts Camp than other lowland sites on CRAR.

Individual small mammal species

Trends in the abundance and richness of the small mammal assemblage reported above (higher in 2016-17 than 2019-20) were primarily driven by changes in the abundance of the three most commonly trapped species: Pale Field Rat (*Rattus tunneyi*), Western Chestnut Mouse (*Pseudomys nanus*) and Delicate Mouse (*Pseudomys delicatulus*); and also by the Common Planigale (*Planigale maculata*; Figure 12).

Trap-revealed abundance of the other two species, both uncommon in the early years of trapping on CRAR, followed a different pattern. The Lakeland Down's Mouse was captured at slightly higher rates in 2019-20 than 2016-17, although total number of captures were low in all years (5 in 2017 and 2020; 6 in 2019), with little power to show trends. For the Long-tailed Planigale, which is largely restricted to Blacksoil habitat, there were no captures in 2016-17, 3 captures in 2019, and 10 captures in 2020.

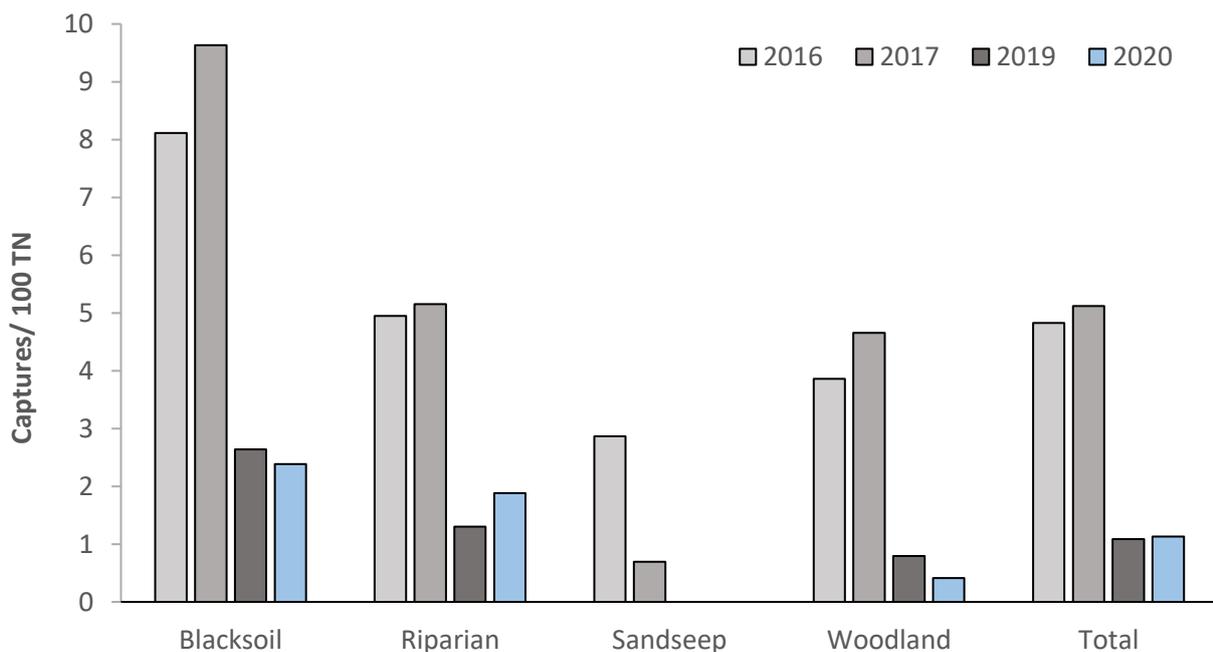


Figure 10. Small mammal abundance (captures per 100 trap nights) by habitat from Standard Live Trapping on CRAR, 2016-2020.

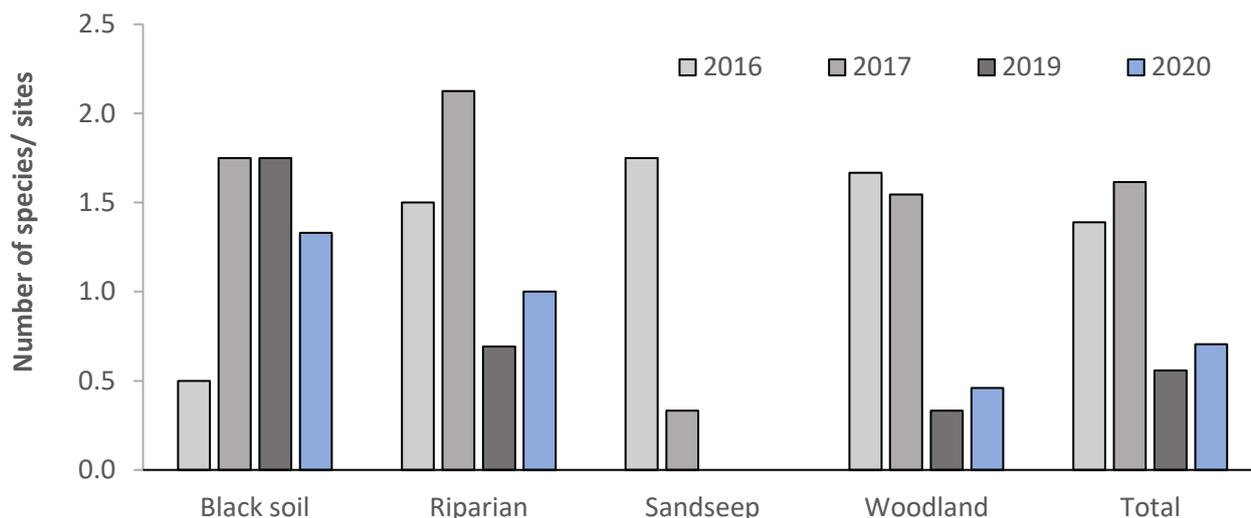


Figure 11. Average species richness per site of small to medium-sized mammals by habitat from Standard Live Trapping on CRAR, 2016-2020.

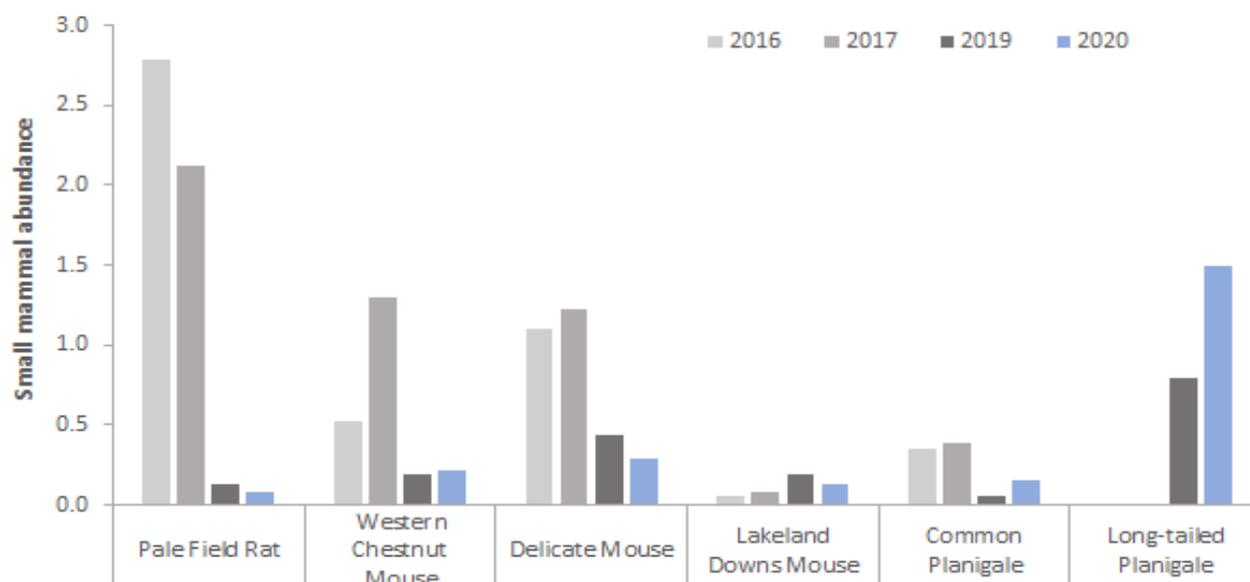


Figure 12. Annual variation in the abundance of individual small to medium-sized mammal species (captures per 100 trap nights) from Standard Live Trapping on CRAR, 2016-2020.

Rocky area small-medium mammals

In 2020, a total of 3,911 and 913 visits from small-medium mammals were detected across the 20 Rocky Area Camera Array sites (Charnley) and 8 Artesian SECR Camera Array sites, respectively. Results for occupancy and abundance are presented in Table 5 for the small-medium mammal guild and for each indicator species; data on the richness of the small-medium mammal guild in 2020 compared with 2019 are presented in Table 6. Species detected in the small-medium mammals guild on CRAR in 2020 were the dasyurids: Northern Quoll and Ningbing False Antechinus; and the rodents: Lakeland Down’s Mouse, Golden-backed Tree-rat, Western Chestnut Mouse, Common Rock-rat and Kimberly Rock-rat, Pale Field Rat and Water Rat (*Hydromys chrysogaster*).

Both the abundance and richness of small-medium mammals were higher in 2020 than 2019, on both the Charnley and Artesian sections of CRAR (Table 5; Table 6). Overall abundance was higher on Charnley than Artesian, mostly due to the very high abundance of the Common Rock-rat at sites in that section. Most species of mammal in this guild were more abundant in 2020 than 2019: in the Charnley section, the Common Rock-rat increased from 17 to 109 visits/ 100 TN; while in the Artesian Range, the Kimberley Rock-rat increased from 1.1 to 5.9 visits/ 100 TN, and the Golden-backed Tree-rat increased from 0.3 to 0.6 visits/ 100 TN (Table 5). The 2020 surveys resulted in the first detection of the Kimberley Rock-rat outside the Artesian Range on CRAR, with a record from Cumbejun on the Charnley section of the property.

The Northern Quoll, a focus of AWC’s conservation efforts in the Kimberley as cane toads invade the region, was detected at 100% of sites in the Artesian Range (a remaining stronghold for the species). In contrast, on Charnley, Northern Quolls persist in a series of isolated populations on eastern Charnley (concentrated around the Synnot Range and Oombient Creek; see Table 5). On Charnley, the abundance of Northern Quolls was lower in 2020 than 2019, but on Artesian, abundance varied little between years.

Two rocky habitat specialist macropods, the Monjon and Short-eared Rock-wallaby, were both recorded at higher levels of abundance in 2020 than 2019 (the former on Artesian, the latter primarily on Charnley).

Table 5. Small-medium mammal occupancy and abundance (‘independent’ visits per 100 trap nights) from 2020 camera surveys from 20 Rocky Area Camera Array sites (eastern Charnley region) and 8 Artesian SECR Camera Array sites on CRAR (2,800 and 1,920 trap nights, respectively).

Species	Section	Occupancy (%)	Abundance (per 100 TN)	Comments
<i>Rocky area small-medium mammal guild (dasyurids, rodents)</i>	Charnley	100	113.7	High abundance mainly attributable to the presence of the Common Rock-rat accounting for 95.7% of visits. 2019 dasyurid and rodent guild abundance was 24.1.
	Artesian	100	18.1	The Common Rock-rat accounted for 32.6% of visits. 2019 dasyurid and rodent guild abundance was 9.8.
Rodents				
Kimberley Rock-rat	Charnley	5	0.04	First time species detected outside the Artesian Range, on eastern Charnley (1 individual at Cumbejun).
	Artesian	75	5.9	Appears to be ubiquitous in the Artesian Range, responsible for the second greatest number of independent small-medium mammal visits. 2019 abundance was 1.1.
Golden-backed Tree-rat	Charnley	0	0	Not detected, confined to the Artesian Range.
	Artesian	75	0.6	Confined to and common in the Artesian Range, detected across 6 of the 8 sites in 2020. 2019 abundance was 0.3.
Common Rock-rat	Charnley	95	108.8	By far the most abundant small-medium mammal detected in 2020. 2019 abundance was 17.
	Artesian	100	3.6	Detected across all 8 sites in 2020.
Dasyurids				
Northern Quoll	Charnley	20	4.5	Detected at 4 out 20 sites in 2020. 2019 abundance was 6.8, detected at 5 sites.
	Artesian	100	6.9	Detected across all Artesian sites and responsible for the greatest number of independent visits. 2019 abundance was 7.0.
Ningbing False Antechinus	Charnley	20	0.2	5 independent visits detected across 4 out of 20 sites, compared to 1 detection in 2019.
	Artesian	50	0.2	8 independent visits across 4 out of 8 sites, compared to 7 detections in 2019 (abundance 0.2).

Species	Section	Occupancy (%)	Abundance (per 100 TN)	Comments
Macropods				
Short-eared Rock Wallaby	Charnley	70	22.1	Common on CRAR in rocky areas (abundance in 2019 was 12.3), detected across the majority of sites and the second most common small-medium mammal detected in 2020.
	Artesian	63	0.4	Detected across 5 of the 8 sites within the Artesian Range, in considerably lower numbers than eastern Charnley.
Monjon	Charnley	0	0	Not detected in eastern Charnley, likely restricted to the Artesian Range. Absent in both 2020 and 2019 surveys.
	Artesian	75	4.6	Relatively common in both 2020 and 2019 surveys. 2019 abundance was 1.8.
Arboreal mammals				
Rock Ringtail Possum	Charnley	0	0	None detected in 2020. In 2019, detected from only Mt Glemont (abundance 0.33).
	Artesian	0	0	Not detected.
Brushtail Possum	Charnley	0	0	Not detected.
	Artesian	13	0.1	3 detections from 1 site (Sub Artesian Woodland South) in 2020. Artesian abundance in 2019 was 0.2.
Scaly-tailed Possum	Charnley	10	0.9	Detected at only 2 of 20 sites. 2019 abundance was 2.4 detected at 5 sites.
	Artesian	75	3.2	Detected across the majority of sites. 2019 abundance was 1.5.
Savanna Glider	Charnley	0	0	Not detected by cameras or 2020 spotlighting surveys. Arboreal camera survey method in development.
	Artesian	0	0	Not detected. Arboreal camera method in development.
Other small-medium mammals				
Northern Brown Bandicoot and Golden Bandicoot	Charnley	5	0.1	Only 3 visits at one site (Oombient North) in 2020, in line with low detectability in 2019 surveys.
	Artesian	50	0.5	Detected at 4 out of 8 sites in 2020 and 7 of 10 sites in 2019 (abundance 0.44), both at low abundances.
Echidna	Charnley	40	0.6	Detected at 8 out of 20 sites (compared to only 6% of sites in 2019), in low abundance in line with 2019 surveys (abundance 0.5).
	Artesian	13	0.03	Only 1 individual detected at Intensive South.

Table 6. Richness of rocky area small-medium mammals (rodents and dasyurids) from camera surveys on two sections of CRAR (Charnley, Artesian) in 2020 compared with 2019.

Guild	Section	Year	Richness
Rocky area small-medium mammals	Charnley	2020	1.45
		2019	0.60
	Artesian	2020	4.25
		2019	0.73

Predators

Dingo

No targeted Predator Array Surveys were undertaken in 2020. Camera detections from the Rocky Area Camera Array (Charnley) and Artesian SECR Camera Arrays are reported here to indicate the presence and persistence of Dingoes. Dingoes were detected across 15 of the 20 Rocky Area Camera Array sites in 2020 (total of 63 detections), with an abundance of 2.3 individuals per 100 TN (up from 0.76 individuals per 100 TN in 2019). On the Artesian Range, only 4 independent visits by Dingoes across 3 sites were recorded by the SECR Camera Arrays (Figure 13).

Bats

Flying foxes

Two species of flying foxes, Black Flying Fox (*Pteropus alecto*) and Little Red Flying Fox (*Pteropus scapulatus*), and their roost sites were observed and monitored opportunistically across 3 sites at CRAR in 2020. The highest counts for both species were in a roost at the Charnley Homestead. Black Flying Foxes were also recorded at Diegul Creek Pool and Kalumba Creek (Table 7). Little is known about flying-fox distribution or movements on CRAR, and it is very likely that further roosting sites will be found (both species, but particularly the Little Red Flying-fox, establish camps opportunistically in areas providing abundant resources). Future monitoring work will continue to map and survey new roost sites.

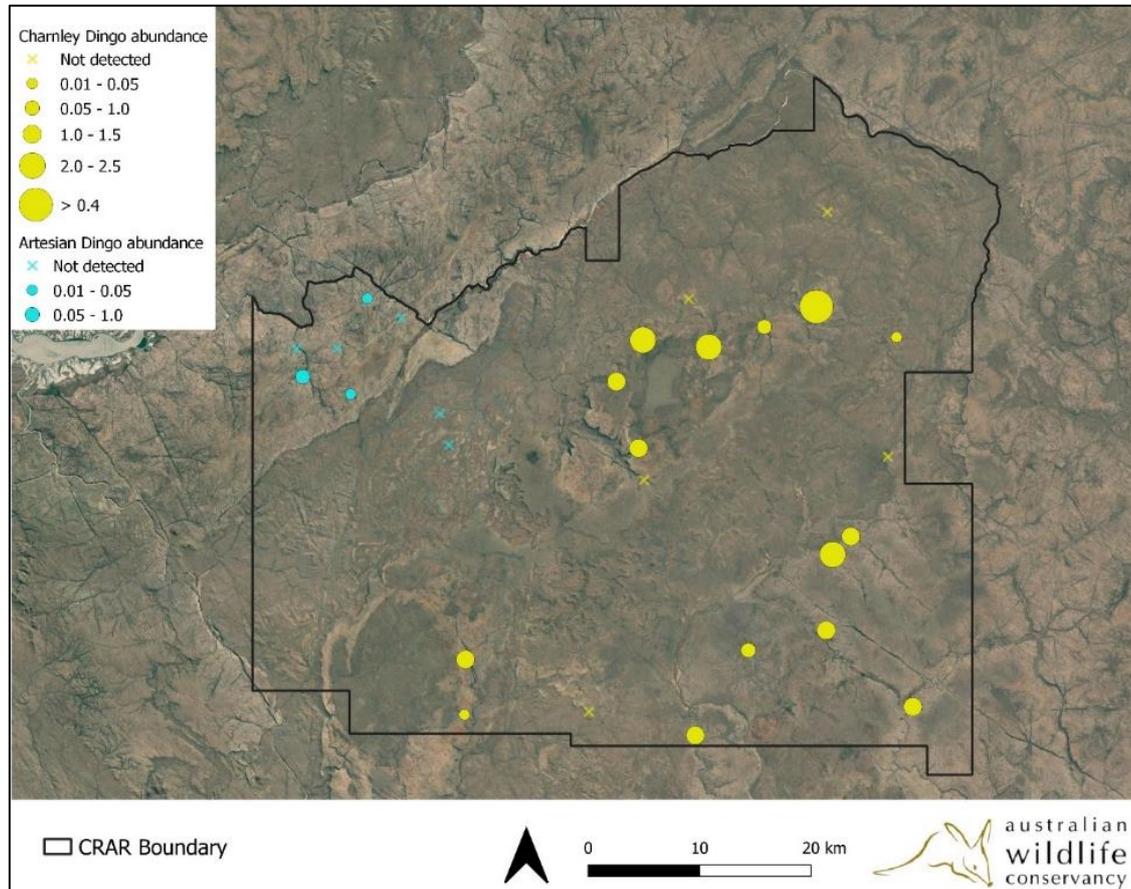


Figure 13. Distribution and abundance (detections per 100 TN) of Dingos based on the 2020 Rocky Area Camera Array (Charnley) (yellow) and Artesian SECR Camera Array (blue).

Table 7. Total roost count estimates per survey at three roost sites on CRAR in 2020 between May and September for each flying fox species present and average counts across surveys (bold text).

Roost site and survey	Black Flying Fox	Little Red Flying Fox
Charnley Homestead (average)	1,750	4,500
21/05/2020	1,000	-
26/07/2020	-	2,000
01/08/2020	2,500	-
20/09/2020	-	7,000
Diegul Creek Pool (average)	170	-
22/07/2020	40	-
28/08/2020	300	-
Kalumba Creek	20	-
24/09/2020	20	-

Reptiles

Small-medium reptiles

Skinks and dragons guild

Between 2019 and 2020, the abundance of skinks and dragons trapped in standard surveys on CRAR decreased on three of four habitat types; average abundance overall fell from 12.4 individuals per 100 TN in 2019 to 7 individuals per 100 TN in 2020 (Figure 14). This substantial decrease may reflect a response to the cumulative effects of the very dry 2018-19 wet season, followed by a below average wet season in 2019-20, and/ or prevailing environmental conditions at the time of each survey. Despite a reduction in abundance there was, however, no major changes in the diversity of skinks and dragons between 2019 and 2020 (Figure 15). Further, as was the case between 2016-2019, skink and dragon assemblages in 2020 also varied according to habitat, with Woodlands maintaining the highest level of species richness and Blacksoil comprising the lowest level of species richness.

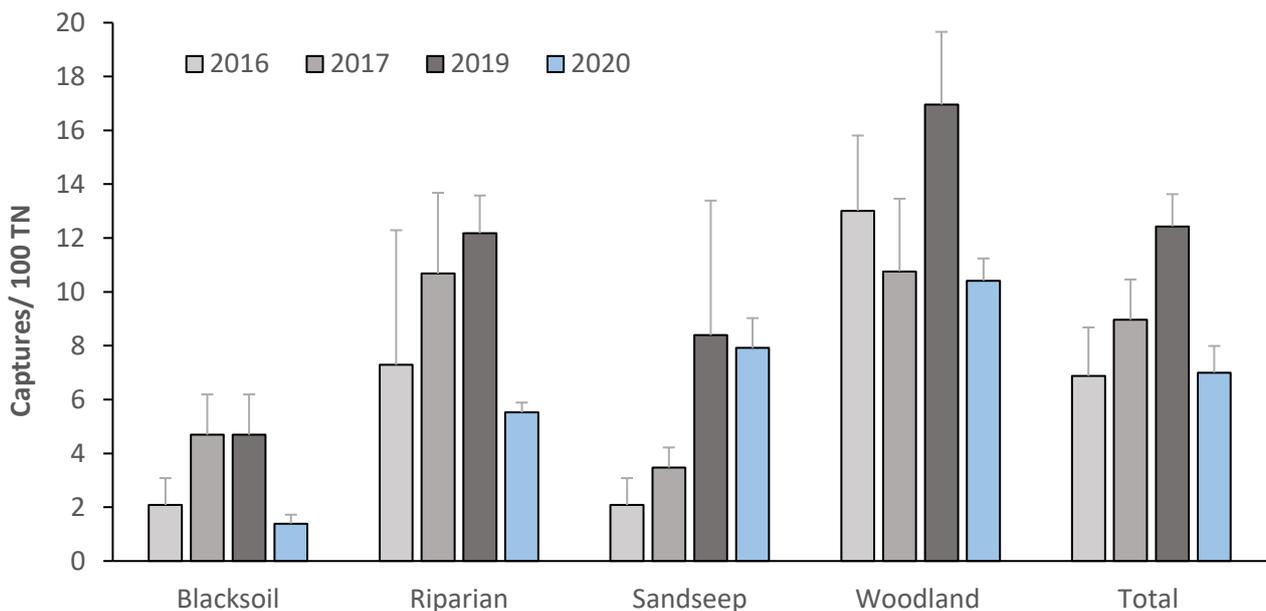


Figure 14. Average abundance (captures/100 trap nights) of skinks and dragons, CRAR, 2016-20. Data from Standard Live Trapping sites, reported per habitat type, and overall. Error bars are \pm SE.

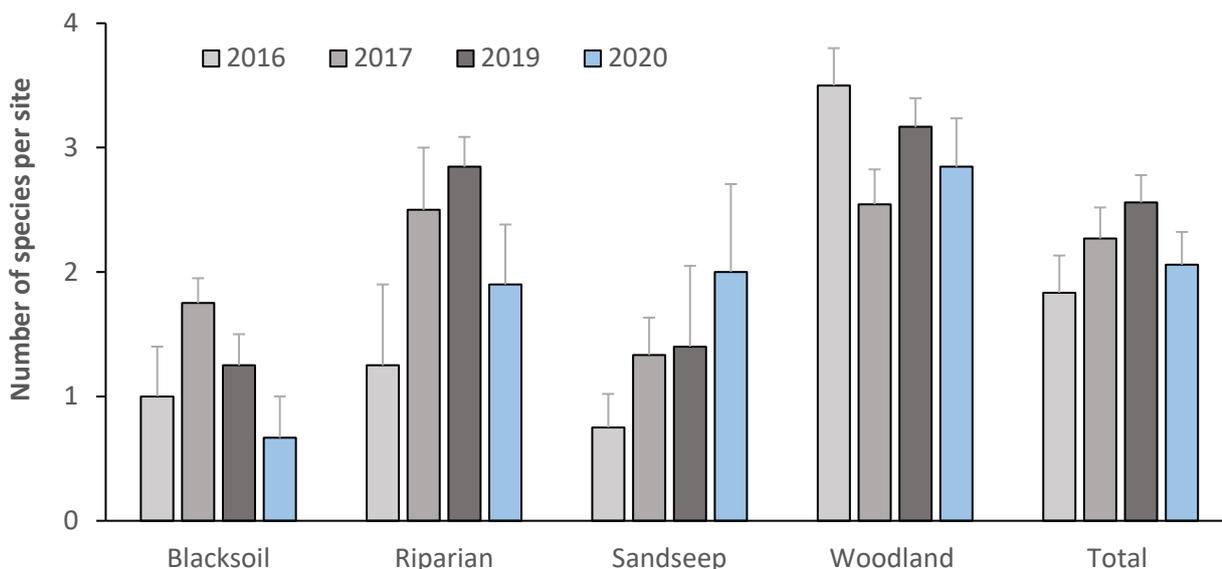


Figure 15. Mean species richness for skinks and dragons CRAR, 2016-20. Data from Standard Live Trapping sites, reported per habitat type, and overall. Error bars are ± SE.

Gecko and pygopod guild

Very few geckoes and pygopods were captured in 2020 (10 in total), a similar result to 2019. Nonetheless, we have presented abundance and richness data in Figure 16, suggesting that woodland habitat may comprise higher gecko and pygopod richness and abundance compared to other strata in Standard Live Trapping sites.

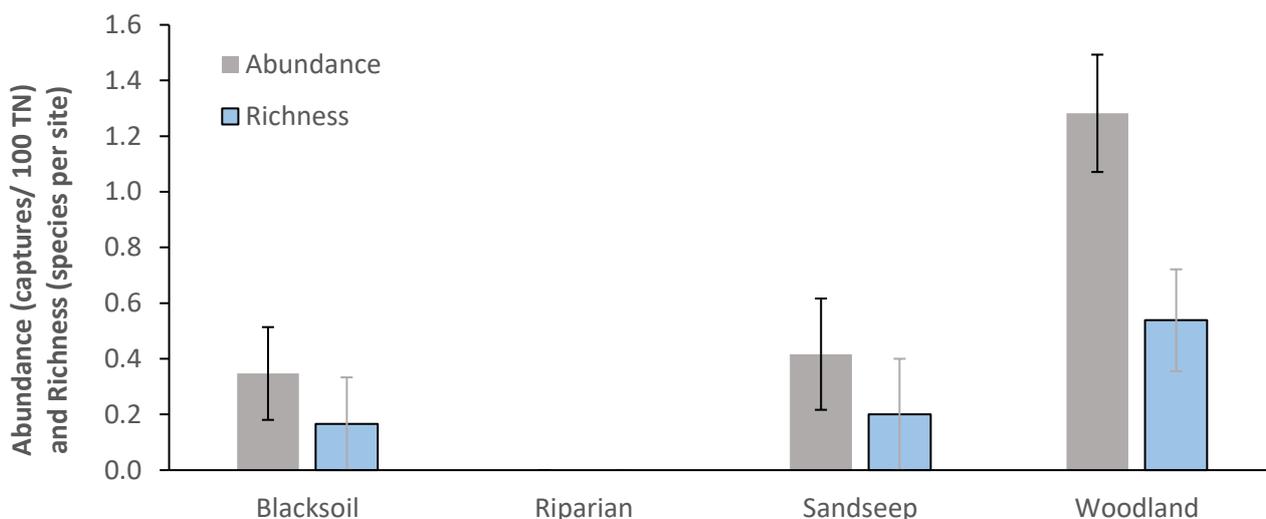


Figure 16. Mean richness and abundance for geckos and pygopods CRAR, 2016-20. Data from Standard Live Trapping sites, reported per habitat type. Error bars are ± SE.

Other reptiles

Large reptiles (varanids) guild

Varanids represent a diverse and important group of native predators and may face significant threat of decline from the introduced cane toad. There are at least 8 species of varanid found on CRAR; for the purposes of this report, the species have been categorised as follows: water monitors (Merten’s Water Monitor, *Varanus mertensi* and Mitchell’s Water Monitor, *Varanus mitchelli*), rock monitors (Black-palmed Rock Monitor, *Varanus glebo palma*, Kimberley Rock Monitor, *Varanus glauerti* and Spiny-tailed Monitor *Varanus acanthurus*), and the Yellow-spotted Monitor. The arboreal monitors Spotted Tree Monitor (*Varanus scalaris*) and Black-headed Monitor (*Varanus tristis*) are not adequately surveyed at this time. Unfortunately, no baseline surveys were established for varanid abundances or distributions before cane toads arrived in eastern Charnley, so measuring how varanid populations have responded to cane toad arrival in 2018-2019 is not possible. Nevertheless, it is imperative that varanids continue to be monitored for population changes into the foreseeable future as the potential impacts of cane toads flows through the ecological communities.

The Varanid Array survey was not undertaken in 2020, therefore metrics for the Yellow Spotted Monitor was calculated via the Rocky Area and Artesian SECR Camera Array surveys, in addition to the rock monitor guild assessed by these surveys. A total of 28 independent visits were recorded across the Rocky Area Camera sites in eastern Charnley, comprising 5 species (Table 8), including a Storr’s Monitor (*Varanus storri*) individual detected (not listed as an indicator) at Dingo Creek. Detections by the Rocky Area Camera Array suggest that Varanid species continue to persist in eastern Charnley despite the presence of cane toads. For the Artesian survey, a total of 133 independent visits were recorded, including visits by Storr’s Monitor (4), Black-headed Monitor/Spotted Tree Monitor (3), and Spotted Tree Monitor (3; species not listed as indicators). The rock monitor guild was detected at higher occupancy and abundance in the Artesian Range than eastern Charnley. The Yellow-spotted Monitor was detected in the Artesian (12 independent visits) but not on eastern Charnley (Table 8). It is likely that the eastern Charnley Rocky Area and Artesian Range surveys are ineffective in capturing the persistence of water monitors, which were readily detected on varanid cameras in 2019 (which may be redesigned in 2022).

Table 8. Varanid occupancy and abundance (‘independent’ visits per 100 trap nights) from 2020 camera surveys from 20 Rocky Area Camera Array sites (Charnley) and 8 Artesian SECR Camera Array sites on CRAR.

Varanid guild/species	Section	Occupancy (%)	Abundance
Rock monitors	Charnley	45	0.86
	Artesian	86	3.24
Yellow-spotted Monitor	Charnley	0	0
	Artesian	75	0.36

Birds

Birds general

Savanna bird guild

A total of 1,698 birds from 72 species were recorded during the 2020 surveys. On average, 48.5 individuals and 11.8 species were observed per site, with numbers varying considerably between surveys, sites and habitat (Figure 17).

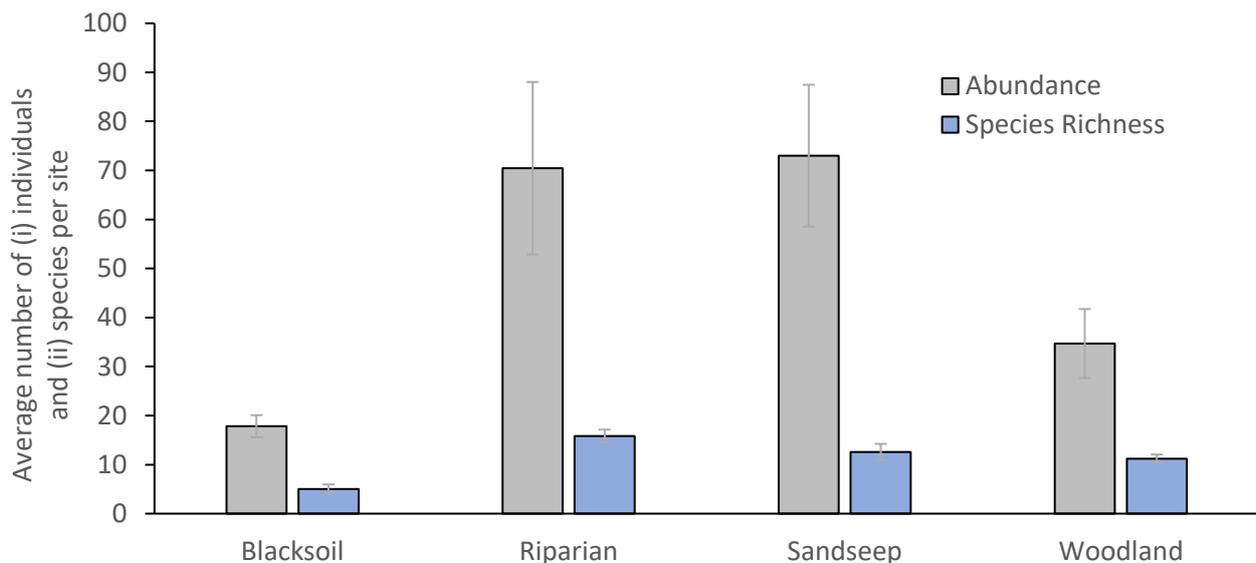


Figure 17. Average number of individuals and species per site observed in 2-ha 20 minute Diurnal Bird Surveys on eastern Charnley in 2020 across four habitats. Error bars represent ± SEM.

Note that several large flocks (>20 individuals) were recorded during some surveys, with the highest being 200 Masked Woodswallow (*Artamus personatus*) observed at a Riparian site. These large flocks in part contributed to the higher average abundance in 2020 than 2019, with all four habitat classifications having approximately double the bird abundance of 2019 (Table 9). Greater bird diversity across the four habitat classes was also

recorded in 2020 compared to 2019 (Table 9). Similar to 2019, Riparian and Sandseep sites had the highest average abundance and species richness observed per site (Figure 17), as these sites generally support more fruiting and flowering plant species.

Table 9. Average site abundance and species richness for Diurnal Bird Surveys on eastern Charnley in 2020 and 2019 across four habitats.

Metric	Year	Blacksoil	Riparian	Sandseep	Woodland
Average no. individuals per site	2020	17.8	70.5	73.0	34.7
	2019	8.8	30.0	29.6	17.9
Average no. species per site	2020	5.0	15.8	12.6	11.2
	2019	3.8	11.6	10.3	8.4

Buff-sided Robin

No Buff-sided Robins were detected in targeted playback surveys in 2020, though the species has previously been recorded at the Maurice Creek site and Charnley Homestead.

Purple-crowned Fairywren

No Purple-crowned Fairywrens were detected in 2020 targeted playback surveys. This species has not been recorded on CRAR since acquisition by AWC, but the species may have historically occurred on the sanctuary and may return following successful restoration of Plain Creek and Oombient Creek. There are records of the Purple-crowned Fairywren on the Isdell and Sprigg Rivers not far from the CRAR boundary.

Black Grasswrens

Black Grasswrens have been recorded from many parts of the Artesian Range, but not on other parts of CRAR. It is predicted that this species is likely to occur across rugged landscapes where abundant vegetation cover is available. Both targeted playback surveys and camera trapping arrays will be used to monitor Black Grasswren populations, however, the former was not conducted during the reporting period. The 2020 Artesian SECR Camera Array survey detected 8 independent visits of Black Grasswrens (abundance = 0.24 individuals per 100 TN) across 3 sites (occupancy = 38%).

Granivorous birds

Gouldian Finch

A total of 24 Gouldian Finches were detected at 2 of the 37 waterhole surveys/sites at Kaangalmun (Figure 2), (occupancy = 4%, abundance = 0.65 individuals per 100 TN), compared to 68 birds observed at 4 out of 23 waterhole sites in 2019 (which involved several different waterhole sites, occupancy = 17%, abundance = 2.96 individuals per 100 TN).

Brown Quail

A total of 12 Brown Quails were detected at 3 of the 37 waterhole surveys/sites (occupancy = 8%, abundance = 0.32 individuals per 100 TN), compared to 15 observed at 2 out of 23 waterhole sites in 2019 (which involved several different waterhole sites, occupancy = 9%, abundance = 0.65 individuals per 100 TN).

Vegetation

Vegetation and habitat structure

The metrics presented in Table 10 are from the 2019 and 2020 vegetation structure surveys conducted on Charnley. Not surprisingly, vegetation and structural variables vary considerably across habitats – variation which is likely to influence faunal composition, richness, and abundance. For example, Sandseep on CRAR has greater amounts of woody debris and the highest proportion of canopy, ground cover, and leaf litter cover than the other three habitats (Riparian, Blacksoil and Woodland). Overall, vegetation metrics remain largely unchanged at eastern Charnley Standard Live Trapping sites between 2019 and 2020 surveys.

Table 10. Vegetation and habitat structure metrics for Charnley in 2019 and 2020. Ground cover is a combination of leaf litter, vegetation ground cover and elevated dead debris.

Habitat type	Year	Leaf litter cover %	Vegetation ground cover %	Ground cover % (<140 cm)	Canopy/tree cover % (>140 cm)	Woody debris (records per 100 m)
Blacksoil	2020	25	58	83	0	0.0
	2019	9	75	85	2	0.0
Riparian	2020	32	56	88	42	2.7
	2019	27	59	87	37	3.1
Sandseep	2020	38	50	88	50	5.1
	2019	44	46	91	48	4.3
Woodland	2020	29	47	76	35	2.3
	2019	35	40	75	34	2.3
All Sites	2020	30	52	83	33	2.4
	2019	31	51	83	33	2.6

Threats

Feral Cats

Feral cats have rarely been detected historically in the Artesian Range and other topographically complex areas of Charnley-Artesian (Hohnen et al. 2016), and although they are essentially ubiquitous across eastern Charnley, are likely to vary considerably in density from one area to another. No Predator Arrays were undertaken in 2020, therefore, detections from the Rocky Area Camera Array and Artesian SECR Camera Array were reported here to indicate the presence and persistence of cats. No cats were detected by the 2020 Artesian camera arrays, whereas on Charnley, cats were detected across 15 of the 20 Rocky Area Camera Array sites in 2020 (75% occupancy) at varying abundance (Figure 18). A total of 55 visits were recorded (abundance 1.96 individuals per 100TN) across all sites in eastern Charnley.

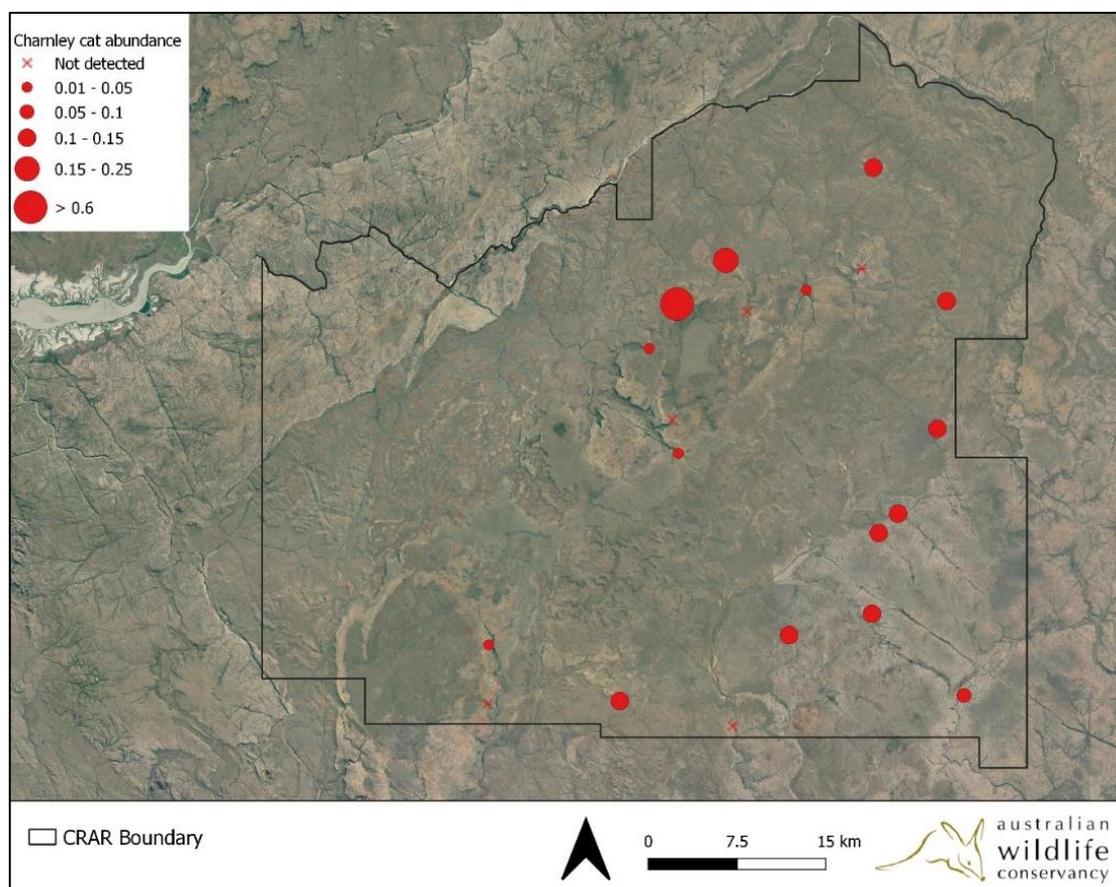


Figure 18. Abundance and distribution of cats based on the 2020 Artesian and Rocky Area Camera Arrays.

Feral herbivores

Large introduced herbivores such as cattle, horses and donkeys are distributed over northern Australia and cause major damage to ecosystems significantly altering biotic interactions (Woinarski and Ash 2002, Legge et al. 2011). At a landscape scale, feral herbivores have the ability to greatly reduce habitat availability, particularly in the ground layer (Legge et al. 2015), and interact with other major threatening processes, such as fire, to further effect biodiversity (Legge et al. 2019).

Cattle

During destocking operations, over 800 cattle were removed during mustering operations across eastern Charnley. Feral herbivore surveys (Figure 19) conducted after the mustering work observed a total of 243 cattle within the 45° angle observation area, an average density of 0.03 head/ha. Extrapolating from these data, the number of cattle on CRAR is estimated at over 8,000.

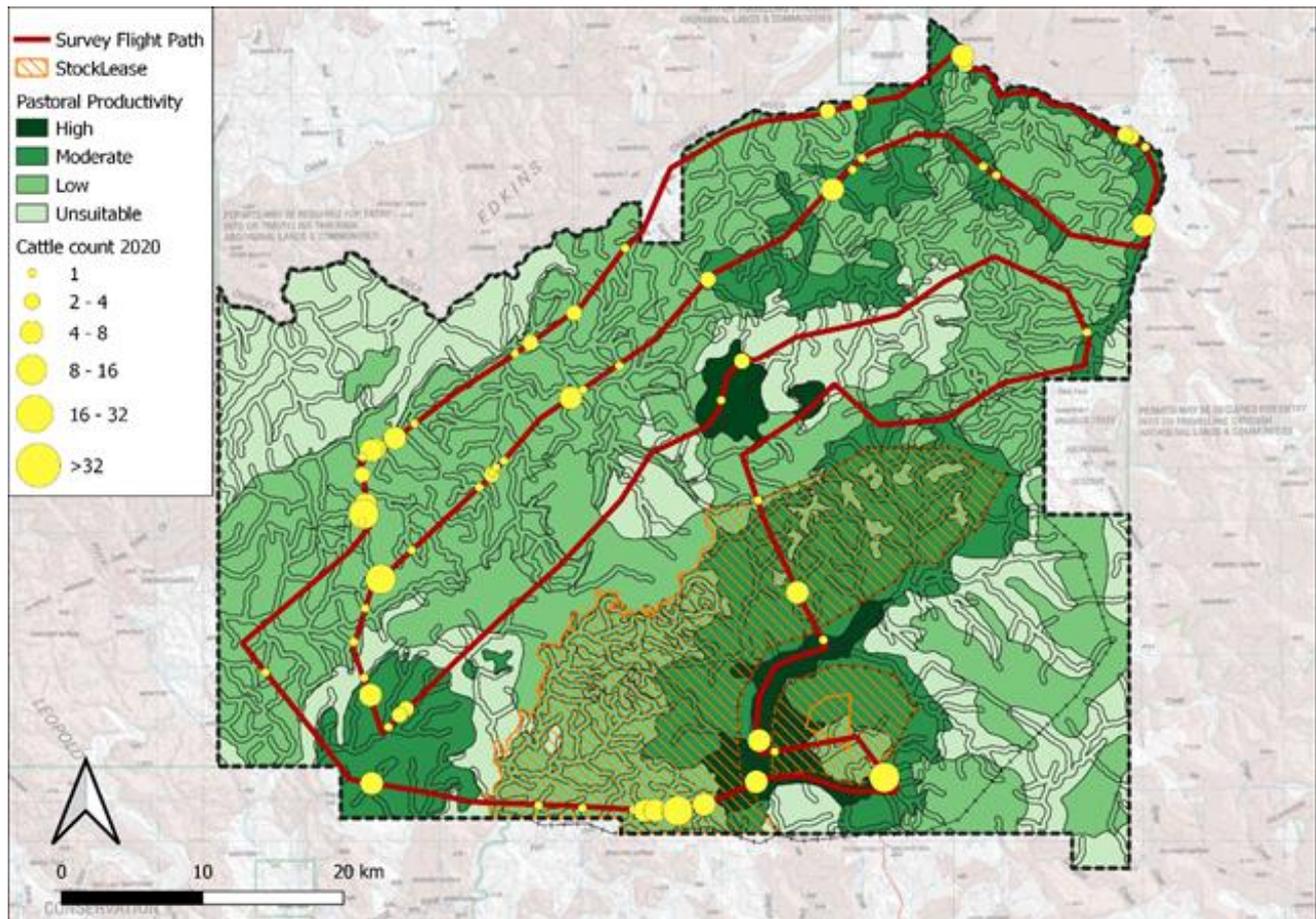


Figure 19. Map of the Feral Herbivore Aerial Survey transect (red) and coverage of various pasture qualities on Charnley River-Artesian Range with cattle data for the 2020 survey shown (yellow circles).

Horse and Donkey

No horses or donkeys were observed during feral herbivore aerial surveys.

Pigs

Feral pigs are a nationally significant environmental pest that threaten natural ecosystems by causing significant damage to wetland and riparian habitats (Commonwealth of Australia 2017). Feral pigs are currently expanding their range in the Kimberley (Smith et al. 2019) and, as such, have become a focus for management of effected habitats on CRAR. Historically, pigs have been abundant on CRAR around the Dead Horse Spring – Maurice Creek areas, and to a lesser extent the Plain creek – Donkey Yard region.

A total of 21 pigs were removed during targeted trapping around Charnley Homestead in 2020. Of the four trapping locations, two were successful at catching pigs (Donkey Pools and the Kill Pit). A further 18 pigs were removed during aerial shoots in November 2020. No pigs were observed during the feral herbivore aerial surveys. However, caution is required when interpreting these results, as pigs can be difficult to spot during aerial surveys.

Cane toads

Cane toads are known to pose a significant threat to populations of native carnivores, in particular to Northern Quolls, Yellow-spotted Monitors, Water Monitors, and large elapid snakes (Burnett 1997; Phillips et al. 2003; Griffiths and McKay 2007; Doody et al. 2009; Shine 2010 and references therein).

The advancing cane toad front has been tracked across the central Kimberley by AWC since 2015. Monitoring for cane toads on Charnley began in 2017, with the first detections from the dry season of 2018 in the north-east and south-east of Charnley. Since then, an extensive monitoring program involving camera arrays and spotlighting creeks has been conducted as part of a research program which was aimed at training Northern Quolls not to eat cane toads using the principle of Conditioned Taste Aversion (CTA) (Wilson et al. 2020). During the 2018-19 wet season, cane toads moved through central Charnley to Grevillea Gorge and down the upper Synnot Valley. As of February 2020, the toad front appeared to be at the base of the Artesian Range, with toads presumably moving through the southern Synnot Valley. They are now thought to be distributed across more than 90% of CRAR. Both cane toads and Northern Quolls were monitored during the 2019-2020 wet season, and into the 2020-21 wet season.

Data from the 2020 (July-August) Rocky Area Camera Array provides further evidence for the establishment of the Cane Toad in eastern Charnley, showing detections across 9 of the 20 sites (45% occupancy), with 5.61 independent visits per 100 trap nights. Conversely, data from the Artesian camera survey (December-January 2020) showed an absence of the Cane Toads at all sites, consistent with the view that the toad front was at the base of the Artesian Range (as of February 2020). Continued monitoring will be crucial to track their spread into the Artesian Range.

Weeds

Grader grass

Grader grass is the most significant weed threat for CRAR. Grader grass infestations were commonly observed along roads and fence lines in eastern Charnley, however, this year's first targeted aerial survey indicates the weed has become more widespread and pervasive with approximately one third of the (linear) area surveyed found to be infested with grader grass (Table 11; Figure 20), noting the survey was focused on known or likely areas of infestation.

In most areas surveyed, grader grass was restricted to the roadsides, with likely sources of spread being graders and vehicles. However, in several places that have seen heavy cattle densities, grader grass has moved off the roads and is now locally widespread. Furthermore, in some areas where the weed was historically noted at creek crossings, it was found to have spread along large sections of the creeks away from the roads. The outcomes of the aerial survey will inform future targeted control efforts.

Table 11. Grader grass infestation across Charnley by survey section in 2020.

Area	Distance surveyed (km)	Grader grass cover (km)	Percent infested (%)
Homestead to Grevillea gorge	33.77	12.13	35.92
4-way to Dillie Gorge	28.95	10.63	36.72
Roads to mud springs	40.57	14.42	35.54
Mud springs to lookout hill	33.06	12.84	38.84
Lookout hill to Kaangalmun Creek	24.10	2.08	8.63
Total	160.44	53.55	33.38

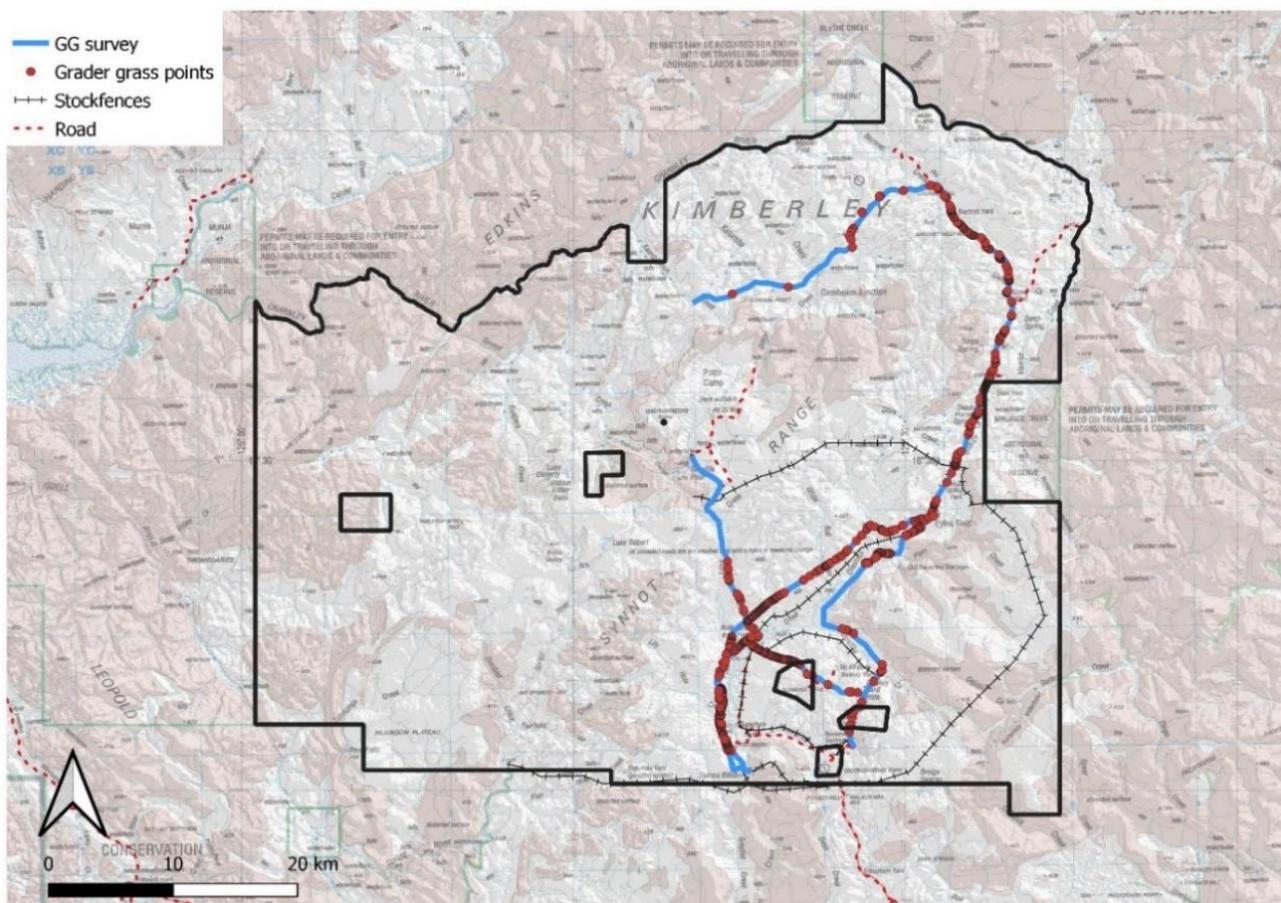


Figure 20. Map of the aerial grader grass survey along Charnley roads. Major roads shown in blue, with grader grass locations as red dots.

Fire

The 2019-2020 Kimberley wet season was slightly below average but brought considerably higher rainfall than the previous 2018-2019 ‘failed wet’. In 2020, 14.7% of CRAR was burnt by prescribed early dry season burns in 2020, compared with 17.6% in 2019 and the average of 21.6% under AWC management. In 2020, 15.7% of CRAR was burnt by late dry season wildfires, an increase on 2019 levels (3.8%), but still greatly below the baseline average of 45.3%. Additional metrics showing the outcomes of 2020 fire management are presented in Table 12: all metrics have improved since AWC management, compared with the baseline. A map of 2020 fire scars is presented in Figure 21.

Table 12. Metrics and outcomes of 2020 fire management on CRAR. Baseline 2000-07; AWC 2008/10-2020

Metric	Baseline (average)	AWC management (average)	2020 result	Change since AWC management
Area burnt by early dry season burns (% of property)	11	21.6	14.7	↑
Area burnt by late dry season wildfire (% of property)	45.3	17.3	15.7	↓
Extent of vegetation not burnt for 3+ years (% of property)	2.9	14.5	21.0	↑
Extent of vegetation unburnt by late dry season fire for 3+ years (% of property)	12.4	54.4	65.5	↑
Mean distance to unburnt vegetation (km)	2.4	1.1	0.8	↓
Mean distance to vegetation unburnt for 3+ years (km)	6.3	1.7	1.3	↓
Mean distance to vegetation unburnt by late dry season fire for 3+ years (km)	5.3	1.2	0.9	↓

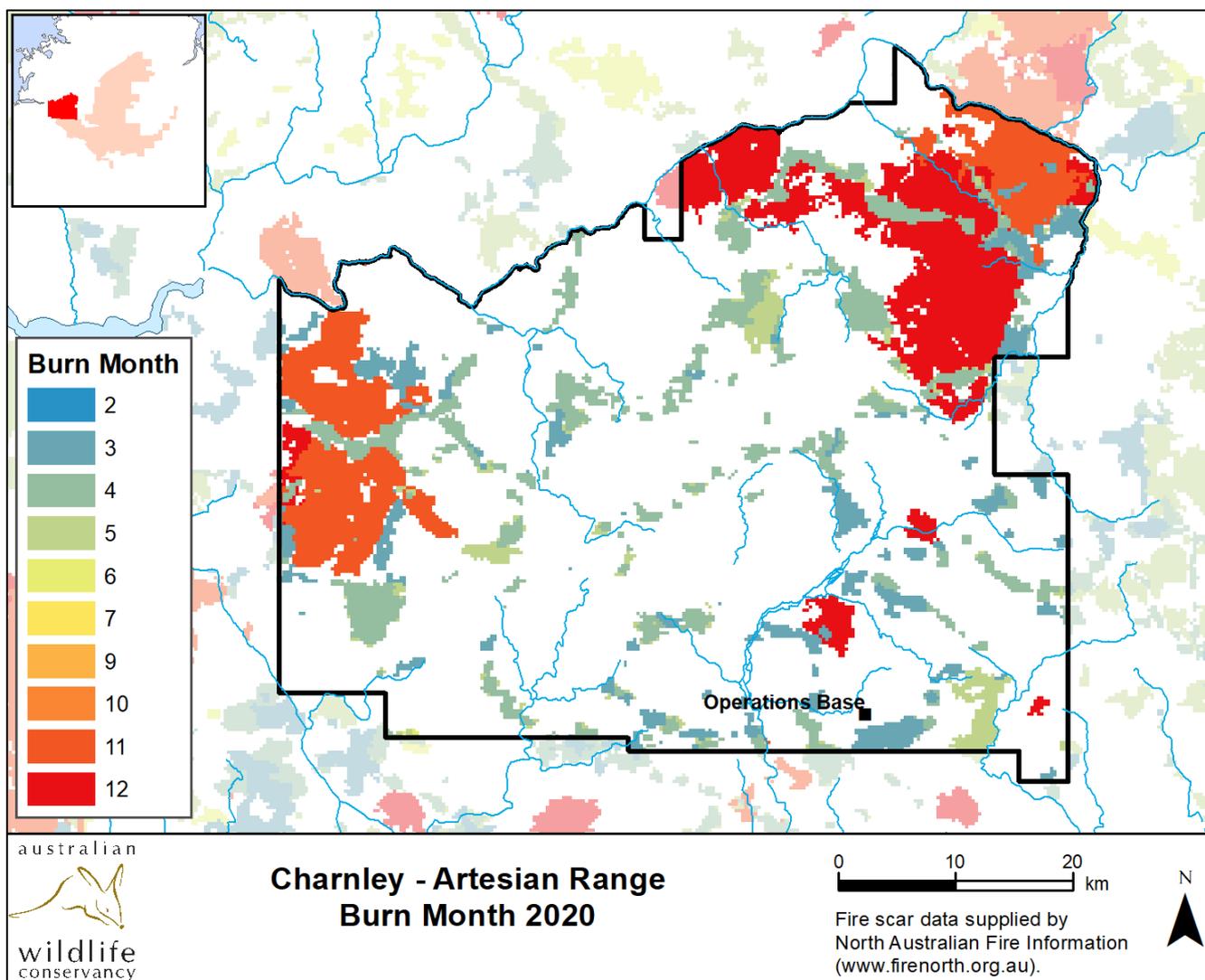


Figure 21. Map of the fire scars by month on CRAR in 2020.

Discussion

This Ecohealth Report is the result of a considerable survey effort (involving 4,080 live-trap nights, 68 bird surveys, 34 vegetation surveys, 6,700 camera trap nights, 573 km of aerial surveys, and several targeted spotlight and observational surveys), undertaken despite the restrictions of COVID-19 and an early onset of the 2020-21 wet season.

Two years of below-average rainfall, including one of the driest wet seasons on record in 2018-19, likely influenced survey results in 2020. The overall abundance of small-medium mammals in live-trapping surveys in 2019 and 2020 was well below levels recorded in 2016-2017; the overall abundance of skinks and dragons was also lower in 2020 than previous levels. Conversely, more individuals of one small mammal species, the Long-tailed Planigale, were trapped in 2020 than in previous years, and the abundance of many small-medium mammals living in rocky habitats, particularly rodents and macropods, increased substantially from 2019 to 2020.

The results of this survey show that Artesian Range continues to be a stronghold for Kimberley endemics and mammals that have declined elsewhere in their range including the Monjon, Kimberley Rock-rat, Golden-backed Tree-Rat, Wyulda, Northern Brown/Golden Bandicoot and Northern Quoll. However, with the cane toad invading the Artesian Range, the persistence of the Northern Quoll is potentially threatened, given its demonstrated vulnerability to cane toads elsewhere in its range. In 2020, the Northern Quoll continued to be detected across all surveyed sites in the Artesian Range, at similar abundance to the 2019 survey. In eastern Charnley, however, invaded earlier by the cane toad, the Northern Quoll was recorded at lower abundance in

2020 than in 2019. Nevertheless, populations of the Northern Quoll are persisting in refugia on Charnley including the Synnot Range and Munboon Escarpments.

Fire regimes have improved markedly on CRAR since AWC management, and this has likely had a positive impact on native flora and fauna. Concurrent management of cattle is also expected to benefit small mammals and other ground-dwelling species susceptible to predation by feral cats (Legge et al. 2019). Surveys conducted in 2020 showed that grader grass is a significant threat to native vegetation and presumably fauna at CRAR; this weed will require coordinated management over several years to contain its spread.

Acknowledgments

AWC acknowledges the Ngarinyin People, the Traditional Custodians, of Wilinggin Country on which Charnley River – Artesian Sanctuary resides. We also acknowledge their continuing connection to land, culture and community. We pay our respects to Ngarinyin Elders past present and emerging.

Enormous thanks to the Charnley-Artesian Sanctuary land management officers for facilitating the 2020 surveys and special thanks are also owed to our 2020 field team (including staff and volunteers) for their many hours in the field and at the computer tagging photos and cleaning data.

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