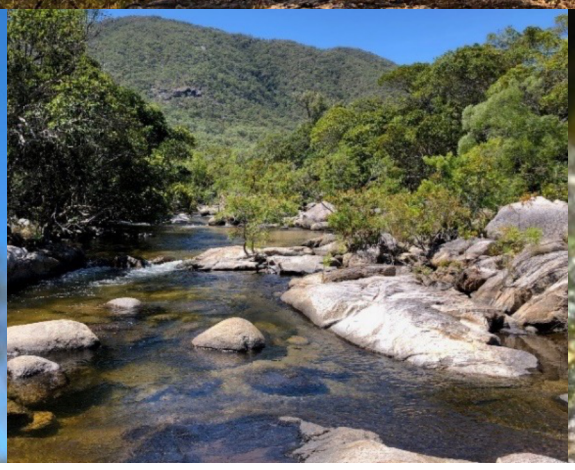
Brooklyn Wildlife Sanctuary

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 Brooklyn Wildlife Sanctuary. Metrics from the program are reported in annual Ecohealth Reports and Scorecards. This is the Ecohealth Report for 2020.

Values of metrics derived in this report were based on data collected during surveys carried out in 2020 and in early 2021: a Standard Trapping Survey, Standard Camera Survey, a Stream-dwelling Frog Survey, and a Fire Scar Analysis. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In September 2020, the Standard Trapping and Standard Camera Surveys were undertaken across a new suite of monitoring sites in the Brooklyn lowlands, comprising live trapping (40 sites) and camera trapping (42 sites).

Overall species richness of small mammals was very low; no sites had more than one native small mammal species present. Trapping detected small mammals on only 25% of sites. The average abundance of small mammals across the 40 sites was 0.41 ± 0.14 individuals per 100 trap nights. The generally low species richness and abundance of small mammals in savanna habitats on Brooklyn is consistent with historically-collected data, and may further be related to the substantially lower rainfall in 2020 (568 mm) compared to the median of 964 mm (since 1989). Future surveys at these sites will clarify trends in abundance and occupancy, as well as the influence of AWC management activities and extrinsic factors such as rainfall. In contrast to the small mammal fauna, trapping detected small-medium reptiles at 95% of sites. Average species richness was 4.18 ± 0.36 reptile species per site. The average abundance of small-medium reptiles was 11.40 ± 1.21 per 100 trap nights across the 40 sites.

There was low activity of native medium-sized mammals across the 42 camera trap sites. Medium-sized mammals were detected at just 26.2% of sites, at an average species richness of 0.36 ± 0.10 species per site.

Between December 2020 and February 2021, a targeted survey of stream-dwelling frogs was undertaken. Mean frog abundance across 10 transects was 37 ± 10.52 individuals per transect, and average species richness was 3.20 ± 0.44 species per transect. Three threatened frog species detected in 2014 were re-detected in 2020; the Endangered Torrent Tree Frog (*Litoria nannotis*), the Vulnerable Serrated-armed Tree Frog (*Litoria serrata*), and the Endangered Common Mist Frog (*Litoria rheocola*; all listed under the State *Nature Conservation Act 1992*). More individual frogs were recorded in 2021 than in 2014, although species richness was lower; 6 species recorded in 2014 were not detected in 2021. There was higher rainfall prior to the 2021 survey than in 2014, which may have affected frog activity at lower-elevation transects and contributed to the lower species richness recorded in 2021.

Feral animals are well established at Brooklyn. Feral cats (*Felis catus*) and pigs (*Sus scrofa*) were each detected at 17% of the 42 camera trap sites, while feral cattle (*Bos taurus*) were recorded at 14% of sites. Cane toads (*Rhinella marina*) were detected at 23% of the 40 live trapping sites. Future Ecohealth surveys will clarify the patterns of abundance and distribution of these introduced species and will inform future AWC management.

The 2020 fire metrics indicate that AWC fire management on Brooklyn has resulted in improvements that will likely benefit native species and ecosystems. Since acquisition by AWC, the average extent of early dry season fire has increased, while the extent of late dry season fire and the distance to unburnt vegetation has decreased.

Contents

Document citation: Hayes C, Howe A, Watson A, Wauchope M, Joseph L, Kanowski J (2021) *Brooklyn Wildlife Sanctuary Ecohealth Report 2020*. Australian Wildlife Conservancy, Perth, WA.

Cover photograph: Clockwise from top: the Brooklyn lowlands (AWC/Catherine Hayes); Common Mist Frog (*Litoria rheocola*) (AWC/Andrew Howe); a creek line surveyed for stream-dwelling frogs (AWC/Catherine Hayes); a Gulf Two-lined Dragon *Diporiphora carpentariensis* (AWC/Andrew Howe).

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 (Ecohealth Monitoring Program) 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 (under development) 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.

This document, the Brooklyn Ecohealth Report 2020, draws on surveys conducted during 2020 and early 2021 to calculate values for metrics that track the status and trend of the Ecohealth indicators. Where data were available, some metrics reported in the Ecohealth Scorecard were calculated based on surveys prior to 2020 (Kemp et al. 2015a, 2015b; Mulder et al. 2017; Howe 2018; Kemp and Kutt 2020). The companion Brooklyn Ecohealth Scorecard 2020 presents the metrics in a summary format.

Brooklyn Wildlife Sanctuary

Brooklyn Wildlife Sanctuary is a 59,964 ha property in north-east Queensland, Australia (Figure 1), and is within the traditional lands of the Djungan people. The property has exceptional biodiversity values. It runs from the summit of Mt Lewis, a major refugium for rainforest biota in the Australian Wet Tropics, through areas of wet sclerophyll forest on the slopes of the Carbine Tableland, to extensive areas of savanna woodlands in the lowlands (Figure 2). Brooklyn contains isolated granite boulder outcrops, such as Mount Alto and Lighthouse Mountain. Brooklyn's location in relation to a centre of evolutionary significance, combined with its topographical and climatic variation, means that it supports a high diversity of plant and animal species including many threatened and regionally endemic taxa. All the montane rainforest and most of the wet sclerophyll forest on Brooklyn are included in the Wet Tropics World Heritage Area.

A total of 510 native terrestrial vertebrate species have now been confirmed on Brooklyn (34 frogs, 313 birds, 70 mammals and 93 reptiles), as well as 16 species of fish. Another 64 species of vertebrates are considered 'likely' or 'very likely' to occur on Brooklyn. Of the terrestrial vertebrates known to occur on Brooklyn, 20 species are listed as threatened under Commonwealth and/ or Queensland legislation (7 frogs, 7 birds, 4 mammals and 2 reptiles).

The total number of native vascular plants confirmed on Brooklyn is 1,446 species. Many species have highly restricted distributions; for example, all of the known locations of the recently-described species *Styphelia geniculata* are on Brooklyn (Crayn et al. 2019). There are 22 plants listed as threatened under Commonwealth and/ or Queensland legislation on Brooklyn, and 17 'Of Concern' Vegetation Management Classes under Queensland legislation. Five Regional Ecosystems have 'Endangered' Biodiversity Status and 22 'Of Concern' Biodiversity Status in Queensland.

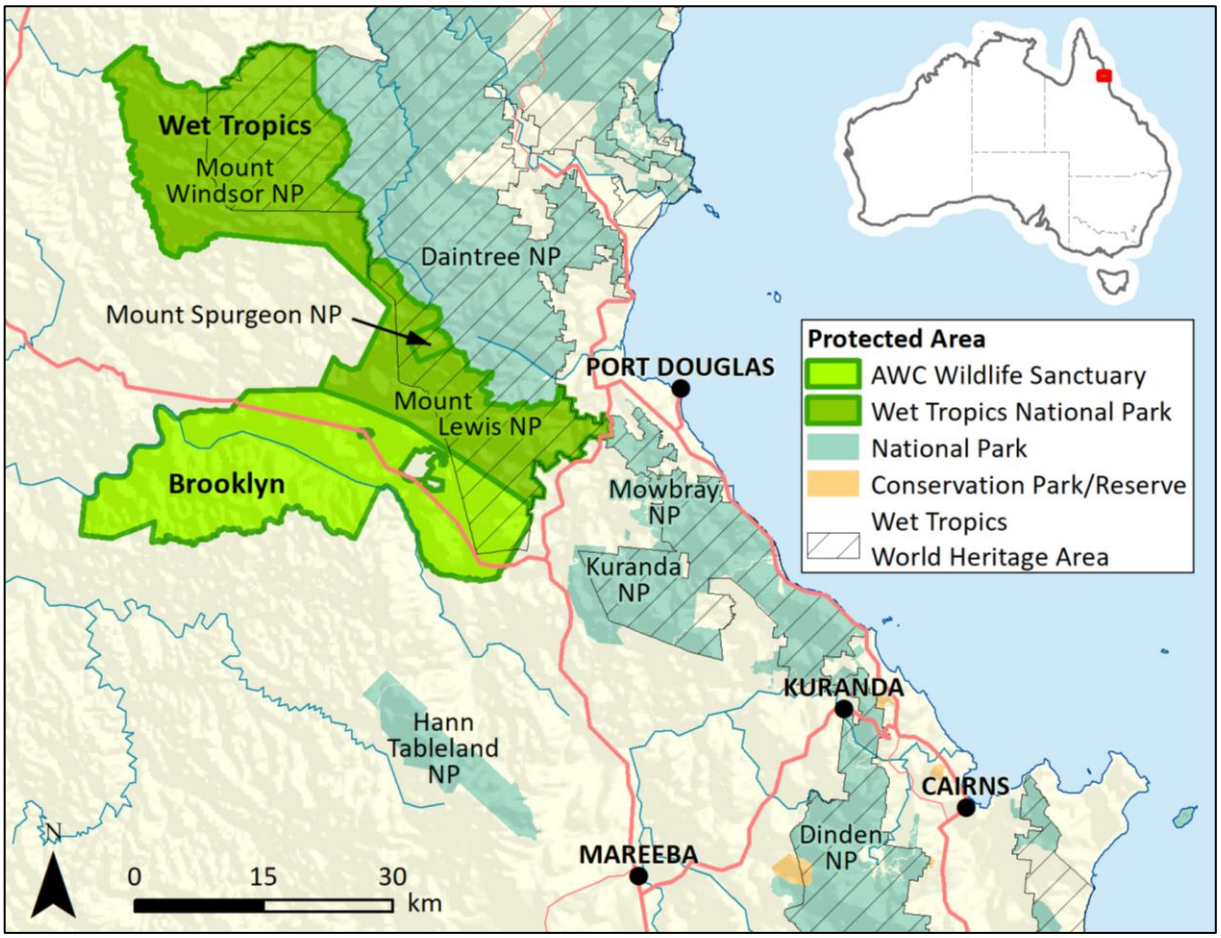


Figure 1. Location of Brooklyn Wildlife Sanctuary

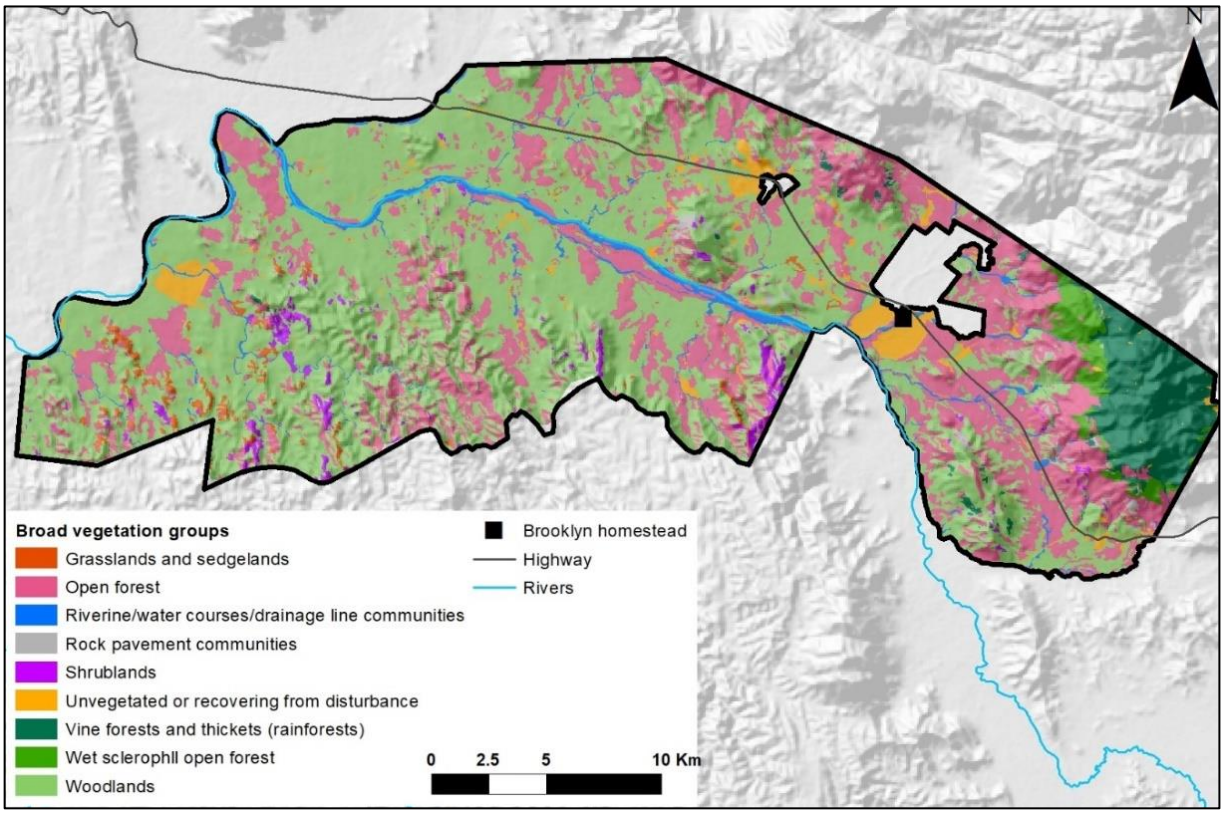


Figure 2. Broad vegetation groups on Brooklyn

Acquisition and management of Brooklyn by AWC

Brooklyn was purchased by AWC in 2004. Prior to its acquisition, the property was heavily grazed by ~3,000 cattle (AWC unpublished data; Kemp and Kutt 2020). A destocking program has been in place since 2005. Mustering and feral control operations are undertaken annually. Feral horses and pigs are also targeted in regular control operations. Brooklyn was also subject to mining activities, which are ongoing in the surrounding area. The history of grazing and mining on Brooklyn has caused substantial challenges posed by the spread of invasive weeds, in particular shrubby stylo (*Stylosanthes scabra*) and grader grass (*Themeda quadrivalvis*; Kemp and Kutt 2020). A major highway into Cape York, the Mulligan Highway, runs through Brooklyn. The high traffic flow through Brooklyn creates further challenges for Sanctuary Managers including arson attacks, trespassers, and squatters.

Fire is a key management tool used by AWC on Brooklyn, with the overall aim of re-establishing ecologically appropriate fire regimes to promote the conservation of species, ecological communities and ecosystem processes (Cooper et al. 2020). Logging has occurred on Brooklyn historically. The suppression of fire over many decades during its history of cattle grazing and logging has affected both the upland and lowland areas of the sanctuary. The wet sclerophyll forest is now being encroached by rainforest species and *Allocasuarina spp.*, as well as invasion by lantana (*Lantana camara*; Stanton and Blackman 2009; Kemp et al. 2015c). Invasion by rubber vine (*Cryptostegia grandiflora*) has occurred on the alluvial flats (Stanton and Blackman 2009). In response to these challenges, specific aims of AWC's fire management program are to:

- protect fire-sensitive vegetation such as rainforest from fire;
- implement a fine-scale mosaic of burnt and unburnt vegetation and a range of ages since fire in the eucalypt forests and woodlands; and
- restore a regular fire regime in wet sclerophyll forest to maintain structure and composition (Cooper et al. 2020).

AWC's fire management program has successfully reduced the incidence of high intensity fire in the savanna woodlands (Stanton and Blackman 2009; Cooper et al. 2020).

Climate and weather summary

The high species and ecosystem diversity on Brooklyn reflects a broad range of topography and a steep rainfall gradient across the sanctuary. In the east, Brooklyn includes mountain rainforests of the Wet Tropics Bioregion, rising to an elevation of 1,140 m with an average rainfall of over 4,000 mm. To the west, the extensive low rugged metamorphic hills of the Einasleigh Uplands Bioregion support mostly low open grassy woodlands. The far western edge of Brooklyn has an elevation of around 300 m, with an annual rainfall of around 600 mm.

Since 1989, the median rainfall at Mount Carbine (approximately in the centre of Brooklyn) was 964 mm (Bureau of Meteorology 2021; weather station number 031180). In 2020, rainfall was substantially below the median, with only 568 mm recorded (Figure 3). Although January and May received higher than median rainfall, the start of the 2019-2020 wet season was much drier than usual in November (0 mm in 2020; median of 31 mm) and December (30 mm in 2020; median of 122 mm).

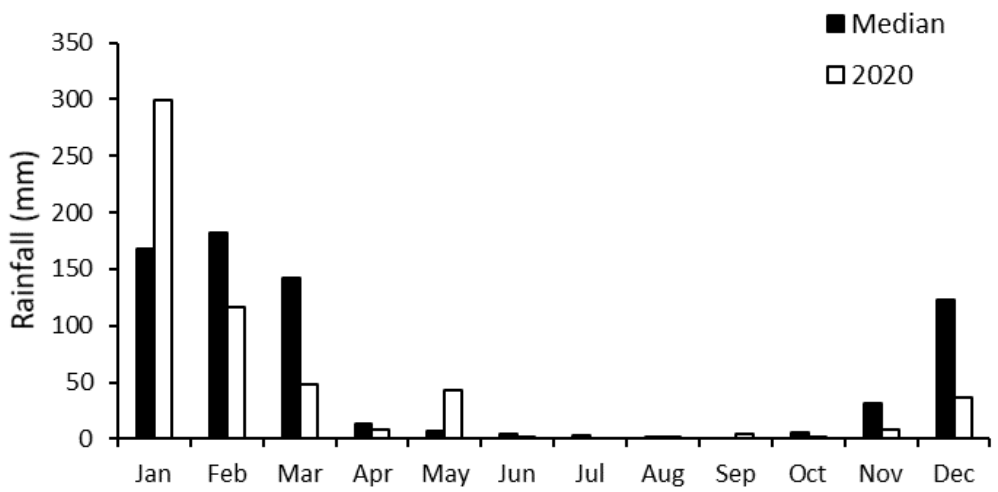


Figure 3. 2020 monthly total rainfall and median rainfall (1989-2020) at Mount Carbine (source: Bureau of Meteorology 2021; weather station number 031180)

Temperature data were taken from the Mareeba Airport for 2020 (weather station number 031210), and from the Mareeba QWRC Station (number 031066) for baseline data between 1952 to 1992 (Figure 4). Mareeba is approximately 60 km south-east of Brooklyn. During the Standard Trapping Survey in September 2020, the mean maximum temperature was exactly the same as the historical mean maximum (28.1 °C). However, the mean minimum temperature - 16.7 °C – was higher than the historical mean of 13.5 °C. Overall, the mean maximum temperature in 2020 (29.5 °C) was slightly hotter than the historical mean (29.0 °C), while the mean minimum temperature in 2020 was nearly two degrees warmer than the historical mean minimum; 18.5 °C and 16.6 °C respectively (Bureau of Meteorology 2021).

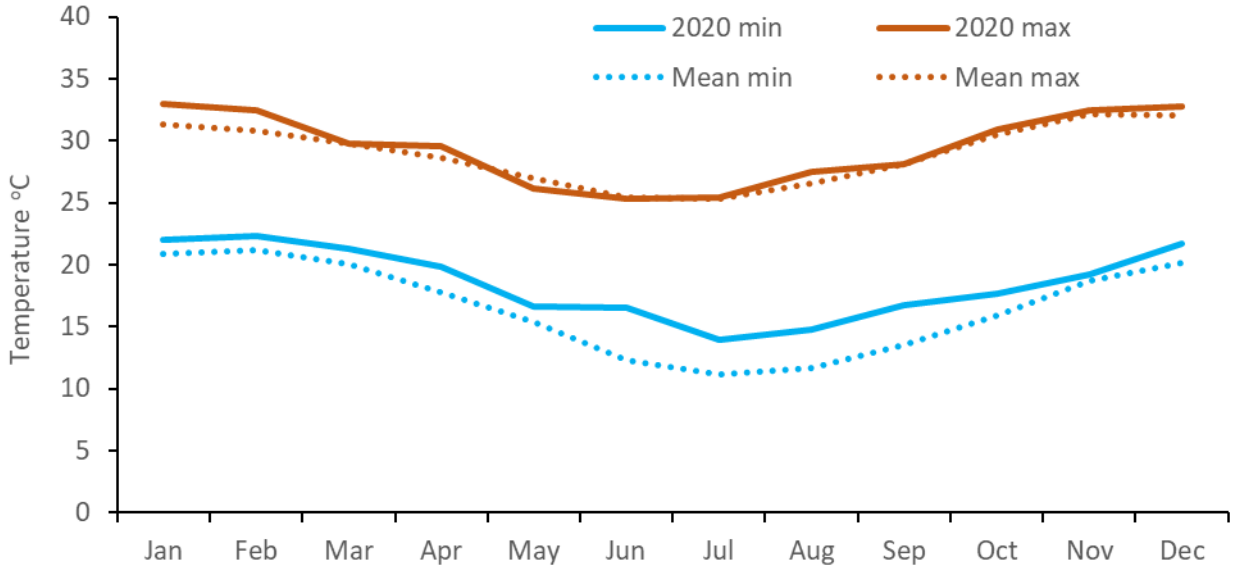


Figure 4. 2020 and mean maximum and minimum temperatures (source: Bureau of Meteorology, data from Mareeba Airport for 2020 (weather station number 031210) and Mareeba QWRC Station for 1952-1992 (weather station number 031066))

Methods

Indicators and metrics

Brooklyn'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). On Brooklyn, 71 biodiversity (species and guilds) indicators have been selected for monitoring (Table 1). Twenty-six of these indicators were reported on in 2020. Threat metrics are selected to ensure monitoring the status and trends of introduced weeds, predators and herbivores and inappropriate fire regimes (where relevant). Fifteen threat indicators have been selected for monitoring (Table 2). In 2020, six of these threat metrics were reported on. In future years, reporting for key weed species will be added.

Table 1. Biodiversity indicators and metrics for the Ecohealth Monitoring Program for 2020.
Rationale for selection: T = threatened or declining; D = strong driver of ecosystem function; S = surveillance monitoring.
Metric definitions for fauna indicators: abundance = average number of detections per 100 live trap or camera trap nights ('TN') across all sites, or average abundance per site or transect; occupancy = percentage of sites where species or guild recorded; richness = average number of species per site; population estimate = estimated number of individuals on sanctuary.

Indicator	Rationale			Survey type	Metric/s
	T	D	S		
Mammals					
Small-medium mammals					
Northern Quoll *Dasyurus hallucatus* (upland)	*	*		Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Northern Quoll (lowland)	*	*		Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Spotted-tailed Quoll *Dasyurus maculatus gracilis*	*	*		Targeted Survey	Abundance (per 100 TN), Occupancy
Black-footed Tree-rat *Mesembriomys gouldii rattoides*	*			Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Giant White-tailed Rat *Uromys caudimaculatus*			*	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Upland *Rattus* species assemblage (Bush Rat *Rattus fuscipes* and Cape York Rat *Rattus leucopus*)			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy
Fawn-footed Melomys *Melomys cervinipes*			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy
Grassland Melomys *Melomys burtoni* (upland)			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy
Grassland Melomys (lowland)			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Northern Brown Bandicoot *Isoodon macrourus* (upland)		*	*	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Northern Brown Bandicoot (lowland)		*	*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Northern Long-nosed Bandicoot *Perameles nasuta*		*	*	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Musky Rat-kangaroo *Antechinus flavipes*			*	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Rusty Antechinus *Antechinus adustus*			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy

Indicator	Rationale			Survey type	Metric/s
	T	D	S		
Sminthopsis assemblage (Common Dunnart *Sminthopsis murina* and Chestnut Dunnart *Sminthopsis archeri*)			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Northern Short-tailed Mouse *Leggadina lakedownensis*			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Eastern Chestnut Mouse *Pseudomys gracilicaudatus*			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Common Rock-rat *Zyzomys argurus*			*	Targeted Survey	Abundance (per 100 TN), Occupancy
Rock-wallaby assemblage (Godman's Rock-wallaby *Petrogale godmani* and Mareeba Rock-wallaby *Petroage mareeba*)			*	Targeted Survey	Abundance (per 100 TN), Occupancy
Upland small mammal guild			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy, Richness
Upland medium mammal guild			*	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy, Richness
Lowland small mammal guild			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy, Richness
Lowland medium mammal guild			*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy, Richness
Arboreal mammals					
Common Brushtail Possum *Trichosurus vulpecula*			*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Upland possum and glider guild			*	Spotlighting Survey (upland)	Abundance (per transect), Occupancy, Richness
Lowland possum and glider guild			*	Spotlighting Survey (lowland)	Abundance (per transect), Occupancy, Richness
Large herbivores					
Agile Wallaby *Macropus agilis*		*	*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Eastern Grey Kangaroo *Macropus giganteus*		*	*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Lowland macropod guild		*	*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy, Richness
Large predatory mammals					
Dingo *Canis dingo* (upland)		*		Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Dingo (lowland)		*		Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Reptiles					
Small-medium reptiles					
Yakka Skink *Egernia rugosa*	*			Targeted Survey	Population estimate, Abundance (per site), Occupancy
Diporiphora species assemblage (*D. australis*, *D. carpentariensis*, *D. jugularis*, *D. nobbi*)			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Northern Leaf-tailed Gecko *Saltuarius cornutus*			*	Targeted Survey	Abundance (per site), Occupancy
Bynoe's Prickly Gecko *Heteronotia binoei*			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Carlia species assemblage (*C. jarnoldae*, *C. munda*, *C. pectoralis*, *C. rostralis*, *C. schmeltzii*, *C. storri*, *C. vivax*)			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Straight-browed Ctenotus, *Ctenotus spaldingi*			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Lygisaurus species assemblage (*L. aeratus*, *L. foliorum*, *L. malleolus*) (upland)			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy

Indicator	Rationale			Survey type	Metric/s
	T	D	S		
Lygisaurus species assemblage (Lowland)			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Upland small-medium reptile guild			*	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy, Richness
Lowland small-medium reptile guild			*	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy, Richness
Reptiles - other					
Black-headed Monitor *Varanus tristis*		*	*	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Birds					
Northern Masked Owl *Tyto novaehollandiae kimberli*	*			Targeted Survey	Abundance (per site), Occupancy
Blue-faced Parrot Finch *Erythrura trichroa*			*	Targeted Survey	Abundance (per site), Occupancy
Weebill *Smicrornis brevirostris*			*	Standard Bird Survey (lowland)	Abundance (per site), Occupancy
Grey-crowned Babbler *Pomatostomus temporalis*			*	Standard Bird Survey (lowland)	Abundance (per site), Occupancy
Peaceful Dove *Geopelia placida*			*	Standard Bird Survey (lowland)	Abundance (per site), Occupancy
Red-browed Finch *Neochmia temporalis*			*	Standard Bird Survey (lowland)	Abundance (per site), Occupancy
Bridled Honeyeater *Bolemoreus frenatus*			*	Standard Bird Survey (lowland)	Abundance (per site), Occupancy
Red-backed Fairy-wren *Malurus melanocephalus*			*	Standard Bird Survey (lowland)	Abundance (per site), Occupancy
Upland bird guild			*	Standard Bird Survey (lowland	Abundance (per site), Occupancy, Richness
Lowland savanna bird guild			*	Standard Bird Survey (lowland	Abundance (per site), Occupancy, Richness
Nocturnal bird guild			*	Targeted surveys	Abundance (per transect), Occupancy, Richness
Frogs					
Torrent Tree Frog *Litoria nannotis*	*			Stream-Dwelling Frog Survey	Abundance (per transect), Occupancy
Common Mist Frog *Litoria rheocola*	*			Stream-Dwelling Frog Survey	Abundance (per transect), Occupancy
Serrated-armed Tree Frog *Litoria serrata*	*			Stream-Dwelling Frog Survey	Abundance (per transect), Occupancy
Northern Dwarf Tree Frog *Litoria bicolor* (stream survey)			*	Stream-Dwelling Frog Survey	Abundance (per transect), Occupancy
Northern Dwarf Tree Frog (lowland)			*	Stream-Dwelling Frog Survey	Abundance (per transect), Occupancy
Stream-dwelling frog guild			*	Stream-Dwelling Frog Survey	Abundance (per transect), Occupancy, Richness
Lowland frog guild			*	Lowland Frog Survey	Abundance (per transect), Occupancy, Richness
Ecological process					
Woody debris			*	Standard Trapping Vegetation Survey	Cubic metres
Vegetation					
Ground cover			*	Standard Trapping Vegetation Survey	Percent cover, Average height
Shrub and tree cover			*	Flora Survey	Percent cover
Vegetation: structure and composition					
Kangaroo Grass *Themeda triandra*			*	Flora Survey	Percentage of native perennial grass cover
Giant Spear Grass *Heteropogon triticeus*			*	Flora Survey	Percentage of native perennial grass cover
Sorghum (native perennial Sarga and Sorghum species)			*	Flora Survey	Percentage of native perennial grass cover
Bluegrass (various species)			*	Flora Survey	Percentage of native perennial grass cover

Indicator	Rationale			Survey type	Metric/s
	T	D	S		
Wiregrass (various species)			*	Flora Survey	Percentage of native perennial grass cover
Shrubs			*	Flora Survey	Percent cover
Trees			*	Flora Survey	Basal area, Average height, Average diameter at breast height
Mistletoes			*	Flora Survey	Density (individuals/ ha)
Ground layer native disturbance indicators (native disturbance increaser - *Aristida spp*.)			*	Flora Survey	Percentage of native perennial grass cover
Ground layer native good health indicators (native disturbance decreasers combined - *Themeda triandra*, *Heteropogon triticeus*, native *Sorghum/ Sarga* spp., native *Bothriochloa* spp., native *Dichanthium* spp)			*	Flora Survey	Percentage of native perennial grass cover
Vegetation: threatened community					
Dry vine scrub extent	*			Targeted Vegetation Survey	Extent
Dry vine scrub condition	*			Targeted Vegetation Survey	Frequency of target ground layer plants, Abundance (per site) of target shrubs and trees
Wet sclerophyll shade intolerant grasses and shrubs	*			Targeted Vegetation Survey	Percent cover
Wet sclerophyll rainforest or casuarina encroachment	*			Targeted Vegetation Survey	Density (individuals/ ha) encroachment stems >50 cm tall, Density (individuals/ ha) encroachment trees > 10 cm diameter at breast height
Vegetation: threatened plants					
Macropteranthes montana (Antique Wood/ Bonewood)	*			Targeted Threatened Plant Survey	Population estimate
Ehretia microphylla (Fukien Tea Tree)	*			Targeted Threatened Plant Survey	Population estimate

Table 2. Threat indicators and metrics for the Ecohealth Monitoring Program for 2020.
Metric definitions for fauna indicators: abundance = average number of detections per 100 live trap or camera trap nights ('TN') across all sites; occupancy = percentage of sites where species detected; population estimate = estimated number of individuals on sanctuary.

Indicator	Rationale	Survey type	Metric/s
Cattle *Bos taurus*	Erosion, soil impaction, overgrazing, weed dispersal, reduction in ground cover, degradation of waterways	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Horses *Equus caballus*	Erosion, soil impaction, overgrazing, weed dispersal, reduction in ground cover, degradation of waterways	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Cats *Felis catus* (upland)	Major threat to wildlife	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy

Indicator	Rationale	Survey type	Metric/s
Cats (lowland)	Major threat to wildlife	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Pigs *Sus scrofa* (upland)	Erosion, soil impaction, weed dispersal, degradation of waterways	Standard Camera Survey (upland)	Abundance (per 100 TN), Occupancy
Pigs (lowland)	Erosion, soil impaction, weed dispersal, degradation of waterways	Standard Camera Survey (lowland)	Abundance (per 100 TN), Occupancy
Cane toad *Rhinella marina* (upland)	Major threat to wildlife	Standard Trapping Survey (upland)	Abundance (per 100 TN), Occupancy
Cane toad (lowland)	Major threat to wildlife	Standard Trapping Survey (lowland)	Abundance (per 100 TN), Occupancy
Weeds			
Targeted weeds	Threat to native vegetation and wildlife	Targeted Weed Survey	Frequency, Occupancy at surveyed sites
Targeted weeds in threatened dry vine scrub	Threat to native vegetation and wildlife	Targeted Vegetation Survey	Frequency at surveyed sites
Gamba grass (*Andropogon gayanus*)	Weed of National Significance, Threat to native vegetation and wildlife	Targeted Weed Survey	Number of infestations, Occupancy at known sites
Grader grass (*Themeda quadrivalvis*)	Threat to native vegetation and wildlife	Targeted Weed Survey	Occupancy at sites surveyed, % cover
Hymenachne (*Hymenachne amplexicaulis*)	Weed of National Significance, Threat to native vegetation and wildlife	Targeted Wetlands and Waterbody Survey	Extent of infestation, Frequency at occupied sites
Rubber vine (*Cryptostegia grandiflora*)	Weed of National Significance, Threat to native vegetation and wildlife	Targeted Weed Survey	Frequency, Occupancy at surveyed sites
Lantana (*Lantana camara*)	Weed of National Significance, Threat to native vegetation and wildlife	Targeted Weed Survey	Frequency, Occupancy at surveyed sites
Giant salvinia (*Salvinia molesta*)	Weed of National Significance, Threat to native vegetation and wildlife	Targeted Wetlands and Waterbody Survey	Occupancy at known sites and surveyed sites
Shrubby stylo (*Stylosanthes scabra*)	Threat to native vegetation and wildlife	Targeted Weed Survey	Occupancy, % cover at surveyed sites
Fire			
Suite of ecologically relevant metrics, calculated for (i) all fire; and (ii) wildfire	Key driver of vegetation dynamics, structure and composition, habitat attributes	Fire Scar Analysis	Extent, Frequency (no. times burnt in given period), Time since fire, Distance to unburnt (mean, maximum)

Survey types and history

To report on the Biodiversity and Threat Indicators, our survey teams conduct a variety of surveys repeated on a schedule of 3-5 years. These include:

- Standard Trapping Survey (upland and lowland)
- Standard Camera Survey (upland and lowland)
- Standard Bird Survey (lowland)
- Stream-dwelling Frog Survey
- The Vegetation, Flora and Weed surveys, and
- A variety of targeted surveys (Common Rock Rat, Yakka Skink, Northern Leaf-tailed Gecko, Northern Masked Owl, Blue-faced Parrot Finch, Nocturnal Birds, specific Threatened Plants, and specific weeds)

In addition to ground-based ecological surveys, satellite data are analysed to compile the:

- Fire Scar Analysis

Three of the ecological ground-based surveys were completed at Brooklyn in 2020 and 2021: a Standard Trapping Survey and Standard Camera Survey of the lowlands in September 2020; and a Stream-dwelling Frog Survey between December 2020 and February 2021 (Table 3). The Fire Scar Analysis has been completed using satellite data from 2000 (four years prior to acquisition) to 2020. The methodology is described and results of these surveys and computations are reported on in this document.

Past survey effort on Brooklyn has included Standard Trapping Surveys, Standard Camera Surveys, and Stream-dwelling Frog Surveys. Changes were made to the number and location of survey sites in the Standard Trapping and Standard Camera surveys to improve on monitoring power. Of the 42 monitoring sites, 12 were first established in 2006 (Kutt et al. 2012) and 4 were established after 2010 (Kemp et al. 2015a; Mulder et al. 2017). The remaining 26 sites were new sites surveyed for the first time in 2020. Thus, the 2020 results effectively represent baseline metrics upon which to compare future Ecohealth monitoring results. With the exception of the Stream-dwelling Frog Survey, no comparisons were made to pre-2020 data due to these changes.

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

Survey name	Effort	Description/comment	Previous surveys
Standard Trapping Survey	4,619 trap nights	40 sites surveyed, each with 4 pitfalls, 20 Elliotts and 6 funnel traps. Sites were open for 3 nights. Stratified to cover 9 major ecosystem types across the Brooklyn lowlands.	2006 – 50 sites 2007 – 50 sites 2010 – 40 sites 2011 – 5 sites 2013 – 22 sites 2014 – 31 sites 2015 – 14 sites (upland) 2016 – 22 sites ----New survey design----- 2018 – 8 of 14 sites (upland) 2020 – 40 of 42 sites (lowland)
Standard Camera Survey	1,534 camera trap nights	42 sites surveyed. Two cameras were deployed at each site, for a minimum of 14 nights. Previous surveys have used varying numbers of cameras at standard trapping sites.	2011 – 5 sites 2013 – 22 sites 2014 – 31 sites 2015 – 14 sites (upland) 2016 – 38 sites ----New survey design----- 2018 – 8 of 14 sites (upland) 2020 – 42 sites (lowland)
Stream-dwelling Frog Survey	10 transects	400 m transects along major creeks covering a range of elevations from lowlands to upper reaches of Mt Lewis.	Feb/ Mar 2014 – 6 transects Dec 2014 – 10 transects

Survey designs

Standard Trapping and Camera Surveys (lowland)

AWC has established 42 lowland monitoring sites stratified across nine of 17 potential ecosystems (Figure 5). The stratification assessment considered the percentage cover of each ecosystem on the sanctuary and target fauna species. The remaining eight ecosystems are not represented in the lowland survey because they cover only a very small proportion of Brooklyn and/or are represented in targeted surveys (e.g., the 'granite boulderfield mixed woodland with vine thicket species' ecosystem is visited in targeted rocky area surveys). A table of the 42 sites, including GPS coordinates and a description of habitat type, is in Appendix 1.

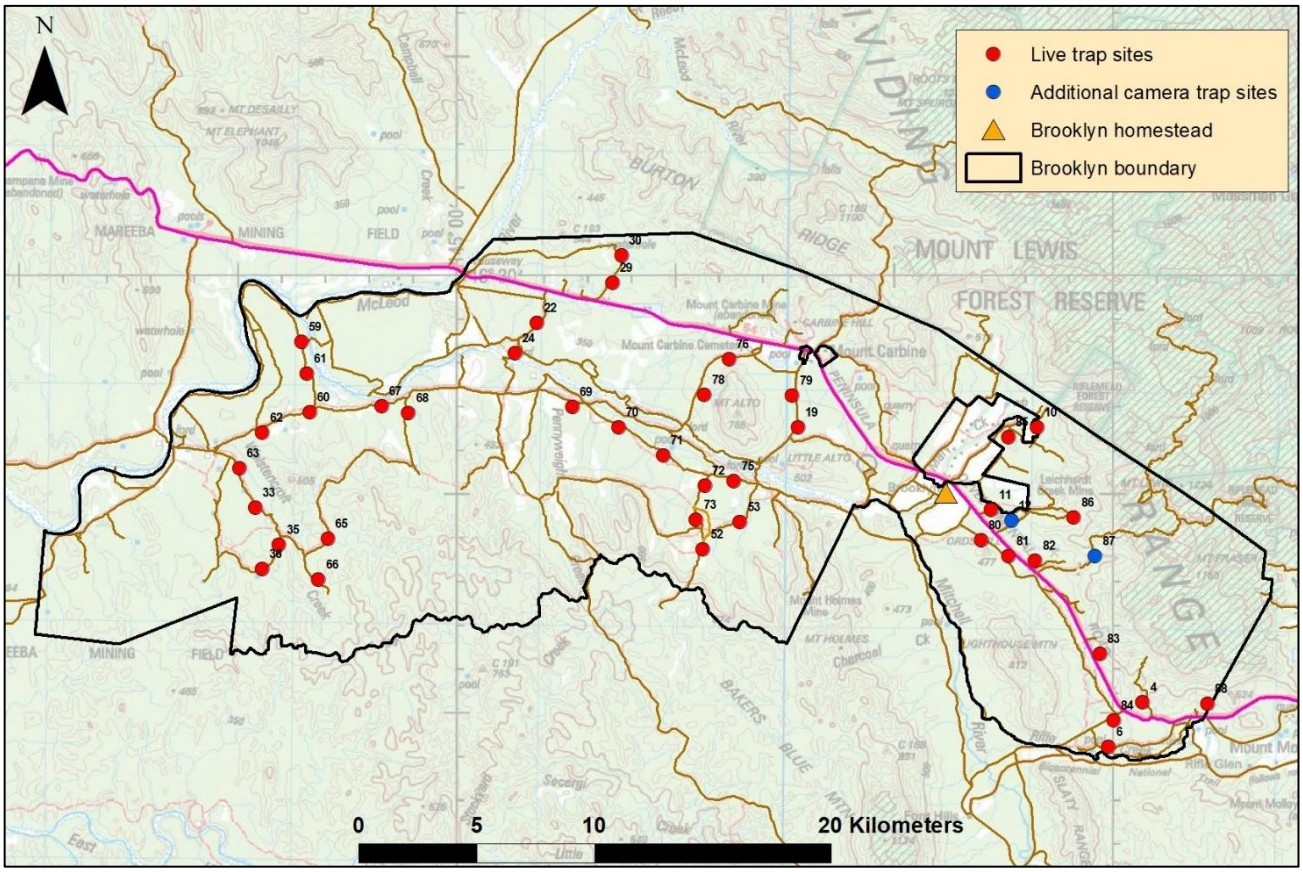


Figure 5. Standard Trapping Survey and Standard Camera Survey monitoring sites on Brooklyn. The red and blue circles comprise the 42 standard sites. Due to logistical constraints only 40 sites were surveyed in the Standard Trapping Survey in 2020 (red circles). The remaining two sites were surveyed as part of the Standard Camera Survey (blue circles).

Stream-dwelling Frog Survey

Ten transects are surveyed to monitor stream-dwelling frogs on Brooklyn. The transects are located on the largest and most permanent creeks on Brooklyn (Mary, Leichhardt, Station and Luster Creeks; Figure 6). Each creek has one transect, except Leichhardt Creek, which has seven transects ranging from the lowlands to the upper reaches of Mount Lewis (370 m - 930 m elevation range). The start and end coordinates of each transect are provided in Appendix 2.

Surveys are conducted every three to five years and are targeted to occur in December. December was considered optimal as humidity is generally high but significant rain has not yet occurred, and the roads and creeks are easily traversable (Kemp et al. 2015b).

However, in late December 2020, an initial visit to the transects revealed that the creeks were extremely dry due to low rainfall in November and December (45 mm). There was very little frog activity observed. The survey was postponed until January after more rain fell. Table 4 shows the variation in rainfall in the two months prior to each frog survey.

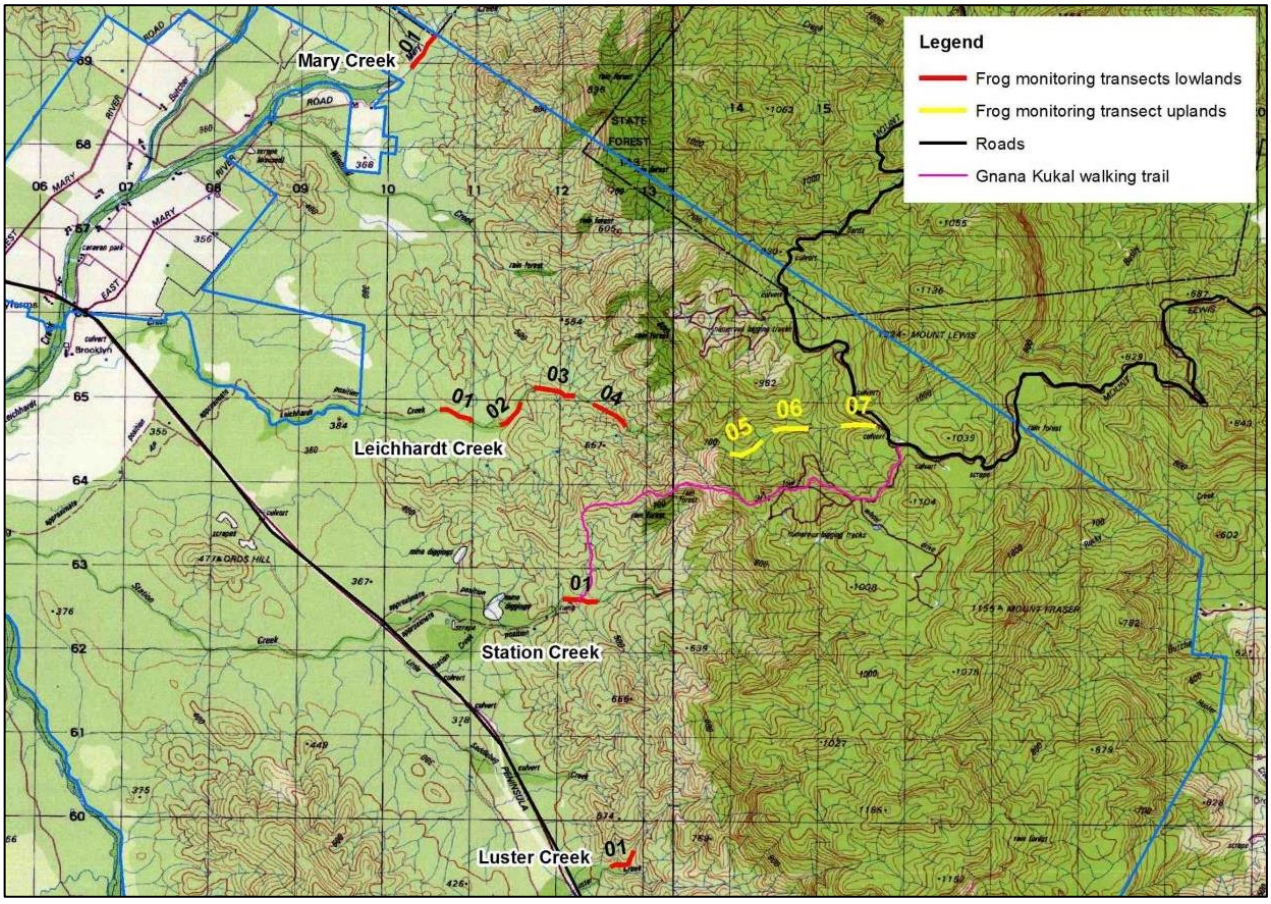


Figure 6. Stream-dwelling Frog Survey transects on Brooklyn

Table 4. Rainfall prior to the Stream-dwelling Frog surveys. The 2021 survey was a single survey, but the 10 transects were split over three separate visits.

Date	Rainfall total in 2 months prior to survey
February/ March 2014	372 mm
December 2014	30 mm
7 January 2021	150 mm
27 January 2021	268 mm
2 February 2021	275 mm

Survey methods

Standard Trapping Survey

A Standard Trapping Survey site encompassed a one hectare survey area, with four permanent pitfall traps, six funnel traps and 20 Elliott (box) traps (Figure 7). Pitfall traps were established in a 'T' array, with three pitfalls on a 20 m line and one pitfall on a 10 m line. Each pitfall trap was a 20 litre bucket that is permanently buried. (Figure 7). A 30 cm high drift fence (dampcourse) was set up between pitfall traps, and three pairs of funnel traps were placed between pitfalls. Funnel traps were covered with insulation to protect captured animals from heat and rain (Figure 8). A handful of dirt and a piece of insulation were placed in each pitfall. Twenty Elliott traps were placed every 10 m along 100 m lines (usually in a north-south direction). Traps were baited with a standard bait ball (oats, peanut butter, sardines and vanilla essence).

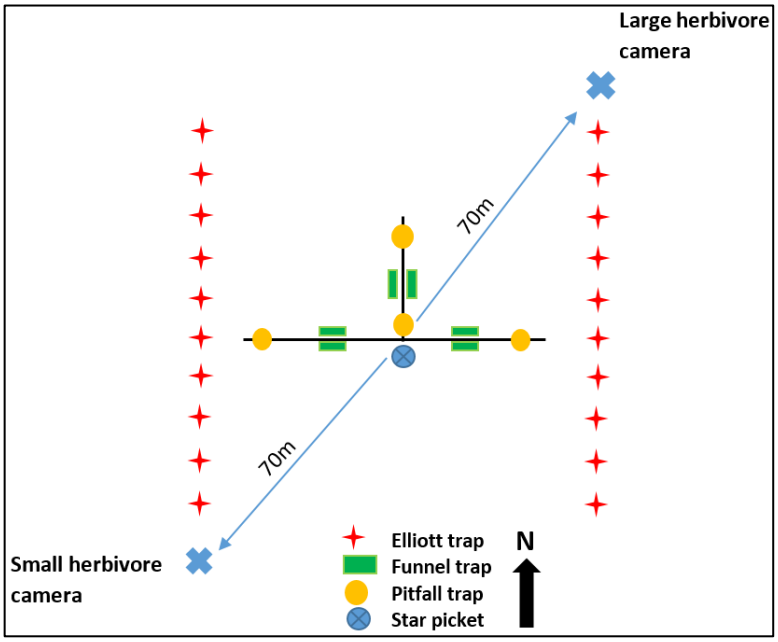


Figure 7. Standard live trap site configuration

Sites were open for three consecutive nights and checked every morning and evening. Captured animals were identified to species level and marked with a paint pen to allow identification of recaptures. Morphometric measurements were taken if required.

Due to logistical constraints in 2020, live trapping was done at 40 of the 42 Standard Trapping Survey sites; sites 12A and 87 were not surveyed (Figure 5).

Figure 8. A standard fauna trapping site. Peter Cheers/AWC

Standard Camera Survey

Two Reconyx Hyperfire PC850 Whiteflash motion sensor camera traps were set at the 42 Standard Camera Survey sites and left in-situ for a minimum of 14 continuous nights. The cameras were placed at opposite sides of the Standard Trapping Survey plot (70 m from the centre pitfall) at the ends of the Elliott trap lines (Figure 7).

The 'small herbivore' camera was placed in the southwest corner. This camera was set 1 m high on a tree. A standard bait ball was placed inside a PVC baitholder and pegged into the ground 1.5 m from the base of the tree. The 'large herbivore' camera was placed in the northeast corner at a height of 1.5 m. A different bait ball (oats, peanut butter, vanilla essence and Dairy Krave) was placed in the baitholder, 3 m from the base of the tree. The cameras were set to high sensitivity, with no quiet period between triggers, three pictures per trigger.

Stream-dwelling Frog Survey

Ten sites were surveyed in January and February 2021. Different transects were completed across three nights for a total effort of 10 individual transects. Each transect comprised a 400 m length of creek. The transects were walked at night by a team of two, comprising at least one ecologist experienced in frog surveys. The safety of each transect was determined in the afternoon prior to the survey, where the depth of water, flow and other potential hazards were identified.

Surveys commenced after dark at the downstream end of the transect. Two observers walked slowly, systematically searching on either side of the creek (up to five metres from the bank where it was safe to do so) and on boulders in the creek. Observers used 200 lumen LED Lenser head-torches, looked for eye-shine on rocks, logs, tree trunks and foliage, and listened for frog calls. When frogs were detected, the species, sex (if determinable), number of individuals and location were recorded.

Frog handling was kept to a minimum. Frogs were released at the same place as captured. Equipment including shoes and containers were sterilised between streams (using bleach).

Analysis methods

Standard Trapping Survey

The 2020 Standard Trapping Survey data were used to calculate Ecohealth metrics for a range of small mammal, small-medium reptile and threat indicator species, assemblages and guilds (Table 5). Captures that were considered irregularities were excluded from the analyses. These included species that were comparatively rare captures (e.g. snakes); captured in a typically unsuitable trap type (e.g. a medium mammal in an Elliott trap); or where only one size class was captured (e.g. juvenile monitors).

Table 5. Metrics calculated from 2020 live trap data

Metric	Calculations
Abundance per transect (Amphibians)	The average (± SE) number of individuals recorded across all transects *For individual species:* (Total number of individuals of that species (excluding recaptures) recorded across all transects/ total number of transects) ± SE *For guilds:* (Total number of individuals of the guild (excluding recaptures) recorded across all transects/ total number of transects) ± SE
Abundance per 100 trap nights (Small-medium mammals; arboreal mammals; large herbivores; predators; reptiles; threats (feral cattle, horses, cats, pigs, cane toads))	The average number of individuals recorded per 100 trap nights across all sites *For individual species:* The average (± SE) over all survey sites of: ((Total number of individuals of that species (excluding recaptures) recorded at survey site/ total number of trap nights at survey site) x 100) *For guilds:* The average (± SE) over all survey sites of: ((Total number of individuals of the guild (excluding recaptures) recorded at survey site/ total number of trap nights at survey site) x 100) **For reptiles:** pitfall and funnel trap nights were counted toward trap nights per site. The total number of trap nights reported for reptiles was calculated using both morning and afternoon sessions (e.g. there were usually 36 funnel trap nights overall per site; as 6 funnels were open during the day and 6 funnels were open during the night, over 3 days and 3 nights in total). **For small mammals:** pitfall and Elliott trap nights were counted toward trap nights per site.
Occupancy (Small-medium mammals; arboreal mammals; large herbivores; predators; reptiles; frogs; threats (feral cattle, horses, cats, pigs, cane toads))	Occupancy: the percentage of sites at which the target species/ assemblage/ guild was recorded. (Number of sites at which target fauna detected)/ Total number of sites. Range from 0% to 100%.
Richness (Mammal, reptile and frog assemblages and guilds)	Measure of diversity: the average number of species per site. (Sum of total number of species recorded at all individual sites)/ Total number of sites. Calculated with standard error.

Standard Camera Survey

Standard Camera Survey data were used to calculated metrics as described in Table 5, for medium mammals, 'other' reptiles (Black-headed Monitor *Varanus tristis*), large native herbivores, Dingoes and threats (cattle, horses, pigs and cats). Camera data were downloaded and processed using Artificial Intelligence (AI) software (Microsoft Azure and Postman). Data were then uploaded into the program 'Timelapse' (Greenberg et al.

2019) for processing: each photo was categorised as containing an animal or being unoccupied, and then for photos containing an animal, the species was classified. Animals were identified to species level if possible. A camera trap 'event' may be defined as 1 or more images of a species separated by a stated interval (Meek et al. 2014). A 24 hour interval was used as the relevant interval for our data analyses. An index of relative abundance, 'abundance per 100 trap nights', was calculated for each species at each site (Table 5), using the 24 hour event interval to determine independent captures. Occupancy was calculated as per Table 5.

Stream-dwelling Frog Survey

Metrics for threatened frog species and the stream frog guild (Table 1) were calculated as described for the Standard Trapping Survey in Table 5, but using the metric of abundance 'per transect'.

Fire Scar Analysis

Fire scar data were derived by AWC from Landsat satellite imagery, and in later years Sentinel-2 satellite imagery. 'Hotspot' data from the North Australian Fire Information (NAFI) website were used to help identify the month of the fire when the Landsat satellite imagery interval extended across multiple months. Each scar was attributed by year, month and season. Fire scars detected from January to July (inclusive) were attributed as 'Early', whereas those detected August to December were attributed as 'Late'. The maps and statistics for the analyses were created using ArcGIS with Spatial Analyst, and were semi-automated using Python scripting. Graphs were produced using Microsoft Excel. Cooper et al. (2020) provide further detail on the annual fire scar mapping and analysis undertaken.

Results

Biodiversity indicators

A total of 65 native species were recorded during the Standard Trapping and Stream-dwelling Frog surveys (12 mammals, 35 reptiles, 9 birds and 9 frogs). Five introduced species were recorded. Species lists for these surveys are provided in Appendix 1 (Standard Trapping Survey) and Appendix 2 (Stream-dwelling Frog Survey).

Mammals

Small-medium mammals: live trapping

Average abundance, occupancy, and average species richness were very low for the lowland small mammal guild and indicator species (Table 6). Thirteen individuals representing 4 native small mammal species were captured in 2020: the Grassland Melomys (1 individual); the Delicate Mouse (3 individuals); the Eastern Chestnut Mouse (8 individuals; Figure 9); and the Common Dunnart (1 individual). A Northern Quoll was caught in an Elliott trap, but was excluded from analysis as an irregular capture. The relevant small mammal metrics are provided in Table 6.

Table 6. Small mammal metrics from the 2020 Standard Trapping Survey

Indicator	Metric^	Value	Comments on status*
Grassland Melomys (lowland)	Abundance Occupancy	0.04 ± 0.04 2.5%	Very low abundance and occupancy; 1 individual captured at 1 site. Three detections on camera traps in the 2016 survey.
Sminthopsis assemblage	Abundance Occupancy	0.03 ± 0.03 2.5%	Very low abundance and occupancy; 1 individual captured at 1 site. Only 12 *Sminthopsis* records in total pre-2020.
Northern Short-tailed Mouse	Abundance Occupancy	0.0 0.0%	Not detected in 2020 lowland survey. 25 records pre-2020. Possible decreasing trend; 3 records from 2016 survey.
Eastern Chestnut Mouse	Abundance Occupancy	0.24 ± 0.13 12.5%	8 individuals captured. 19 records pre-2020. Possible increasing trend as this species was not recorded since 2011.
Lowland small mammal guild	Abundance Occupancy Richness	0.41 ± 0.14 25.0% 0.25 ± 0.07	

^Abundance is average abundance per 100 live trap nights across 40 sites. Occupancy is the percentage of sites at which the species or guild was detected. Richness is average species richness across the 40 sites.

Figure 9. An Eastern Chestnut Mouse captured in the 2020 Standard Trapping Survey. Emily Rush/AWC

No trend analyses were undertaken to compare the 2020 results with prior surveys of the Brooklyn lowlands due to changes in the survey design explained above.

Most of the small mammal captures in 2020 were on the eastern, wetter and more structurally complex area of Brooklyn (Figure 10). These sites experience higher rainfall and generally contain more diverse habitat structure than the more open sites in the drier western side (Kemp et al. 2015a). A range of small to medium mammal species are typically captured more frequently when the more easterly sites are surveyed (Kemp et al. 2015a). The exceptions were sites 52, 72 and 73, south of the Mitchell River (Figure 10). Although these sites are located in generally drier and more open country, they were observed to have a relatively thick layer of shrubby stylo during the 2020 trapping, which could have provided some level of cover to the 6 individual Eastern Chestnut Mice that were captured in this area.

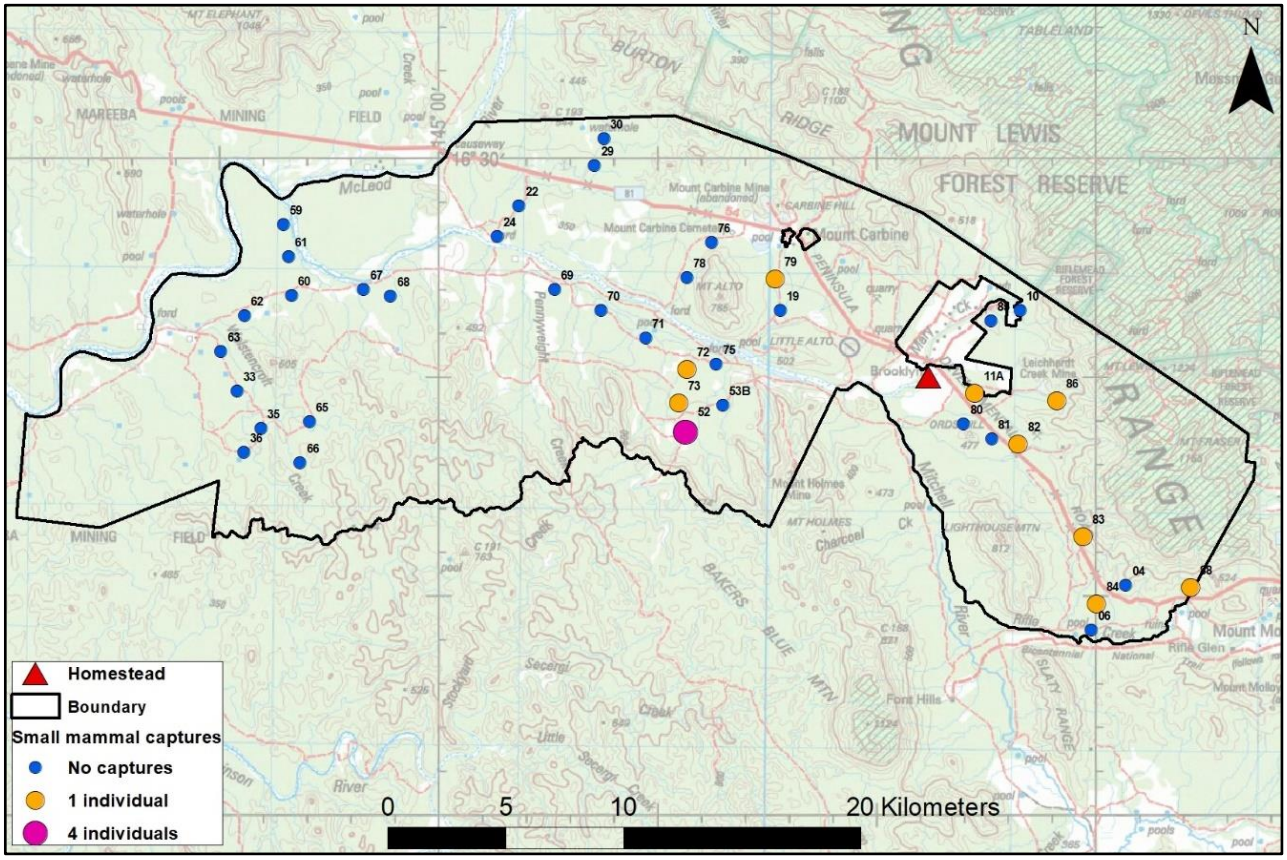


Figure 10. Native small mammal captures at Standard Trapping Survey sites on Brooklyn in 2020

No small mammals were trapped to the west of these sites, despite the Northern Short-tailed Mouse and the Canefield Rat occasionally being trapped in the western area previously (Kemp et al. 2015a). These species are known to experience irruptions but are sometimes trapped at low levels outside of irruptions (Kutt and Kemp 2014; Kemp et al. 2015a). The substantially lower than median rainfall in 2020 may have had some influence on the small mammal fauna (particularly on native rodents) by affecting food resources and subsequently reproductive success (e.g. Madsen and Shine 1999; Pavey and Nano 2013).

One Delicate Mouse was trapped at each of 2 sites that had been burnt in early dry-season fires prior to the survey, as part of AWC's standard fire management program (sites 84 and 88). Small mammals face an increased risk of predation after high-intensity fire, through the reduction of vegetative cover and an influx of predators into burnt sites (Leahy et al. 2015). However, fire also stimulates the growth of palatable vegetation, and some mammals including the Delicate Mouse favour recently burnt areas (e.g., Kutt and Woinarski 2007). These 2 captures suggest that sufficient resources remained in the vicinity of the trapping area to support some small mammal fauna following the patchy, early season fires. The fire history of the trapping sites and variation in small mammal captures will be examined in more detail in future years as this survey is repeated.

Small-medium mammals: camera trapping

Medium-sized mammals were detected on camera at only 11 of the 42 sites. Five species were detected; there was low average species richness across the 42 sites (0.36 ± 0.10; Table 7). The Northern Brown Bandicoot was the most common species and was detected at 7 sites, followed by the Black-footed Tree-rat at 3 sites. The Common Brushtail Possum and Northern Quoll were each found at 2 sites. The Echidna was found at 1 site. All medium-sized mammal indicator species had low abundance per 100 trap nights and low occupancy across the 42 sites (Table 7).

Table 7. Medium and arboreal mammal metrics from 2020 Standard Camera Survey

Indicator	Metric^	Value
Northern Quoll (lowland)	Abundance Occupancy	0.21 ± 0.16 4.8%
Black-footed Tree-rat	Abundance Occupancy	0.42 ± 0.26 7.1%
Northern Brown Bandicoot (lowland)	Abundance Occupancy	2.30 ± 0.92 16.7%
Lowland medium mammal guild (includes *Trichosurus vulpecula*)	Abundance Occupancy Richness	3.16 ± 1.03 26.2% 0.36 ± 0.10
Arboreal mammals		
Common Brushtail Possum	Abundance Occupancy	0.18 ± 0.13 4.8 %

^Abundance is average abundance per 100 camera trap nights across 42 sites. Occupancy is the percentage of sites at which the species or guild was detected. Richness is average species richness across the 42 sites.

Consistent with small mammal captures, many of the medium mammal species captured on camera traps in 2020 were found more frequently in the eastern sites, particularly the Northern Quoll and Northern Brown Bandicoot. The western-most record was a Common Brushtail Possum at site 79, close to the foothills of Mount Alto.

In recent decades, declines in small-medium sized mammals have occurred throughout Australia's tropical savannas (Woinarski et al. 2011). This decline is likely due to the interacting effects of predation by feral cats (Frank et al. 2014; McGregor et al. 2015), landscape degradation by introduced herbivores (Legge et al. 2011; Kutt et al. 2012; Stobo-Wilson et al. 2020) and inappropriate fire regimes (Griffiths et al. 2015; Lawes et al. 2015). Comparatively less is known about the small-medium mammal fauna in Queensland than in the Northern Territory or the Kimberley (Ziembicki et al. 2015). However, the mammal fauna in some areas of northern Queensland appears to be experiencing similar declines to that across northern Australia generally (Kutt and Gordon 2012; Perry et al. 2015). In light of these declines, it is critical that the status of the small-medium mammal fauna on Brooklyn is monitored closely. The 2020 survey provides important baseline metrics against which future Ecohealth monitoring of changes in abundance and occupancy of small-medium sized mammal indicators can be identified and appropriate management actions pursued where necessary.

Large herbivores

Lowland macropods were the most commonly recorded guild on camera traps in 2020; they were present at 24 of the 42 camera trap sites (Table 8). The Agile Wallaby was the most common species, recorded at 19 sites, followed by the Eastern Grey Kangaroo, recorded at 7 sites. The Swamp Wallaby (*Wallabia bicolor*) was recorded at only 1 site (Table 8). Unlike the small and medium-sized mammals, both the Agile Wallaby and Eastern Grey Kangaroo were recorded at sites in the more open, western side of Brooklyn, which is typical of their habitat preference of open woodland (Schmidt et al. 2010). The Swamp Wallaby, which typically prefers more complex habitat (Troy and Coulson 1993), was detected at a low-elevation site in the foothills on the eastern side of Brooklyn.

Large herbivorous mammals are strong drivers of ecosystem processes because of the influence their browsing can have on vegetation, particularly when populations become overabundant due to declines of predators (Prowse et al. 2019; Mills et al. 2020). This survey provides the baseline metric for future Ecohealth monitoring of large herbivorous mammals to support effective management decisions.

Table 8. Large herbivore metrics from 2020 Standard Camera Survey

Indicator	Metric^	Value
Agile Wallaby	Abundance Occupancy	3.55 ± 0.98 45.2%
Eastern Grey Kangaroo	Abundance Occupancy	1.04 ± 0.51 16.7%
Lowland macropod guild	Abundance Occupancy Richness	4.65 ± 1.05 57.1% 0.64 ± 0.10

^Abundance is average abundance per 100 camera trap nights across 42 sites. Occupancy is the percentage of sites at which the species or guild was detected. Richness is average species richness across the 42 sites.

Predators

The Dingo was only recorded at 2 sites on Brooklyn in 2020, an occupancy of 4.8%. It had a low average abundance of 0.13 ± 0.09 individuals per 100 trap nights across the 42 lowland sites. AWC is developing a targeted survey method for monitoring Dingoes and this will be employed on Brooklyn. In the meantime, repeated surveys across these lowland sites will clarify trends of Dingo abundance and occupancy.

Reptiles

Small-medium reptiles

During the 2020 survey, 34 species of reptiles were captured across the 40 sites. All sites except 1 (site 24) had at least 1 reptile present. The Tommy Roundhead (*Diporiphora australis*) had the highest occupancy (present at 50% of sites). The Metallic Snake-eyed Skink (*Cryptoblepharus metallicus*) had the highest individual abundance (39 individuals captured). One new species was confirmed for the sanctuary; the Gulf Two-lined Dragon (*Diporiphora carpentariensis*), on the basis of updated taxomony (previously *D. bilineata*; Melville et al. 2019).

Figure 11. An Eastern Fat-tailed Gecko *Diplodactylus platyurus*, captured in the 2020 Standard Trapping Survey. Emily Rush/AWC

The relevant reptile metrics are provided in Table 9. Several snakes and monitors were excluded from the calculations of small-medium reptile metrics: the Faint-striped Blind Snake (*Anilios broomi*), Frilled Lizard (*Chlamydosaurus kingii*), Carpentaria Small-eyed Snake (*Cryptophis boschmai*), Collared Whipsnake (*Demansia torquata*) (2 individuals), Storr's Monitor (*Varanus storri*) (2 individuals), Black-headed Monitor (*Varanus tristis*), and the Eastern Bandy-bandy (*Vermicella annulata*). Two Tommy Roundheads were also excluded from the abundance calculations as they were caught in Elliott traps, and any reptiles that could not be identified to species level were not included in the species richness calculations. Reptiles were recorded at all of the sites that were burnt, ranging from 1 to 8 species per site.

Table 9. Small-medium reptile metrics from 2020 Standard Trapping Survey

Indicator	Metric^	Value
Diporiphora species assemblage	Abundance Occupancy Richness	1.38 ± 0.27 50.0 % 0.55 ± 0.09
Bynoe's Prickly Gecko	Abundance Occupancy	0.91 ± 0.24 37.5 %
Carlia species assemblage	Abundance Occupancy Richness	2.41 ± 0.53 60.0 % 0.73 ± 0.11
Straight-browed Ctenotus	Abundance Occupancy	0.25 ± 0.13 10.0 %
Lygisaurus species assemblage (lowland)	Abundance Occupancy Richness	0.52 ± 0.19 20.0 % 0.20 ± 0.06
Lowland small-medium reptile guild	Abundance Occupancy Richness	11.40 ± 1.21 95.0 % 4.18 ± 0.36

^Abundance is average abundance per 100 live trap nights across 40 sites. Occupancy is the percentage of sites at which the species or guild was detected. Richness is average species richness across the 40 sites.

No trend analysis was undertaken with pre-2020 reptile capture data, due to changes in the location and number of trapping sites during historical inventory surveys. As these surveys are repeated in coming years, more inferences can be made about the status and trajectory of Brooklyn's reptile fauna.

Large reptiles

The Black-headed Monitor (*Varanus tristis*) was recorded at only 1 site (an occupancy of 2.4%) and had an average abundance of 0.07 ± 0.07 individuals per 100 trap nights across the 42 sites. Cane toads are suspected to have driven declines of varanid reptiles (Doody et al. 2009). Continued monitoring of the varanid population on Brooklyn across the new set of standard sites will be key to detecting any trends in occupancy and abundance of the monitor population.

Frogs

Stream-dwelling frogs

Across the 10 transects, a total of 370 individuals of 9 native species were recorded. Mean frog abundance was 37.00 ± 10.52 individuals per transect. Average species richness was 3.20 ± 0.44 species per transect. A species list is provided in Appendix 2.

Average frog abundance was higher in 2021 than 2014, but average species richness was lower (Table 10). Six species recorded in December 2014 were not detected in 2021. The lower species richness in 2021 was driven by the 2 lowest-elevation sites. In particular, at site LeichhardtCk01, only 1 individual of a relatively common species (the Northern Stony Creek Frog, *Litoria jungguy*) was recorded in 2021, compared with 30 individuals of 8 species in December 2014. There was substantial variation in rainfall in the 2 months prior to the surveys at this site (30 mm in December 2014; 275 mm in February 2021). It is feasible that fewer lower-elevation woodland frogs, which are less commonly recorded in fast-flowing streams and waterfalls (Kemp et al. 2015b), were using the creek as habitat in February 2021 after the heavier rainfall. Similarly, in February 2014 after substantial rainfall (372 mm), Kemp et al. (2015b) recorded five fewer species at this site than the following survey in December 2014. During the scout of the site in December 2021 (after 45 mm of rain), AWC ecologists anecdotally noted that the lower-elevation sites were comprised of small pools joined by trickles, which may provide more suitable conditions for those woodland species. However, during the scout, very little frog activity was detected. In future, surveys could be undertaken at both the start of the wet season (e.g. after ~30-40 mm) and again after more substantial rainfall.

Table 10. Frog metrics from 2021 Stream-dwelling Frog Survey

Indicator	Metric^	Value	Year	Comments on status and trend*
Torrent Tree Frog	Abundance Occupancy	10.00 ± 3.23 70.0%	2021	Slight increase in mean abundance since December 2014 (6.80 ± 1.78), and slight decrease in occupancy (80.0 % in 2014).
Common Mist Frog	Abundance Occupancy	15.30 ± 8.80 60.0%	2021	Increase in mean abundance since December 2014 (7.30 ± 4.49), and increase in occupancy (40.0 % in 2014).
Serrated-armed Tree Frog	Abundance Occupancy	1.80 ± 1.18 30.0%	2021	Decrease in mean abundance since December 2014 (5.90 ± 3.36), and slight decrease in occupancy (40.0 % in 2014).
Northern Dwarf Tree Frog (stream survey)	Abundance Occupancy	0 0.0%	2021	Not detected in 2021.
Stream-dwelling frog guild	Abundance Occupancy Richness	37.00 ± 10.52 100.0% 3.20 ± 0.44	2021	Slight increase in mean abundance since December 2014 (30.80 ± 8.01). Decrease in mean species richness per transect since December 2014 (4.80 ± 0.63), possibly related to survey timing and associated variation in rainfall.

^ Abundance is average abundance across 10 transects. Occupancy is the percentage of transects at which the species or guild was detected. Richness is average species richness across the 10 transects.
** Metric comparisons were made to the December 2014 survey, as all 10 transects were sampled in both December 2014 and in the 2021 survey. In February/ March 2014, only 6 transects were surveyed.*

Threatened frogs

Three threatened frogs were recorded in 2021 (Table 10); the Torrent Tree Frog (listed as Endangered under the State *Nature Conservation Act 1992* (NCA)), the Common Mist Frog (listed as Endangered under the NCA), and the Serrated-armed Tree Frog (listed as Vulnerable under the NCA). The Torrent Tree Frog was recorded in greater abundance, but at 1 less transect in 2021 than in December 2014 (Table 10). It was not re-detected at the highest-elevation transect. Both the occupancy and abundance of the Serrated-armed Tree Frog declined: this species was detected at 3 of the 4 transects where it had been recorded in 2014, and in substantially lower numbers in 2021. The Endangered Common Mist Frog was recorded at 2 transects where it had not been previously observed (including the highest-elevation transect), and in greater abundance than in 2014.

Overall, it is encouraging that the 3 threatened frog species are persisting on these creek lines. In particular, the Torrent Tree Frog and Common Mist Frog have suffered declines at higher elevations during the past decades, but were known to persist at elevations of below 400 m (McDonald and Alford 1999). They have more recently reappeared at higher elevations, including on Brooklyn (McDonald et al. 2005; Kemp et al. 2015b; McKnight et al. 2017). This may suggest that these species are able to coexist with the chytrid fungus *Batrachochytrium dendrobatidis*, which drove the initial declines (Puschendorf et al. 2011; Kemp et al. 2015b; McKnight et al. 2017). The absence of the Torrent Tree Frog from the highest-elevation transect and the lower abundance and occupancy of the Serrated-armed Tree Frog in 2021 are potentially concerning; their status will be carefully monitored in subsequent surveys.

Threat indicators

Introduced species

The threat metrics available from the 2020 lowland surveys are provided in Table 11. During live trapping, 21 individual cane toads were recorded across 9 sites. The remaining feral species were recorded on camera traps at 7 sites (cats and pigs) and 6 sites (cattle). Feral cats were only detected at sites west of Mount Alto, in the drier and generally less structurally complex habitats on Brooklyn. This is in contrast to the small mammal distribution pattern, where records were located in the eastern area of the sanctuary, with the exception of the 3 sites just south of the Mitchell River (Figure 10).

Introduced species pose a major threat to native Australian species and ecosystems. Landscape degradation by feral herbivores and predation by feral cats are considered key factors driving the current decline in small mammal populations (e.g. Woinarski et al. 2011; Ziembicki et al. 2015). The invasive cane toad has been implicated in declines of a range of native fauna including dasyurid marsupials and varanids (Shine 2010). Ongoing Ecohealth monitoring of these threatening processes will be fundamental to informing future targeted AWC management activities.

Table 11. Threat metrics from 2020 live and camera trap surveys

Indicator	Metric^	Value
Cattle	Abundance Occupancy	0.59 ± 0.26 14.3 %
Horses	Abundance Occupancy	0.0 0.0 %
Cats (lowland)	Abundance Occupancy	0.75 ± 0.29 16.7 %
Pigs (lowland)	Abundance Occupancy	0.44 ± 0.15 16.7 %
Cane toad (lowland)	Abundance Occupancy	0.44 ± 0.16 22.5%

^Abundance is average abundance per 100 camera trap nights across 42 sites for cattle, horses, cats and pigs; and per 100 live trap nights across 40 sites for cane toads. Occupancy is the percentage of sites at which the species was detected.

Fire

During 2020, ground-based and aerial prescribed burning was conducted by the Brooklyn Sanctuary Manager. The 2020 metrics indicate improvements considered to be beneficial for ecological health since AWC management commenced. The area burnt by early dry season fire has increased, while the area burnt by late dry season fire has reduced since management commenced (Table 12). The cumulative extent of the sanctuary burnt by late dry season fire in the previous three years has reduced by over 19% compared to baseline measures (Table 12). More detail on the Brooklyn fire program is in the annual Fire Reports (Cooper et al. 2020).

Table 12. Fire metrics for 2020. Baseline values for metrics are the average for the years immediately prior to acquisition of Brooklyn by AWC: i.e., 1999-2004 for annual metrics, and 2001-2004 for 3 year metrics. AWC management values for metrics are the average for the years following acquisition of Brooklyn by AWC: i.e., 2005 onwards, for annual metrics, and 2007-2020, for 3 year metrics.

Metric	**Baseline** average (1999/01-04)	**AWC management** average (2005/07-20)	**2020 result**
Area burnt by early dry season (EDS) fire (%)	7	14	14
Area burnt by late dry season (LDS) fire (%)	14	8	0.1
Total area burnt (%)	20	22	14
Cumulative extent burnt by LDS fire in past 3 years (%)	43	21	24
Modal frequency of fires in last 7 years	2	-	0
Modal frequency of LDS fires in last 7 years	0	-	0
Area of long-unburnt vegetation, including estimated area of long-unburnt patches within EDS fire scars (%) Note: baseline includes areas subject to heavy grazing.	49	53	47
Mean distance to unburnt vegetation (km)	0.7	0.4	0.3
Mean distance to vegetation long unburnt by LDS fire (km)	1.4	0.5	0.6

Discussion

The 2020 lowland survey produced vital baseline data on a range of mammal and reptile indicators on Brooklyn, as well as on the distribution and occupancy of feral cats and herbivores, across 42 standard monitoring sites. Small and medium-sized mammal abundance and occupancy was generally very low across the sanctuary, with nearly all live captures and camera trap detections in the more structurally complex, eastern area of Brooklyn. Reptiles were present at 95% of sites and captures were spread more evenly across the sanctuary.

It is difficult to draw inferences from the present results, other than to note that the low number of mammals detected has been an historical feature of Brooklyn (Kutt et al. 2012), and generally reflects broader trends of low mammal abundance across the northern Australian savannas. Future surveys, which will be undertaken at the same 42 sites as surveyed in 2020, will allow changes in the distribution, abundance and occupancy of the mammal and reptile fauna to be detected and ultimately to be interpreted in the context of varying rainfall, temperature patterns and fire histories.

It was encouraging that the 3 threatened frog species that were last surveyed in 2014 continue to persist on the creek lines on the lowlands and slopes of Mt Lewis. Species richness in 2021 was lower than in December 2014, and the Vulnerable Serrated-armed Tree Frog was recorded at fewer transects and in lower abundance than in 2014. While these results were likely due in part to variation in total rainfall prior to the surveys, future monitoring will be vital to allow the detection of changes in frog assemblages.

The 2020 fire metrics suggest improvements in the fire regime since AWC management that are likely to benefit biodiversity on Brooklyn. In particular, only 0.1% of the sanctuary was affected by late dry season fire in 2020, while the cumulative extent of the sanctuary burnt by late dry season fire in the previous three years has almost halved since acquisition.

Acknowledgments

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

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

The north-east Science team is grateful for the support provided by the Brooklyn Sanctuary Managers Andrew and Megan Francis, over the multiple site preparation trips and the 2020 and 2021 surveys.

Figure 12. An essential survey activity – making bait balls for baiting Elliott traps (clockwise from left: volunteers Dani Matheus-Holland, Miranda Rampton, Aiden Wright and Vivianne Browne)

2020 and 2021 survey participants:

- Dr Catherine Hayes (AWC)
- Dr Alexander Watson (AWC)
- Andrew Howe (AWC)
- Emily Rush (AWC)
- David Nelson (AWC)
- Patrick Webster (volunteer)
- Vivianne Browne (volunteer)
- Peter Cheers (volunteer)
- Daniela Matheus-Holland (volunteer)
- Aiden Wright (volunteer)
- Miranda Rampton (volunteer)

References

Bureau of Meteorology (2021) Climate data online. Available at: http://www.bom.gov.au/climate/data/, accessed 30 March 2021.

Cooper T, Webb T, Lewis F, et al. (2020) *Brooklyn Wildlife Sanctuary: 2019 Fire Pattern Analysis*. Australian Wildlife Conservancy, Perth, WA.

Crayn DM, Puente-Lelièvre C, Jensen R (2019) Unusual new species of *Styphelia* (Ericaceae, Epacridoideae, Styphelieae) from north-eastern Australia. *Australian Systematic Botany* 32, 216-227.

Doody JS, Green B, Rhind D, et al. (2009) Population-level declines in Australian predators caused by an invasive species. *Animal Conservation* 12, 46-53.

Frank ASK, Johnson CN, Potts JM, et al. (2014) Experimental evidence that feral cats cause local extirpation of small mammals in Australia's tropical savannas. *Journal of Applied Ecology* 51, 1486-1493.

Greenberg S, Godin T, Whittington J (2019) Design patterns for wildlife-related camera trap image analysis. *Ecology and Evolution* 9, 13706-13730.

Griffiths AD, Garnett ST, Brook BW (2015) Fire frequency matters more than fire size: testing the pyrodiversity-biodiversity paradigm for at-risk small mammals in an Australian tropical savanna. *Biological Conservation* 186, 337-346.

Howe A (2018) *Brooklyn Wildlife Sanctuary: uplands omnibus survey report 2018*. Australian Wildlife Conservancy, Perth.

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

Kemp J, Mulder E, Jensen R, et al. (2015a) *Brooklyn Wildlife Sanctuary: ecological survey report 2014*. Australian Wildlife Conservancy, Perth.

Kemp J, Mulder E, Jensen R, et al. (2015b) *Monitoring threatened creek-dwelling frogs, Brooklyn Wildlife Sanctuary 2014*. Australian Wildlife Conservancy, Perth.

Kemp J, Mulder E, Jensen R, et al. (2015c) *Brooklyn Wildlife Sanctuary wet sclerophyll and rainforest ecological survey report 2015*. Australian Wildlife Conservancy, Perth.

Kemp JE, Kutt AS (2020) Vegetation change 10 years after cattle removal in a savanna landscape. *The Rangeland Journal* 42, 73-84.

Kutt AS, Gordon IJ (2012) Variation in terrestrial mammal abundance on pastoral and conservation land tenures in north-eastern Australian tropical savannas. *Animal Conservation* 15, 416-425.

Kutt AS, Kemp JE (2014) Distribution, habitat and conservation status of *Leggadina lakedownensis* (Rodentia: Muridae) in Queensland. *Australian Zoologist* 33, 258-264.

Kutt AS, Vanderduys EP, Perry JJ, et al. (2012) Signals of change in tropical savanna woodland vertebrate fauna 5 years after cessation of livestock grazing. *Wildlife Research* 39, 386-396.

Kutt AS, Woinarski JC (2007) The effects of grazing and fire on vegetation and the vertebrate assemblage in a tropical savanna woodland in north-eastern Australia. *Journal of Tropical Ecology* 23, 95–106.

Lawes MJ, Murphy BP, Fisher A, et al. (2015) Small mammals decline with increasing fire extent in northern Australia: evidence from long-term monitoring in Kakadu National Park. *International Journal of Wildland Fire* 24, 712-722.

Leahy L, Legge SM, Tuft K, et al. (2015) Amplified predation after fire suppresses rodent populations in Australia's tropical savannas. *Wildlife Research* 42, 705-716.

Legge S, Kennedy MS, Lloyd R, et al. (2011) Rapid recovery of mammal fauna in the central Kimberley, northern Australia, following the removal of introduced herbivores. *Austral Ecology* 36, 791-799.

Madsen T, Shine R (1999) Rainfall and rats: Climatically-driven dynamics of a tropical rodent population. *Australian Journal of Ecology* 24, 80-89.

McDonald K, Alford R (1999) A review of declining frogs in northern Queensland. In: *Declines and disappearances of Australian frogs* (Ed A Campbell) pp 14-22. Environment Australia, Canberra pp 14-22.

McDonald KR, Mendez D, Muller R, et al. (2005) Decline in the prevalence of chytridiomycosis in frog populations in North Queensland, Australia. *Pacific Conservation Biology* 11, 114-120.

McGregor H, Legge S, Jones ME, et al. (2015) Feral cats are better killers in open habitats, revealed by animal-borne video. *PloS one* 10, e0133915-e0133915.

McKnight DT, Alford RA, Hoskin CJ et al. (2017) Fighting an uphill battle: the recovery of frogs in Australia's Wet Tropics. *Ecology* 98, 3221-3223.

Meek PD, Ballard G, Claridge A, et al. (2014) Recommended guiding principles for reporting on camera trapping research. *Biodiversity and Conservation* 23, 2321-2343.

Melville J, Smith Date KL, Horner P, et al. (2019) Taxonomic revision of dragon lizards in the genus *Diporiphora* (Reptilia: Agamidae) from the Australian monsoonal tropics. *Memoirs of Museum Victoria* 78, 23-55.

Mills CH, Waudby H, Finlayson G, et al. (2020) Grazing by over-abundant native herbivores jeopardizes conservation goals in semi-arid reserves. *Global Ecology and Conservation* 24, e01384.

Mulder E, Barnett G, Heathcote J, et al. (2017) *Brooklyn Wildlife Sanctuary ecological survey report 2016*. Australian Wildlife Conservancy, Perth.

Pavey CR, Nano CEM (2013) Changes in richness and abundance of rodents and native predators in response to extreme rainfall in arid Australia. *Austral Ecology* 38, 777-785.

Perry JJ, Vanderduys EP, Kutt AS (2015) More famine than feast: pattern and variation in a potentially degenerating mammal fauna on Cape York Peninsula. *Wildlife Research* 42, 475-487.

Prowse TAA, O'Connor PJ, Collard SJ, et al. (2019) Eating away at protected areas: total grazing pressure is undermining public land conservation. *Global Ecology and Conservation* 20, e00754.

Puschendorf R, Hoskin CJ, Cashins SD, et al. (2011) Environmental Refuge from Disease-Driven Amphibian Extinction. *Conservation Biology* 25, 956-964.

Schmidt B, Coulson G, Di Stefano J (2010) Habitat partitioning among sympatric grey kangaroos and swamp wallabies in box-ironbark remnants. In *Macropods: the Biology of Kangaroos, Wallabies and Rat-kangaroos* (Eds G Coulson and M Eldridge) pp 219-230. CSIRO Publishing, Melbourne.

Shine BR (2010) The Ecological Impact of Invasive Cane Toads (Bufo Marinus) in Australia. *The Quarterly Review of Biology* 85, 253-291.

Stanton P, Blackman M (2009) A note on fire management in privately owned sclerophyll forests and woodlands in north-eastern Queensland. *The Forester* 52, 14-15.

Stobo-Wilson AM, Stokeld D, Einoder LD, et al. (2020) Habitat structural complexity explains patterns of feral cat and dingo occurrence in monsoonal Australia. *Diversity and Distributions* 26, 832-842.

Troy S, Coulson G (1993) Home-range of the swamp wallaby, *Wallabia bicolor*. *Wildlife Research* 20, 571-577.

Woinarski JCZ, Legge S, Fitzsimons JA, et al. (2011) The disappearing mammal fauna of northern Australia: context, cause, and response. *Conservation Letters* 4, 192-201.

Ziembicki MR, Woinarski JCZ, Webb JK, et al. (2015) Stemming the tide: progress towards resolving the causes of decline and implementing management responses for the disappearing mammal fauna of northern Australia. *Therya* 6, 169-225.

Appendix 1

2020 Standard Trapping Survey

Table 13. 2020 survey sites, ecosystem description and coordinates

Site name	Ecosystem	Latitude	Longitude
BROO04	Mid to low open forest to woodland on metamorphics or metabasalts and associated colluvium	-16.662562	145.261490
BROO06	Open forests and woodlands on alluvium - box or ironbark dominated	-16.679577	145.248425
BROO10	Open forests and woodlands on alluvium - Corymbia clarksoniana dominated	-16.558091	145.221201
BROO11	Open forests and woodlands on alluvium - Corymbia clarksoniana dominated	-16.589453	145.203805
BROO12A	Open forests and woodlands on alluvium - Corymbia clarksoniana dominated	-16.593437	145.211533
BROO19	Open forests and woodlands on alluvium - Corymbia clarksoniana dominated	-16.557783	145.130008
BROO22	Open forests and woodlands on alluvium - box or ironbark dominated	-16.518048	145.030643
BROO24	Open forests and woodlands on alluvium - box or ironbark dominated	-16.529659	145.022307
BROO29	Eucalyptus tardecidens woodland to open forest on hard-setting soils of residuals and metamorphics	-16.502668	145.059419
BROO30	Tall open forest to woodland on metamorphics, and associated colluvium	-16.492485	145.062922
BROO33	Mid to low open forest to woodlands with Terminalia platyptera on residual surfaces, and minor bedrock	-16.588496	144.923288
BROO35	Mid to low open forest to woodland on metamorphics or metabasalts and associated colluvium	-16.602726	144.932395
BROO36	Mid to low open forest to woodland on metamorphics or metabasalts and associated colluvium	-16.611904	144.925910
BROO52	Tall to low open forest to woodland with Eucalyptus chlorophylla, E. culleni and E. leptophleba on residuals	-16.604344	145.093958
BROO53	Melaleuca stenostachya or M. citrolens on residuals, colluvium, undulating metamorphics and associated minor geologies	-16.593838	145.108054
BROO59	Eucalyptus tardecidens woodland to open forest on hard-setting soils of residuals and metamorphics	-16.525174	144.940862
BROO60	Melaleuca stenostachya or M. citrolens on residuals, colluvium, undulating metamorphics and associated minor geologies	-16.552136	144.944047
BROO61	Tall open forest to woodland on metamorphics, and associated colluvium	-16.537634	144.942984
BROO62	Eucalyptus tardecidens woodland to open forest on hard-setting soils of residuals and metamorphics	-16.560064	144.926016
BROO63	Mid to low open forest to woodlands with Terminalia platyptera on residual surfaces, and minor bedrock	-16.573452	144.917232
BROO65	Mid to low open forest to woodland on metamorphics or metabasalts and associated colluvium	-16.600586	144.950813
BROO66	Mid to low open forest to woodland on metamorphics or metabasalts and associated colluvium	-16.615740	144.947360
BROO67	Mid to low open forest to woodlands with Terminalia platyptera on residual surfaces, and minor bedrock	-16.549858	144.971541
BROO68	Tall to low open forest to woodland with Eucalyptus chlorophylla, E. culleni and E. leptophleba on residuals	-16.552533	144.981809

Site name	Ecosystem	Latitude	Longitude
BROO69	Mid to low open forest to woodlands with Terminalia platyptera on residual surfaces, and minor bedrock	-16.549940	145.044240
BROO70	Eucalyptus tardecidens woodland to open forest on hard-setting soils of residuals and metamorphics	-16.559811	145.063303
BROO71	Eucalyptus tardecidens woodland to open forest on hard-setting soils of residuals and metamorphics	-16.568645	145.078919
BROO72	Open forests and woodlands on alluvium - box or ironbark dominated	-16.580261	145.094567
BROO73	Tall to low open forest to woodland with Eucalyptus chlorophylla, E. culleni and E. leptophleba on residuals	-16.591937	145.091057
BROO75	Open forests and woodlands on alluvium - box or ironbark dominated	-16.578459	145.105685
BROO76	Melaleuca stenostachya or M. citrolens on residuals, colluvium, undulating metamorphics and associated minor geologies	-16.532097	145.103840
BROO78	Tall open forest to woodland on metamorphics, and associated colluvium	-16.545421	145.094526
BROO79	Open forests and woodlands on alluvium - box or ironbark dominated	-16.545927	145.127844
BROO80	Tall open forest to woodland on metamorphics, and associated colluvium	-16.601030	145.199827
BROO81	Melaleuca stenostachya or M. citrolens on residuals, colluvium, undulating metamorphics and associated minor geologies	-16.606945	145.209827
BROO82	Open forests and woodlands on alluvium - Corymbia clarksoniana dominated	-16.608710	145.220535
BROO83	Tall open forest to woodland on metamorphics, and associated colluvium	-16.644059	145.246753
BROO84	Open forests and woodlands on alluvium - Corymbia clarksoniana dominated	-16.669646	145.250316
BROO85	Low altitude mid high to low open forest to woodland on granite	-16.561715	145.210131
BROO86	Low altitude mid high to low open forest to woodland on granite	-16.592309	145.235199
BROO87	Low altitude mid high to low open forest to woodland on granite	-16.607002	145.243246
BROO88	Low altitude mid high to low open forest to woodland on granite	-16.663608	145.285723

Table 14. Species caught in the 2020 Standard Trapping Survey

Scientific name	Common name	No. sites recorded	Total individuals
Reptiles			
Amalosia rhombifer	Zigzag Velvet Gecko	4	6
Anilios broomi	Faint-striped Blind Snake	1	1
Carlia jarnoldae	Lined Rainbow-skink	1	2
Carlia munda	Shaded-litter Rainbow-skink	13	23
Carlia rostralis	Black-throated Rainbow-skink	1	1
Carlia schmeltzii	Robust Rainbow-skink	1	1
Carlia storri	Storr's Rainbow-skink	4	13
Carlia vivax	Tussock Rainbow-skink	10	16
Chlamydosaurus kingii	Frilled Lizard	1	1
Cryptoblepharus adamsi	Adam's Snake-eyed Skink	6	10
Cryptoblepharus metallicus	Metallic Snake-eyed Skink	18	39
Cryptoblepharus virgatus	Striped Snake-eyed Skink	5	5
Cryptophis boschmai	Carpentaria Small-eyed Snake	1	1
Ctenotus spaldingi	Straight-browed Ctenotus	4	6
Ctenotus zebrilla	Southern Cape York Finesnout Ctenotus	6	9
Delma tincta	Excitable Delma	3	3
Demansia torquata	Collared Whipsnake	2	1
Diplodactylus platyurus	Eastern Fat-tailed Gecko	8	11
Diporiphora australis	Tommy Roundhead	21	33
Diporiphora carpentariensis	Gulf Two-lined Dragon	2	2
Gehyra dubia	Dubious Dtella	10	13
Glaphyromorphus crassicaudus	Cape York Mulch-skink	1	1
Heteronotia binoei	Bynoe's Prickly Gecko	15	21
Lerista zonulata	Girdled Slider	4	7
Lucasium steindachneri	Box-patterned Gecko	8	10
Lygisaurus foliorum	Tree-base Litter-skink	8	12
Menetia greyii	Common Dwarf Skink	1	1
Morethia taeniopleura	Fire-tailed Skink	2	2
Oedura castelnaui	Northern Velvet Gecko	6	8
Pygmaeascincus timlowi	Dwarf Litter-skink	5	9
Rhinella marina	Cane toad	9	21
Strophurus williamsi	Eastern Spiny-tailed Gecko	1	1
Varanus storri	Storr's Monitor	2	2
Varanus tristis	Black-headed Monitor	1	1
Vermicella annulata	Eastern Bandy-bandy	1	1
Mammals			
Dasyurus hallucatus	Northern Quoll	1	1
Melomys burtoni	Grassland Melomys, Loolong	1	1
Mus musculus	House mouse	5	5
Pseudomys delicatulus	Delicate Mouse, Molinipi	3	3
Pseudomys gracilicaudatus	Eastern Chestnut Mouse, Karrooka	5	8
Sminthopsis murina	Common Dunnart	1	1

Table 15. All species recorded on camera traps in the 2020 Standard Camera Survey

Scientific name	Common name	Average abundance per 100 trap nights
Ardeotis australis	Australian Bustard	0.07 ± 0.07
Bos taurus	Feral cattle	0.59 ± 0.26
Canis dingo	Dingo	0.13 ± 0.09
Centropus phasianinus	Pheasant Coucal	0.07 ± 0.07
Corvus orru	Torresian Crow	0.46 ± 0.46
Cracticus nigrogularis	Pied Butcherbird	0.07 ± 0.07
Cracticus torquatus	Grey Butcherbird	0.13 ± 0.09
Dasyurus hallucatus	Northern Quoll	0.21 ± 0.16
Felis catus	Feral cat	0.75 ± 0.29
Geophaps scripta	Squatter Pigeon	0.20 ± 0.20
Grallina cyanoleuca	Magpie-Lark	0.20 ± 0.20
Gymnorhina tibicen	Australian magpie	0.33 ± 0.19
Isoodon macrourus	Northern Brown Bandicot	2.30 ± 0.92
Macropus agilis	Agile Wallaby	3.55 ± 0.98
Macropus giganteus	Eastern Grey Kangaroo	1.04 ± 0.51
Melomys sp.	Melomys species	0.17 ± 0.13
Mesembriomys gouldii rattoides	Black-footed Tree Rat	0.42 ± 0.26
Philemon corniculatus	Noisy Friarbird	0.07 ± 0.07
Rattus sp.	Rattus species	0.06 ± 0.06
Sminthopsis sp.	Sminthopsis species	0.06 ± 0.06
Struthidea cinerea	Apostlebird	0.13 ± 0.13
Sus scrofa	Feral Pig	0.44 ± 0.15
Tachyglossus aculeatus	Echidna	0.06 ± 0.06
Trichosurus vulpecula	Common Brushtail Possum	0.18 ± 0.13
Varanus tristis	Black-headed Monitor	0.07 ± 0.07
Varanus varius	Lace Monitor	0.07 ± 0.07
Wallabia bicolor	Swamp Wallaby	0.06 ± 0.06

Appendix 2

Stream-dwelling Frog Survey

Table 16. Locations of 10 Stream-dwelling Frog Survey transects surveyed on Brooklyn in 2021

Creek	Transect name	Start coordinates	End coordinates	First surveyed	Most recent survey
Mary	MaryCk01	-16.552159, 145.223232	-16.549083, 145.225217	16/12/2014	27/01/2021
Station	StationCk01	-16.60951, 145.23923	-16.60973, 145.24295	27/02/2014	02/02/2021
Luster	LusterCk01	-16.63836, 145.24429	-16.63657, 145.24679	1/03/2014	02/02/2021
Leichhardt	LeichhardtCk01	-16.58958, 145.22538	-16.59047, 145.22911	28/02/2014	02/02/2021
Leichhardt	LeichhardtCk02	-16.590835, 145.232399	-16.588326, 145.234895	28/02/2014	27/01/2021
Leichhardt	LeichhardtCk03	-16.586923, 145.236193	-16.587765, 145.239751	7/03/2014	27/01/2021
Leichhardt	LeichhardtCk04	-16.588477, 145.242427	-16.590142, 145.245687	7/03/2014	27/01/2021
Leichhardt	LeichhardtCk05	-16.593359, 145.257685	-16.592267, 145.260719	17/12/2014	07/02/2021
Leichhardt	LeichhardtCk06	-16.59131, 145.261947	-16.590946, 145.265687	17/12/2014	07/02/2021
Leichhardt	LeichhardtCk07	-16.590867, 145.269235	-16.59126, 145.272868	17/12/2014	07/02/2021

Table 17. Frog species recorded across 10 transects in 2021 Stream-dwelling Frog Survey

Species	Total individuals recorded	Sites recorded
Cophixalus ornatus	1	1
Hylarana daemeli	9	4
Litoria nannotis	100	7
Litoria nasuta	1	1
Litoria rheocola	153	6
Litoria serrata	18	3
Litoria jungguy	68	6
Litoria xanthomera	7	1

Document history

Data used to derive Ecohealth metrics in this report was drawn from the following survey reports: Kemp et al. (2015a; 2015b); Mulder et al. (2017); Howe (2018).

Text and analyses

Name	Position	Date
Catherine Hayes	Wildlife Ecologist, North East	31/03/2021 01/06/2021
Andrew Howe	Senior Field Ecologist, North East	31/03/2021

Review

Name	Position	Date
Alexander Watson	Regional Ecologist, North East	30/03/2021
Mareshell Wauchope	Senior Field Ecologist, National Science	13/4/2021 31/5/2021
Catherine Hayes	Wildlife Ecologist, National Science	10/06/2021
Liana Joseph	National Science Manager	9/10/2021

Approval

Name	Position	Date
John Kanowski	Chief Science Officer	18/10/2021