Brooklyn Wildlife Sanctuary

Ecohealth Report 2021

australian wildlife conservancy

Summary

Australian Wildlife Conservancy (AWC) has implemented an Ecological Health Monitoring Program to measure changes in the status and trend of conservation assets and threats to those assets across Brooklyn Wildlife Sanctuary (Brooklyn). Metrics from the program are reported in annual Ecohealth Reports and summarised in the annual Scorecards. This is the Ecohealth Report for 2021. Values of metrics derived in this report were based on data collected during surveys carried out in 2021. The complete set of metrics and their values are summarised in the accompanying Ecohealth Scorecard.

In implementing the Ecohealth program in 2021, 504 camera trap nights and 10 transect surveys were conducted. These included targeted surveys: the Northern Quoll Camera Survey and a Stream-dwelling Frog survey. The Northern Quoll Camera Survey was undertaken by 4 Elements Consulting.

In 2021, the Northern Quoll Camera Survey consisted of three rounds of camera trapping in March, July and October. This survey was previously conducted in July, October and February 2017/18, and July, October and February 2018/19. We found the density of Northern Quolls (*Dasyurus hallucatus*) on Brooklyn to be similar from 2017-2021, with variation in density throughout the year being consistent with their breeding ecology. For each of the three periods surveyed, the density of Northern Quolls declined from July to October and then increased in February/March, likely reflecting variation in both detectability and abundance throughout the year due to their life history.

The Stream-dwelling Frog survey was undertaken on the largest permanent creeks on Brooklyn in December 2014, and January and February 2021. More individual frogs were recorded in 2021 than in 2014, although species richness was lower; with six species recorded in 2014 not detected in 2021. A total of 370 native frogs of nine species were recorded, with mean frog abundance 37.0 ± 10.5 individuals per transect. Average species richness was 3.2 ± 0.4 species per transect. Three threatened frog species detected in 2014 were re-detected in 2021; 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 Queensland *Nature Conservation Act 1992*. It is likely that higher rainfall prior to the 2021 survey affected frog activity at lower elevation transects, which may have contributed to the lower species richness recorded in 2021.

Fire scar analysis on Brooklyn continues to indicate ecological benefits are gained from the prescribed burning program. This program primarily aims to reduce the extent of late dry season wildfires on the sanctuary. In 2021, wildfire extent was only one third of baseline levels. It is expected that wildlife will continue to benefit from patchier, cooler burns and a reduced distance to travel to unburnt habitats.

Contents

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Introduction

Australian Wildlife Conservancy (AWC) currently owns, manages, or works in partnerships across 31 properties in Australia, covering almost 6.5 million hectares, to implement our mission: *the effective conservation of Australian wildlife and their habitats*. AWC relies on information provided by an integrated program of monitoring and research to measure progress in meeting its mission and to improve conservation outcomes.

AWC's Ecohealth Monitoring Program has been designed to measure and report on the status and trends of species, ecological processes and threats on each of these properties (Kanowski et al. 2018). Data from the monitoring program are used to address the following broad questions relevant to our mission:

- 'are species persisting on a property?'
- 'are habitats being maintained?'
- 'are threats below ecologically-significant thresholds?'

For threatened and iconic species, including reintroduced species, AWC's monitoring program aims to obtain more detailed information related to their conservation management; for example, data on survival, recruitment, condition, distribution and/or population size.

The structure of the Ecohealth Program is as follows. AWC's Monitoring and Evaluation framework provides guidance on the development of the Ecohealth Monitoring Plans for each property managed by AWC: these plans describe the conservation values and assets of each property, the threats to these assets, and the monitoring program that will be used to track their status and trend, and to evaluate outcomes. Annual survey plans and schedules are developed to implement these plans. The outcomes of these surveys are presented in annual Ecohealth Reports and summary Ecohealth Scorecards.

This document is one of a series of annual Ecohealth reports for the Brooklyn Wildlife Sanctuary (referred to here as Brooklyn). The companion Ecohealth Scorecard presents the indicators and their metrics in a summary format.

Brooklyn Wildlife Sanctuary

Brooklyn is located in north-east Queensland and is a 59,219 ha in extent (Figure 1). Brooklyn is within the traditional lands of the Djungan people. The property has exceptional biodiversity values. It extends 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 savannah woodlands in the lowlands, and isolated granite boulder outcrops (Figure 2). 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, the known locations of the recently described plant *Styphelia geniculata* are all 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.

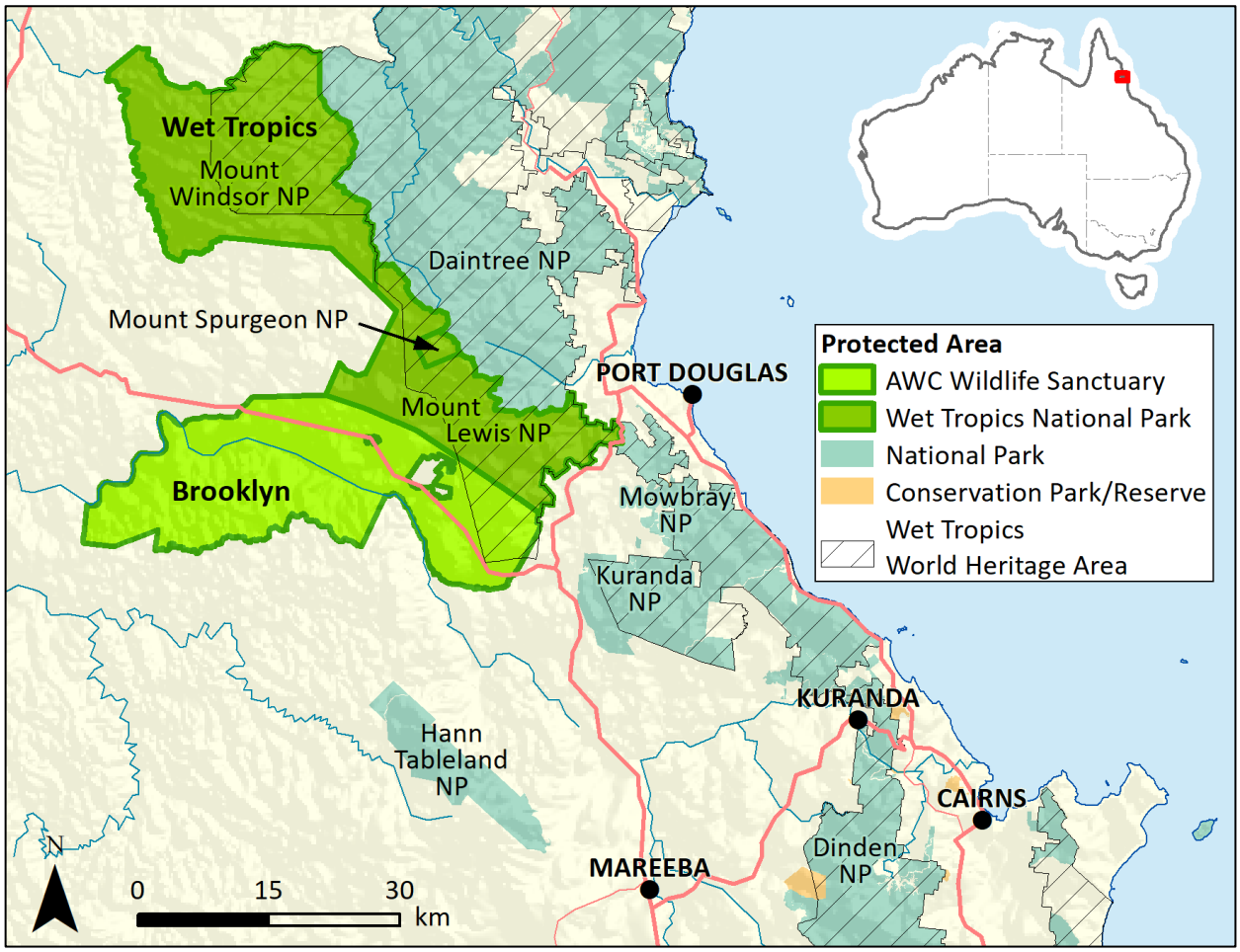

Figure 1. Location and regional context of Brooklyn Wildlife Sanctuary.

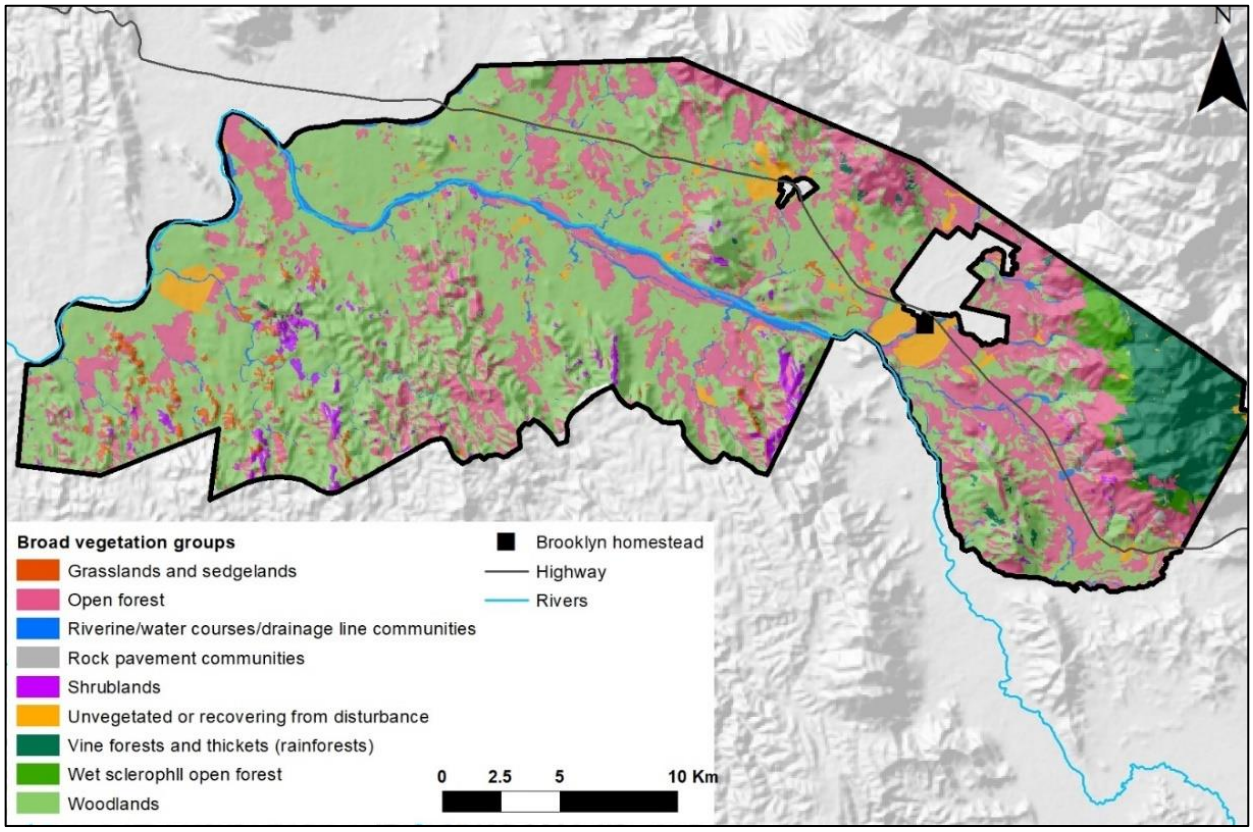

Figure 2. Extent and distribution of broad vegetation types of Brooklyn.

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, and AWC currently runs a small herd (50-100) on a small, fenced, proportion of the sanctuary. Mustering and feral control operations are undertaken annually. Feral horses and pigs are also targeted in regular control operations. Brooklyn was also subject to logging and 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). 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. 2015a). 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

Brooklyn encompasses a broad range of topography with a steep rainfall gradient across the sanctuary. In the east, Brooklyn includes mountains rising to an elevation of 1,140 m with an average rainfall of over 4,000 mm, whereas 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 (~ the centre of Brooklyn) was 952 mm (Bureau of Meteorology 2021; weather station 031180). In 2021, rainfall was below the median, with 838 mm recorded (Figure 3). January, April, October and December received higher than mean rainfall for 2021, but for other months lower than average rainfall was recorded (Figure 4).

Temperature data were taken from the Mareeba Airport for 2021 (weather station 031210), and from the Mareeba QWRC Station (weather station 031066) for baseline data between 1952 to 1992 (Figure 5). Mareeba is approximately 60 km south-east of Brooklyn. The mean maximum temperature in 2021 (29.25°C) was slightly hotter than the historical mean maximum (28.95°C), while the mean minimum temperature in 2021 was 2.2°C warmer than the historical mean minimum (18.76°C and 16.56°C respectively; Bureau of Meteorology 2021).

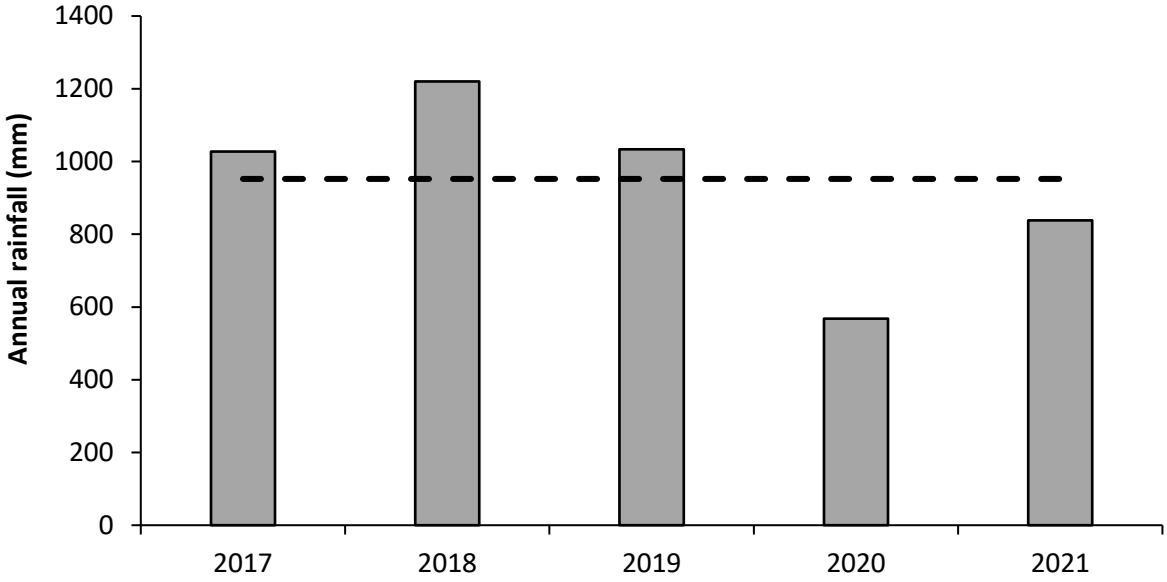

Figure 3. Annual rainfall on Brooklyn, 2017–2021. Dashed line = average using data from 15 years since 1989 Source: Bureau of Meteorology 2021; weather station 031180, Mount Carbine.

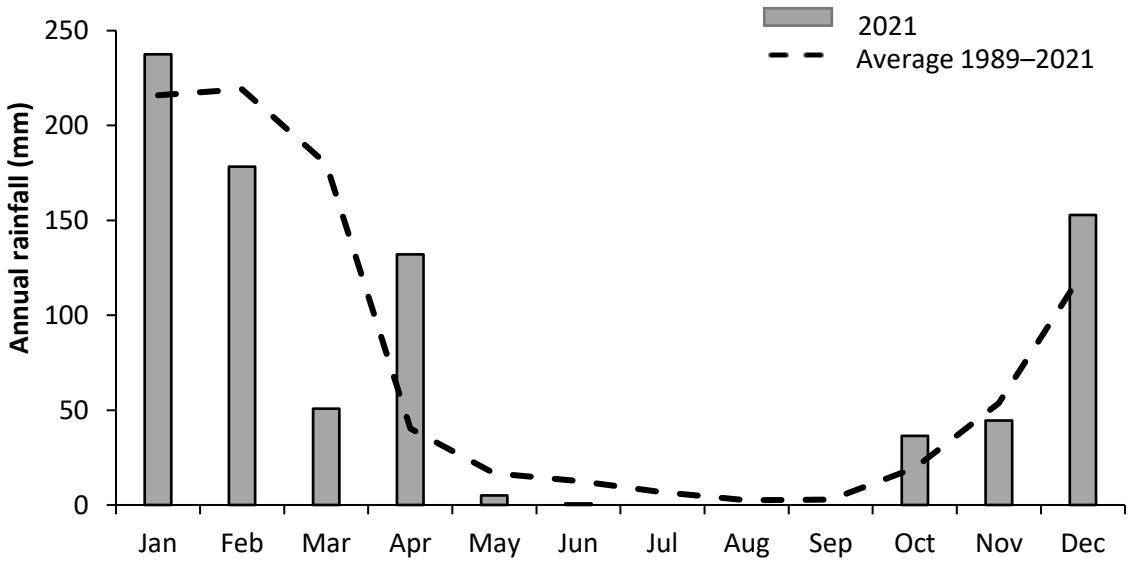

Figure 4. Monthly rainfall on Brooklyn. Dashed line = average monthly rainfall, 1989–2021. Source: Bureau of Meteorology 2021; weather station 031180, Mount Carbine.

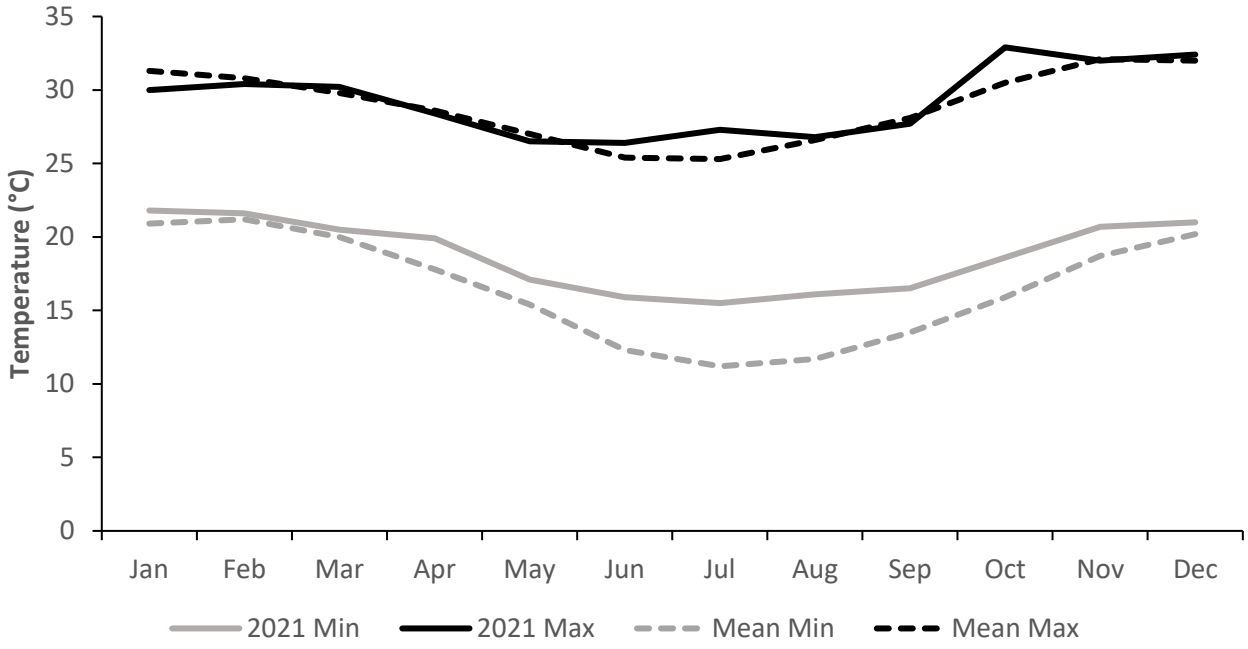

Figure 5. 2021 Mean maximum and minimum temperatures. Source: Bureau of Meteorology, data from Mareeba Airport 2021 (weather station 031210) and Mareeba QWRC Station for 1952–1992 (weather station 031066).

Methods

Monitoring and evaluation framework

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

Key threatened and iconic vertebrates

The Ecohealth program is focused on species of high conservation value, including threatened and 'iconic' species (e.g., regional endemics, species with high public profile and other species of conservation importance because of the role they play in an ecosystem, etc). Where relevant, reintroduced species are also in this category. AWC will aim to develop *Conservation Plans* for the extant threatened and iconic species to ensure early detection of any serious issues that arise and to trigger timely responses. These plans will specify metrics to monitor outcomes for target species against nominated performance criteria.

Vertebrate assemblages and surveillance species

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

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

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

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

Indicators and metrics

On Brooklyn, 55 biodiversity (species and guilds) indicators have been selected for monitoring (Table 1). Six of these indicators are reported upon in this report, including 4 related to threatened and iconic species, and the remainder to surveillance monitoring of faunal assemblages.

Threat metrics are selected to monitor the status and trends of weeds, introduced predators and herbivores, and fire regimes. Fifteen threat indicators have been selected for monitoring (Table 2). One of these threat indicators (fire) is reported on in this report.

Table 1. Biodiversity indicators and metrics for Brooklyn.

Key threatened and iconic vertebrates

Indicator	Survey name	Survey method	Metric/s
Mammals			
Northern Quoll (*Dasyurus hallucatus*)	Northern Quoll Camera Survey	Sensor cameras	Density
Frogs			
Torrent Tree Frog (*Litoria nannotis*)	Stream-dwelling Frog Survey	Stream transects	Abundance, occupancy
Common Mist Frog (*Litoria rheocola*)	Stream-dwelling Frog Survey	Stream transects	Abundance, occupancy
Serrated-armed Tree Frog (*Litoria serrata*)	Stream-dwelling Frog Survey	Stream transects	Abundance, occupancy

Vertebrate assemblages and surveillance species

Indicator	Survey name	Survey method	Metric/s
Mammals			
Assemblage richness	Standard Trapping Survey, Northern Quoll Camera Survey	Live trapping, sensor cameras, incidentals	Number of species
Small-medium mammal			
Upland *Rattus* species assemblage (Bush Rat, *R. fuscipes*; and Cape York Rat, *R. leucopus*)	Standard Trapping Survey (upland)	Live trapping and sensor cameras	Abundance, occupancy
Sminthopsis assemblage (Common Dunnart, *S. murina*; and Chestnut Dunnart, *S. archeri*)	Standard Trapping Survey (upland)	Live trapping and sensor cameras	Abundance, occupancy
Rock-wallaby assemblage (Godman's Rock-wallaby, *Petrogale godmani*; and Mareeba Rock-wallaby, *P. mareeba*)	Targeted Rock-wallaby Survey	Sensor cameras	Abundance, occupancy
Upland small mammal guild	Standard Trapping Survey (upland)	Live trapping	Abundance, occupancy, richness
Lowland small mammal guild	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy, richness
Upland medium mammal guild	Standard Trapping Survey (upland)	Sensor cameras	Abundance, occupancy, richness
Lowland medium mammal guild	Standard Trapping Survey (lowland)	Sensor cameras	Abundance, occupancy, richness
Spotted-tailed Quoll (*Dasyurus maculatus gracilis*)	Targeted Spotted-tailed Quoll Survey	Sensor Cameras	Abundance, occupancy

Indicator	Survey name	Survey method	Metric/s
Black-footed Tree-rat (*Mesembriomys gouldii rattoides*)	Standard Camera Survey (lowland)	Sensor cameras	Abundance, occupancy
Giant White-tailed Rat (*Uromys caudimaculatus*)	Standard Camera Survey (upland)	Sensor cameras	Abundance, occupancy
Fawn-footed Melomys (*Melomys cervinipes*)	Standard Trapping Survey (upland)	Live trapping	Abundance, occupancy
Grassland Melomys (*Melomys burtoni*; upland)	Standard Trapping Survey (upland)	Live trapping	Abundance, occupancy
Grassland Melomys (*Melomys burtoni*; lowland)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Northern Brown Bandicoot (*Isoodon macrourus*; upland)	Standard Trapping Survey (upland)	Sensor cameras	Abundance, occupancy
Northern Brown Bandicoot (*Isoodon macrourus*; lowland)	Standard Trapping Survey (lowland)	Sensor cameras	Abundance, occupancy
Northern Long-nosed Bandicoot (*Perameles nasuta*)	Standard Camera Survey (upland)	Sensor cameras	Abundance, occupancy
Musky Rat-kangaroo (*Hypsiprymnodon moschatus*)	Standard Camera Survey (upland)	Sensor cameras	Abundance, occupancy
Rusty Antechinus (*Antechinus adustus*)	Standard Trapping Survey (upland)	Live trapping	Abundance, occupancy
Northern Short-tailed Mouse (*Leggadina lakedownensis*)	Standard Trapping Survey (upland)	Live trapping	Abundance, occupancy
Eastern Chestnut Mouse (*Pseudomys gracilicaudatus*)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Common Rock-rat (*Zyzomys argurus*)	Targeted Common Rock-rat Survey	Sensor cameras	Abundance, occupancy
Arboreal mammals			
Assemblage richness	Spotlighting and Standard Camera Survey	Spotlighting and sensor cameras	Number of species
Upland possum and glider guild	Possum and Glider Spotlighting Survey (uplands)	Spotlighting	Abundance, richness
Lowland possum and glider guild	Possum and Glider Spotlighting Survey (lowlands)	Spotlighting	Abundance, richness
Common Brushtail Possum (*Trichosurus vulpecula*)	Standard Camera Survey (lowlands)	Sensor cameras	Abundance, occupancy
Large herbivores			
Lowland macropod assemblage	Standard Camera Survey (lowland)	Sensor cameras	Abundance, richness
Agile Wallaby (*Macropus agilis*)	Standard Camera Survey (lowland)	Sensor cameras	Abundance, occupancy
Eastern Grey Kangaroo (*Macropus giganteus*)	Standard Camera Survey (lowland)	Sensor cameras	Abundance, occupancy
Large predatory mammals			
Dingo (*Canis dingo*; upland and lowland)	TBD	TBD	Abundance, occupancy
Reptiles			
Assemblage richness	Standard Trapping Survey (upland), Standard Trapping Survey (lowland)	Spotlighting, sensor cameras, incidentals	Number of species
Small-medium reptiles			
Upland small-medium reptile guild	Standard Trapping Survey (upland)	Live trapping	Abundance, richness

Indicator	Survey name	Survey method	Metric/s
Lowland small-medium reptile guild	Standard Trapping Survey (lowland)	Live trapping	Abundance, richness
Diporiphora species assemblage (*D. australis*, *D. carpentariensis*, *D. jugularis*, *D. nobbi*)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Carlia species assemblage (*C. jarnoldae*, *C. munda*, *C. pectoralis*, *C. rostralis*, *C. schmeltzii*, *C. storri*, *C. vivax*)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Lygisaurus species assemblage (*L. aeratus*, *L. foliorum*, *L. malleolus*; upland)	Standard Trapping Survey (upland)	Live trapping	Abundance, occupancy
Lygisaurus species assemblage (*L. aeratus*, *L. foliorum*, *L. malleolus*; lowland)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Yakka Skink (*Egernia rugosa*)	Targeted Yakka Skink Survey	Targeted survey	Population estimate, abundance (per site), occupancy
Bynoe's Prickly Gecko (*Heteronotia binoei*)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Straight-browed Ctenotus, (*Ctenotus spaldingi*)	Standard Trapping Survey (lowland)	Live trapping	Abundance, occupancy
Black-headed Monitor (*Varanus tristis*)	Standard Camera Survey (lowland)	Sensor cameras	Abundance, occupancy
Birds			
Assemblage richness	All targeted bird surveys, research observations	All surveys methods for birds, incidentals	Number of species
Northern Masked Owl (*Tyto novaehollandiae kimberli*)	Northern Masked Owl Targeted Survey	Targeted survey	Occupancy
Blue-faced Parrot Finch (*Erythrura trichroa*)	Targeted Blue-faced Parrot Finch Survey	Targeted survey	Abundance
Weebill (*Smicrornis brevirostris*)	Targeted Bird Survey	Call playback	Occupancy
Grey-crowned Babbler (*Pomatostomus temporalis*)	Targeted Bird Survey	Call playback	Occupancy
Bridled Honeyeater (*Bolemoreus frenatus*)	Targeted Bird Survey	Call playback	Occupancy
Red-backed Fairy-wren (*Malurus melanocephalus*)	Targeted Bird Surveys	Call playback	Occupancy
Frogs			
Assemblage richness	Stream-Dwelling Frog Survey	Stream transects	Number of species
Stream-dwelling frog guild	Stream-Dwelling Frog Survey	Stream transects	Abundance, richness

Table 2. Threat indicators and metrics for Brooklyn 2021

Indicator	Survey name/methods	Metric/s	Performance criteria
Pest animals			
Feral cattle (*Bos taurus)*	Feral Herbivore survey (aerial; upland and lowland)	Number of cattle detected	TBD
Feral horse (*Equus caballus*)	Feral Herbivore survey (aerial)	Number of horses detected	TBD

Indicator	Survey name/methods	Metric/s	Performance criteria
Feral cat (*Felis catus*) (upland and lowland)	Targeted survey	Number of cats detected	TBD
Pig (*Sus* scrofa) (upland and lowland)	Feral Herbivore survey (aerial; upland and lowland)	Number of pigs detected	TBD
Cane toad *Rhinella marina* (upland and lowland)	Standard Trapping Survey (upland and lowland)	Number of cane toads detected, abundance, occupancy	TBD
Weeds			
Targeted weeds	Targeted Weed Survey	Frequency, occupancy at surveyed sites	TBD
Targeted weeds in threatened dry vine scrub	Targeted Vegetation Survey	Frequency at surveyed sites	TBD
Gamba grass (*Andropogon gayanus*)	Targeted Weed Survey	Number of infestations, occupancy at known sites	TBD
Grader grass (*Themeda quadrivalvis*)	Targeted Weed Survey	Occupancy at sites surveyed, % cover	TBD
Hymenachne (*Hymenachne amplexicaulis*)	Targeted Wetlands and Waterbody Survey	Extent of infestation, frequency at occupied sites	TBD
Rubber vine (*Cryptostegia grandiflora*)	Targeted Weed Survey	Frequency, occupancy at surveyed sites	TBD
Lantana (*Lantana camara*)	Targeted Weed Survey	Frequency, occupancy at surveyed sites	TBD
Giant salvinia (*Salvinia molesta*)	Targeted Wetlands and Waterbody Survey	Occupancy at known sites and surveyed sites	TBD
Shrubby stylo (*Stylosanthes scabra*)	Targeted Weed Survey	Occupancy, % cover at surveyed sites	TBD
Fire			
Fire	Fire Scar Analysis	Extent, frequency, time since fire, distance to unburnt vegetation	Area burned by late season fires

Survey types and history

To report on the biodiversity and threat indicators, our survey teams conduct a variety of surveys repeated on a schedule of 1–5 years, as required to obtain timely information on each indicator. These include:

For key threatened and iconic vertebrates, two targeted surveys are used:

- Northern Quoll Camera Survey
- Stream-dwelling Frog Survey

For surveillance monitoring of assemblages and species, these include:

- Standard Trapping Survey (upland and lowland)
- Standard Camera Survey (upland and lowland)
- Targeted Spotted-tailed Quoll Survey
- Targeted Rock-wallaby Survey
- Targeted Common Rock-rat Survey
- Possum and Glider Spotlighting Survey
- Targeted Yakka Skink Survey
- Targeted Bird surveys for Weebill, Grey-crowned Babbler, Bridled Honeyeater and Red-backed Fairy-wren;
- Targeted Northern Masked Owl Survey

- Targeted Blue-faced Parrot Finch Survey

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

- Feral Herbivore survey (aerial)
- Targeted Survey - Feral Cats
- Targeted Vegetation Survey (TBD)
- Targeted Weeds Survey (TBD)
- Targeted Wetlands and Waterbody Survey (TBD)
- Fire scar analysis

Two of these ecological surveys were conducted on Brooklyn in 2021 (Table 3). The Fire Scar Analysis was completed using satellite data from 1999–2004 (a few years prior to acquisition) to 2021. Data used to derive Ecohealth metrics on Northern Quolls was received from 4 Elements consulting and for other indicators the following reports were used: Kemp et al. (2015a; 2015b); Hayes et al. (2021) and Matheus-Holland et al. (2021).

The methodology is described and results of these surveys and computations are reported on in this document.

Table 3. Survey history and effort for Ecohealth surveys on Brooklyn reported on in this report. CTN = Camera Trap Nights.

Survey name	Effort in 2021	Description/comment	Previous surveys
Northern Quoll Camera Survey	504 CTN	36 sites surveyed in a grid of 6 x 6 cameras in March, July and October 2021. One camera was deployed at each site, for 14 nights.	Jul 2017 — 36 sites (504 CTN) Oct 2017 — 36 sites (504 CTN) Feb 2018 — 36 sites (504 CTN) Jul 2018 — 36 sites (504 CTN) Oct 2018 — 36 sites (504 CTN) Feb 2019 — 36 sites (504 CTN)
Stream-dwelling Frog Survey	4 km transects	10 x 400 m transects along major creeks covering a range of elevations from lowlands to upper reaches of Mt Lewis.	Dec 2014 — 10 transects (4 km)

Survey design and methods

In addition to the methods outlined below, fauna records were collected incidentally when staff were on site.

Northern Quoll Camera Survey

Four Elements Consulting conducted the Northern Quoll Camera Survey on Brooklyn from 2017–2021. Each year, the survey consisted of 36 established monitoring sites in the south-eastern part of the Sanctuary (Figure 6). The survey design consists of a 6 x 6 camera grid, with each camera spaced 350 m apart, encompassing 306.25 ha (Figure 6). A single Bestguarder Trail Camera (Model SG990v) was set at each site and mounted horizontally on a tree. A bait canister filled with chicken necks was placed below the camera. Cameras were deployed for 14 consecutive days. After cameras were collected, images were sorted and individual quolls identified.

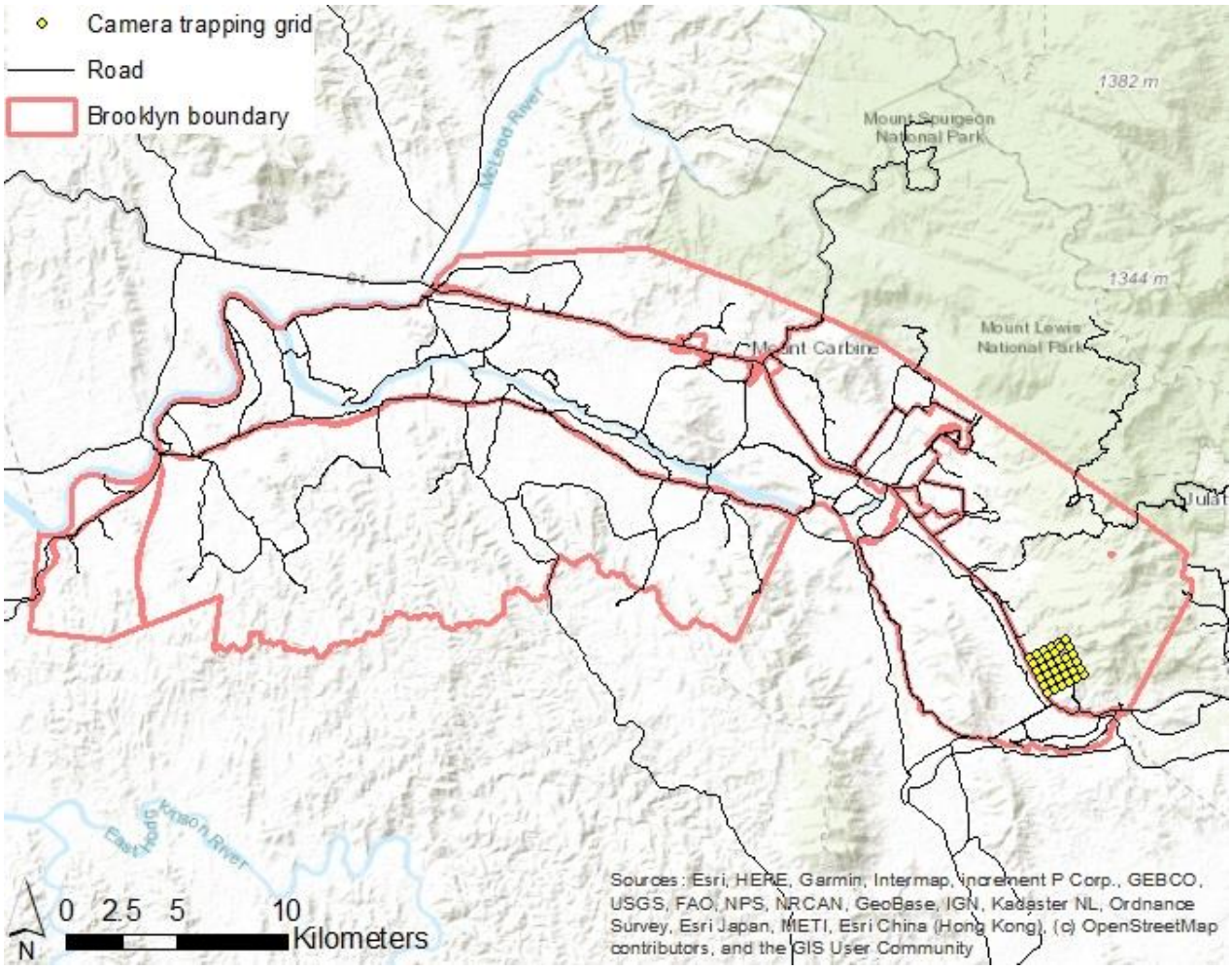

Figure 6. Camera trap grid (36 cameras) location on Brooklyn Sanctuary.

Stream-dwelling Frog Survey

In 2021, 10 transects were surveyed to monitor stream-dwelling frogs. These permanent transects are located on the largest and most permanent creeks on Brooklyn (Figure 7). Three creeks have one transect each, the fourth creek has seven transects across an elevation range of 370–930 m. A habitat/landscape photo was taken before the start of each survey — at the downstream-end of the transect (pointing upstream). After dark, surveys commenced at the downstream-end of the transect, with at least two staff systematically searching either side of the creek (to 5 m from the water's edge). Searching was done using 200 lumen LED Lenser head-torches, looking for eye-shine on rocks, logs, tree trunks and foliage, and also by listening for frog calls.

Surveys are planned every three to five years 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 2021 after more rain fell.

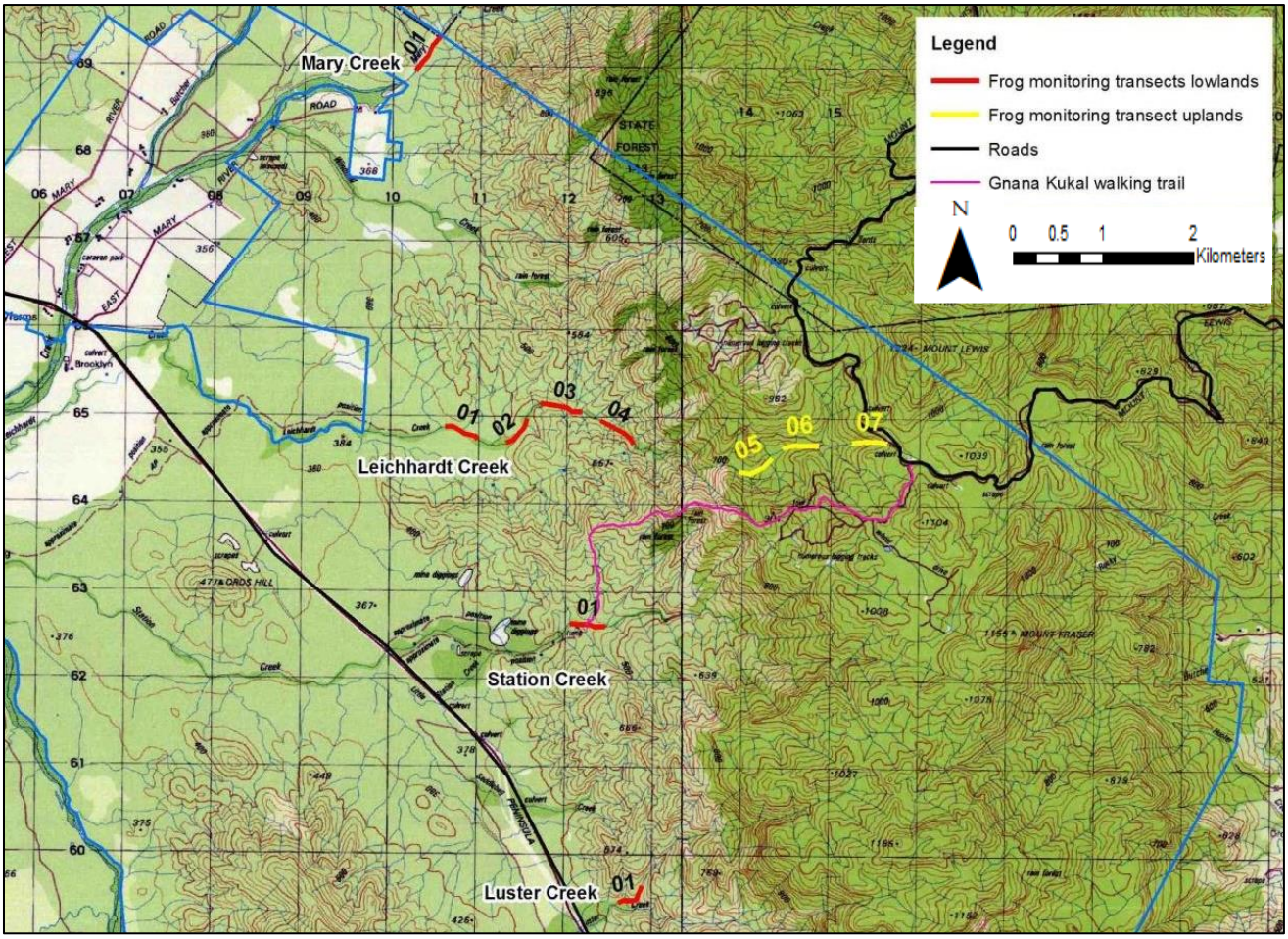

Figure 7. Stream-dwelling Frog Survey transects on Brooklyn.

Analysis methods

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

As there are diverse ecosystems on Brooklyn ranging from rainforest to open grassland, the metrics are reported for species and groups of species of a particular 'guild'. This requires that all sites surveyed, and all species reported on, are correctly assigned to a particular guild (or guilds) prior to undertaking these calculations.

Table 4. Metrics and associated calculations for Brooklyn for results presented in this report.

Indicator	Metric	Survey data sources	Description	Analysis summary/calculation
Assemblage richness	Number of species	All surveys and incidental records	A measure of intactness for the whole sanctuary	The number of species detected on the sanctuary within the last 2–5 years is compared to the number of species listed as 'confirmed', 'very likely' or 'likely' on the sanctuary species list.
Northern Quoll	Density	Northern Quoll Camera Survey	Quolls were individually identified SECR analysis was used to measure density	Spatial Capture Recapture Analysis (SECR) is used to estimate the number of individuals per km^2 (± SE) (further details below). The ShinyApp SecrApp 1.3 was used to estimate density. Multiple combinations of detection function, distribution, detector type, buffer and likelihood were used to determine the best model. Suggested buffer width is the most reasonable to use as this is estimated by the model and depends on scale of movement of the animal (Efford 2011). The best model (lowest AIC; Akaike 1987) was a half-normal detection function, a binomial distribution, full likelihood, count detector type and the suggested buffer of 1,550m. The prediction code was run to estimate density and standard error for each session.
Amphibians (Stream-dwelling frogs, individual species)	Abundance	Stream-dwelling Frog Survey	A measure of activity; either number of detections per 100 trap nights, or per site.	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
Amphibians (individual species)	Occupancy	Stream-dwelling Frog Survey	A measure of distribution; the proportion of sites where the species was recorded using a particular technique.	The number of transects at which the species was recorded/number of transects surveyed (x100 as reported in percentage)
Amphibians (Stream-dwelling frog guild)	Richness	Stream-dwelling Frog Survey	A measure of diversity; average number of species per transect.	The average number of species recorded at each transect ± SE

Fire scar analysis

Fire scar data were derived from Landsat satellite imagery, and in later years supplemented by 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 two 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'. For each year, unburnt areas were created by erasing the recorded fires from the entire boundary area. The maps and statistics for the analyses were created using ArcGIS (Environmental System Research Institute Inc., Redlands, CA, USA) with Spatial Analyst, and were semi-automated using Python scripting. Graphs were produced using Microsoft Excel. Detailed methods are provided in Cooper et al. (2020).

Results

Key threatened and iconic vertebrates

Northern Quoll Camera Survey

The average density of Northern Quolls on Brooklyn in 2021 was estimated to be 2.95 (± 0.59 SE) individuals/km^2. Overall, the average density of Northern Quolls per year appeared similar from 2017–2021. In 2017 the average density of Northern Quolls was 2.97 (± 0.67 SE) and 3.89 (± 0.59 SE) in 2018 (Figure 8). The variation in density within years is consistent with their breeding ecology (Heiniger et al. 2020). Northern Quolls breed in the middle of the dry season (June), males die off by the end of the dry season (October), and juvenile recruitment occurs after denning (February). On Brooklyn, the density of Northern Quolls declined from July/August to October/November and increased from October/November to February/March (Figure 8). Northern Quoll density was highest in July/August 2018 showing a density of 5.22 individuals/km^2 (± 0.61 SE). Conversely, the lowest density of Northern Quolls at this is site was in October/November 2021 with 1.65 individuals/km2 (± 0.41 SE; Figure 8).

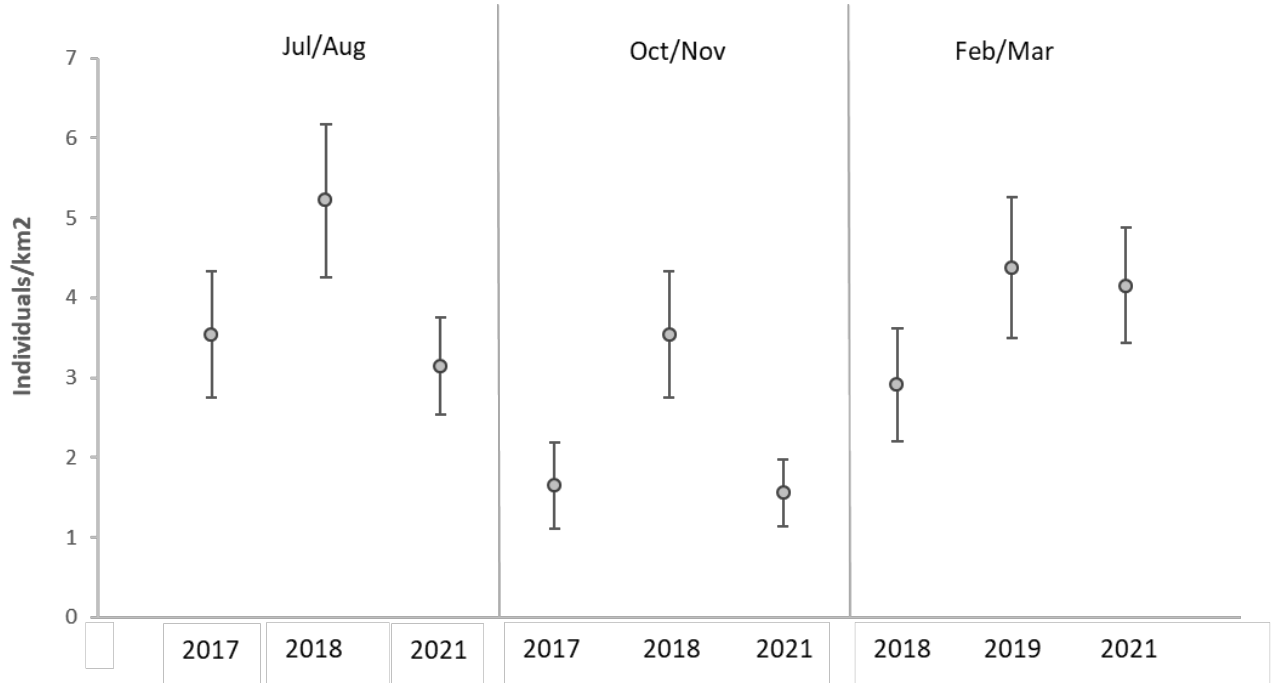

Figure 8. SECR results from July 2017–March 2021 for the most parsimonious model.

Torrent Tree Frog, Common Mist Frog and Serrated-armed Tree Frog

All three Key Threatened and Iconic Indicator species were recorded in 2021 (Table 5). The Torrent Tree Frog (*Litoria nannotis*) was recorded in greater abundance, but lower occupancy in 2021 than in 2014 (Table 5); it was not re-detected at the highest-elevation transect. The endangered Common Mist Frog (*Litoria rheocola*) had a large increase in abundance and occupancy; it was recorded at two transects where it had not been previously observed (including the highest-elevation transect; Table 5). Both the occupancy and abundance of the Serrated-armed Tree Frog (*Litoria serrata*) declined in 2021 compared to 2014 (Table 5).

Table 5. Frog metrics from 2021 Stream-dwelling Frog Survey.[1]

Indicator	Abundance^		Occupancy^	
	2014	2021	2014	2021
Torrent Tree Frog	6.8 ± 1.8	10.0 ± 3.2	80%	70%
Common Mist Frog	7.3 ± 4.5	15.3 ± 8.8	40%	60%
Serrated-armed Tree Frog	5.9 ± 3.4	1.8 ± 1.2	40%	30%

[1]. Only metrics for the species detected at more than three sites are shown.

^ Abundance is average abundance across 10 transects. Occupancy is the percentage of transects at which the species or guild was detected.

Vertebrate assemblages and surveillance species

Surveys to support evaluation of most assemblage and surveillance indicators were not conducted in 2021.

Frogs

In 2020–21, 9 frog species were recorded from 40 known or likely to occur on Brooklyn. Missing species were those that are detected only after substantial rainfall.

The Stream-dwelling Frog survey was undertaken on the largest and most permanent creeks on Brooklyn in December 2014, and January and February 2021. More individual frogs were recorded in 2021 than in 2014, although species richness was lower (Table 6); with six species recorded in 2014 not detected in 2021. A total of 370 native frogs of nine species were recorded, with mean frog abundance 37.0 ± 10.5 individuals per transect in 2021 as opposed to 30.80 ± 8.01 in 2014. In 2021, the average species richness was 3.2 ± 0.4 species per transect and 4.8 ± 0.63 in 2014. Differences are possibly related to survey timing and associated variation in rainfall.

Table 6. Stream-dwelling frog guild metrics

Indicator	Richness		Abundance	
	2014	2021	2014	2021
Stream-dwelling frog guild	4.8 ± 0.63	3.2 ± 0.4	30.80 ± 8.01	37.0 ± 10.5

Threat indicators

Fire

During 2021, ground-based and aerial prescribed burning was conducted by the Brooklyn Sanctuary Manager. The 2021 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 7). The proportion of the sanctuary burnt by late dry season fire in 2021 was close to one third of the baseline average (Table 7). More detail on the Brooklyn fire program is in the annual fire reports (Cooper et al. 2020).

Table 7. Fire metrics for Brooklyn for 2021.

Metric	**Baseline** average 1999/ 2001–04	**AWC** average 2005/07 –20	**2021 result**	**Trend** (AWC vs baseline)	**Trend** (2021 vs baseline)
Area burnt by early dry season (EDS) fire (%)	7	**14**	**13**	↑	↑
Area burnt by late dry season (LDS) fire (%)	14	**8**	**5**	↓	↓
Total area burnt (%)	20	**22**	**18**	↔	↔
Cumulative extent burnt by LDS fire in past 3 years (%)	43	**21**	**27**	↓	↓
Modal frequency of fires in last six years	2		**1**	↓	↓
Modal frequency of LDS fires in last six years	0		**0**	↔	↔
Area of long-unburnt vegetation (3+ years since fire) (%) *Note: baseline includes areas subject to heavy grazing*.	42	**45**	**42**	↔	↔
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**	↓	↓

Notes: Area-base metrics are expressed as % of the 59,220 ha sanctuary.

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 onwards, for 3-year metrics.

Trend: change in metric compared with baseline, considering (i) average across AWC management; (ii) current year.

Change in metric shown by arrows: increase ↑, no change ↔, reduction ↓).

Inferred consequences for ecological health depicted by colour: improving in green (e.g., ↑ or ↓, depending on the metric); deteriorating in red (e.g., ↑ or ↓); no change, or if the change cannot be interpreted in terms of ecological health, in black. (↔, ↑ or ↓)

Discussion

This Ecohealth report summarises the results of two targeted surveys conducted in 2021, for Northern Quolls and stream-dwelling frogs, as well as assemblage and fire metrics.

The results of the Northern Quoll survey suggest the population on Brooklyn has remained relatively stable since the start of targeted surveys in July 2017. The variation in density estimates between 2017, 2018 and 2021 is likely due to fluctuations in rainfall, which has been shown to affect fecundity and distribution of mammals (Ujvari et al. 2016). The low rainfall in 2016 likely influenced recruitment in that season and therefore density of Northern Quolls observed in 2017/18. Increased rainfall in 2017 is likely to have led to increased resource availability, and therefore density of Northern Quolls, observed in 2018/19. Another below average rainfall year in 2020 seems to have resulted in another slight reduction in breeding over the wet season 2020/2021, however density in autumn 2021 was only slightly lower density than 2018 suggesting Northern Quolls were not too negatively affected by recent lower rainfall events.

The intensive surveys conducted on a small plot of 300 ha may not provide density estimates that can be extrapolated to the larger Sanctuary (59,000 ha), particularly since records collected over the past 15 years indicate Northern Quoll distribution on Brooklyn is indeed clumped and unevenly spread across the landscape (Allen et al. 2013; Matheus-Holland et al. 2020). The survey design appears to be sensitive enough to detect year to year fluctuations in abundance in response to rainfall, with Northern Quoll populations responding strongly the year after good rainfall events. However, the current survey design does not inform broader patterns of occupancy that may fluctuate in response to resource redistribution because of disturbances such as fire, or in response to weather events and climate change. Looking ahead, survey experimental design alternatives are under investigation that aim to provide further insight into occupancy, temporal range extensions and contractions.

Ecohealth surveys in 2021 provide encouraging results that all three threatened frog species are persisting. Although the Torrent Tree Frog and Common Mist Frog previously suffered declines at higher elevations (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). Another positive result was the large increase in abundance recorded for the endangered Common Mist Frog, over twice the abundance recorded in 2014, as well as an 20% increase in occupancy.

Overall frog species richness in 2021 was lower than in 2014. The Vulnerable Serrated-armed Tree Frog was recorded at fewer transects and in lower abundance than in 2014 and the Torrent Tree Frog was absent from the highest-elevation transect. While these results were likely due in part to variation in total rainfall prior to the surveys, further monitoring is needed to confirm any long-term changes in frog assemblages on Brooklyn.

Fire scar analysis on Brooklyn continues to indicate ecological benefits are gained from the prescribed burning program. This program is accomplishing its primary aim to reduce the extent of late dry season wildfires on the sanctuary, with only approximately one-third of the extent burned by late dry season wildfires in 2021 compared to baseline metrics taken before fire management actions were implemented. It is expected that wildlife will continue to benefit from patchier, cooler burns and a reduced distance to travel to unburnt habitats; in 2021 the mean distance to unburnt vegetation was less than half the mean distance observed prior to AWC's fire management program.

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