GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Northern quoll targeted surveys in the Chichester Ranges: a six-year summary

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Biodiversity and Conservation Science

Northern quoll targeted surveys in the Chichester Ranges: a six-year summary

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Report prepared for Roy Hill Pty Ltd

December 2020

Department of Biodiversity, Conservation and Attractions

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Cover image: a female northern quoll with young

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Summary

DBCA has undertaken targeted surveys for northern quolls (*Dasyurus hallucatus*) within the Chichester Ranges from 2014 to 2019 as a component of Roy Hill's Northern Quoll Research Plan. The purpose of these surveys was to identify long term monitoring sites for northern quolls and to provide further data to estimate the population size and distribution of quolls within the Chichester Ranges. Northern quoll populations have fluctuated at monitoring sites, including Quoll Knoll, Mesa 228, and Wall Creek. Reasons for northern quoll absences are likely due to predation by feral cats, high-intensity fire activity, and other climatic variation (e.g., low rainfall). Despite this, northern quolls have persisted at most monitoring sites, showing that the Chichester Ranges can support small disjunct populations of northern quolls in areas of suitable habitat. Feral cat control using a range of techniques is critical to continue to make these areas habitable for northern quolls. Monitoring techniques have evolved over the six-year monitoring period from the use of cage traps to predominately camera traps. The use of camera traps compared to more labour intensive and intrusive cage trapping allows for the presence of a range of animals too large or too cautious to enter cage traps. Camera traps also permit longer monitoring periods which means a higher chance of an animal being detected, as well as facilitating the comparison of the presence of northern quolls across longer periods of time. Monitoring of the Chichester Ranges has identified many sites with low abundances of northern quolls, whereas the greater Pilbara region supports several large quoll populations with high conservation value. Further conservation and research of these populations is of high importance, particularly as the threat of cane toad invasion looms. DBCA recommends a review of the current approved Roy Hill northern quoll research plan to transfer the focus from the Chichester Ranges and redirect research effort towards remaining knowledge gaps that benefit the conservation of northern quolls.

1 Introduction

This report summarises the northern quoll (*Dasyurus hallucatus*) research undertaken by the Department of Biodiversity, Conservation and Attractions (DBCA) for Roy Hill, as well as collaborative research projects with Charles Sturt University, Edith Cowan University, some results from Fortescue Metals Group programs, and other monitoring programs funded by Roy Hill that have provided data on northern quolls from 2014 to 2019. This research is focused on northern quoll populations and their threatening processes within the Chichester Ranges. The research is a component of Roy Hill's Northern Quoll Research Plan (NQRP) (100RH-3000-EN-REP-2033) to meet the requirements of Condition 3 of *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval 2011/5867. The purpose of this research was to identify potential monitoring sites for northern quolls (*Dasyurus hallucatus*) and to provide further data to estimate the population and distribution of quolls within the Chichester Ranges.

This summary covers the annual survey efforts undertaken throughout the area by DBCA from 2014 up to and including 2019 (Johnson and Anderson, 2014, Dunlop et al., 2015, Dunlop and Johnson, 2016, Dunlop et al., 2018, Birch et al., 2019, Cowan et al., 2020b), as well as further surveys and works (not specifically targeting northern quolls) undertaken by Animal Pest Management Services, Aussie Feral Pests (AFP), and Ecoscape Pty Ltd, for and on behalf of Roy Hill during this six-year period. The results of these surveys are summarised and discussed in this report.

1.1 Northern quoll *Dasyurus hallucatus*

The northern quoll is a medium-sized omnivorous marsupial (~520g), the smallest of Australia's four species of *Dasyurus* (Oakwood, 1997). Northern quolls were once widely distributed from the Pilbara and Kimberley in Western Australia, across the Top End to southern Queensland, but have now contracted in distribution and density to several disjunct populations within their former range (Moore et al., 2019, Braithwaite and Griffiths, 1994). In 2005, the northern quoll was listed as an Endangered species under the Commonwealth's EPBC Act 1999 (Oakwood et al., 2016, Department of Sustainability, 2011). This was due to an alarming decrease or complete collapse of some of the once locally abundant populations in Queensland and the Northern Territory, and a subsequent contraction of its range (Oakwood et al., 2016). Northern quolls have declined at a rapid rate in association with the spread of the introduced cane toad *Rhinella marina*, which poisons quolls in their predation attempts (Moore et al., 2019).

Several other ecological factors are contributing to the decline of northern quolls and other critical weight range (CWR) mammals, including predation by feral cats (*Felis catus*) and red foxes (*Vulpes vulpes*), altered fire regimes, grazing and subsequent habitat modification by introduced herbivores, habitat loss and fragmentation, as well as the cumulative and interactive effects between these (Braithwaite and Griffiths, 1994, Woinarski et al., 2014, Johnson and Isaac, 2009). Modelling the life history parameters of northern quolls indicate that juvenile survival rates have the most impact on overall population persistence (Moro et al., 2019). This suggests that management should focus on protecting the quoll dispersing phase by removal of threats (feral predators) or preservation of habitat corridors by burning outside of quoll dispersal times. Northern quolls inhabit a variety of areas, including rocky outcrops and ridges, rainforests, eucalypt forest and woodland, sandy lowlands, shrublands, grasslands, and desert (Department of Sustainability, 2011, Cook and Morris, 2013). In the Pilbara, northern quolls appear to depend more on complex rocky habitat (Molloy et al., 2017) compared to northern quolls in the Northern Territory or Queensland, where tree hollows and logs are common (Oakwood, 1997). Complex rocky habitat can provide sheltered crevices for small animals to take refuge from predation (Hernandez-Santin et al., 2016) and fire (Burrows et al., 2009), and can offer other resources needed for survival including water and food (Henneron et al., 2019). When rearing young, female northern quolls require sheltered crevices which are cooler and deeper than other available, but unutilised crevices (Cowan et al., 2020c).

The ridges and mesas of channel-iron deposits and banded iron formations in which northern quolls can inhabit are often the primary focus of iron-ore extraction in the Hamersley Province (Ramanaidou and Morris, 2010), while granite outcrops are often quarried for road and rail beds. For this reason, Pilbara northern quolls are recognised as specially protected fauna by the Commonwealth Department of Environment and Energy (Department of the Environment, 2016), due to the likelihood that the species will be impacted by the removal or alteration of habitat by mining activity and associated infrastructure development.

Although being primarily carnivorous—feeding on invertebrates and small vertebrates—northern quolls will also opportunistically eat eggs and fleshy fruit, or scavenge on roadkill or waste (Dunlop et al., 2017). Northern quolls are sexually dimorphic, with males tending to be larger than females (Oakwood, 2002). The species is the largest animal in the world to undergo suicidal reproduction (semelparity), whereby males, after an intense mating period, experience major immune system collapse and eventual death, usually in the first year (Oakwood et al., 2001, Fisher et al., 2013). This enables females to drive intense competition between males, and allows females to have offspring with the maximum genetic diversity (Chan et al., 2020), and their young to have access to maximum food abundance during the period of pouch young development and dispersal (Fisher et al., 2013). Females breed synchronously over a period of months, when 6-8 young are born, grow in the pouch and are deposited in dens after eight to nine weeks (Oakwood, 2000).

While the biology and ecology of the northern quoll has been studied in the Northern Territory (Begg, 1981, Braithwaite and Griffiths, 1994, Oakwood, 1997, Oakwood, 2000, Oakwood, 2002) and to a lesser extent in the Kimberley (Cook, 2010, How et al., 2009, Schmitt et al., 1989), similar studies in the Pilbara are only recently increasing. Due to the limited evidence available to allow for the creation of ecologically equivalent offsets for the northern quoll in the Pilbara (Department of Sustainability, 2011), a proportion of offset funds for this species has been directed towards scientific research. DBCA has also implemented a Pilbara-wide quoll research program (Cramer et al., 2016), to provide a regional context for more targeted population research.

1.2 Roy Hill EPBC Requirements and Research Plan

Roy Hill Pty Ltd (Roy Hill) has Commonwealth and WA Office of Environment Protection Authority approval for the Roy Hill Rail and Associated Infrastructure Project which comprised the construction and operation of a heavy-haul standard gauge railway line approximately 344km in length connecting the Roy Hill Mine to Port Hedland, in the Pilbara Region of Western Australia. The Rail Project also incorporated the construction of support infrastructure including a permanent access road running the length of the rail alignment, additional construction roads, bridges, passing sidings, borrow and ballast areas, lay down areas, and four temporary construction workforce camps. Since construction was completed in late 2015 and operations began, camps, borrow pits and other temporary construction sites have been decommissioned, with these areas now subject to rehabilitation. The project was referred to the Department of Sustainability, Environment, Water, Populations and Community (DSEWPaC) and conditions were imposed (EPBC 2011/5867) due to the impact on listed species under the EPBC Act—including the northern quoll. In response to this approval, Roy Hill developed a Northern Quoll Research Plan (NQRP) (Roy Hill Holdings Pty Ltd., 2014) targeting research and monitoring efforts on the Chichester Ranges as required under Condition 3 of EPBC2011/5867 approval.

The NQRP was designed to align with the DBCA Pilbara Northern Quoll Regional Research Program (Dunlop et al., 2014). The specific objectives of the NQRP include:

1) To better understand northern quoll distribution, ecology, and abundance and other demographic parameters in the Chichester Ranges and allow comparison with other studies in the Pilbara.

2) To inform management for the conservation of northern quoll populations in and around mining sites and other developments in the Chichester Ranges.

3) To help clarify the genetic and conservation status of the Chichester Ranges northern quoll population.

1.3 Northern quoll monitoring

Records of northern quolls in the Pilbara have increased as a result of environmental impact assessments and industry development in the region. Significant effort has been made in recent years to determine the presence and extent of northern quolls within the Pilbara region outside of impact areas, including the Chichester Ranges (Biota Environmental Sciences, 2005, Davis et al., 2005, Ecologia Environment, 2008).

A small population of northern quolls was discovered in 2014 at a rock outcrop complex referred to as ‘Quoll Knoll’, within the Roy Hill Special Rail Lease (SRL), located approximately 225 km south of Port Hedland. Quoll presence was initially confirmed by Phoenix Environmental as part of the Roy Hill Fauna Trapping and Translocation Program in April 2014 (Roy Hill Holdings Pty Ltd., 2014). This population has been monitored opportunistically since and is the focus of ongoing feral cat control. The northern quoll population at Quoll Knoll is considered significant due to the low density and sparse spread of quoll populations in the south-east of the Pilbara (Molloy et al., 2017). This population is close to the south-eastern Pilbara limit of known quoll records (around Bonney Downs Station), although a small number of records have been identified further east in Karlamilyi National Park (NatureMap, 2020, Dunlop, 2019, Dunlop, 2017). The Quoll Knoll population appears to be self-sustaining, with evidence of breeding and immigration.

Regular surveys for this threatened species have also been undertaken at nearby sites by DBCA and Roy Hill with the data used for comparisons and outlined in this report.

2 Methods

In 2014, DBCA undertook a preliminary survey for Roy Hill along the southern section of the Chichester Ranges to identify possible sites in which to establish cameras and traps for the subsequent monitoring years (see Johnson and Anderson, 2014). Since 2014, several locations of intermittent occupancy have been identified in this region. In the original survey, cage traps were deployed in areas where remote camera traps identified northern quoll presence. Since then, key sites have been identified and monitored annually, including Quoll Knoll, Wall Creek, Mesa 228, Python Pool, and Euro Springs. Unlike core areas of northern quoll habitat in the Pilbara, such as the granite outcrops located near to and south of Port Hedland (i.e. Red Rock; Figure 1, located approximately 50 km south), or the western edge of the Hamersley Range (Pannawonica region), northern quolls are not in high numbers and are not consistently present at the Chichester Ranges locations that were monitored annually.

The original sites that were surveyed by DBCA in 2014 and the sites that were subject to ongoing monitoring up to and including 2019, at the end of the six-year period are shown in Figure 2.

Figure 1: The granite inselberg ‘Red Rock’, located on Indee Station.

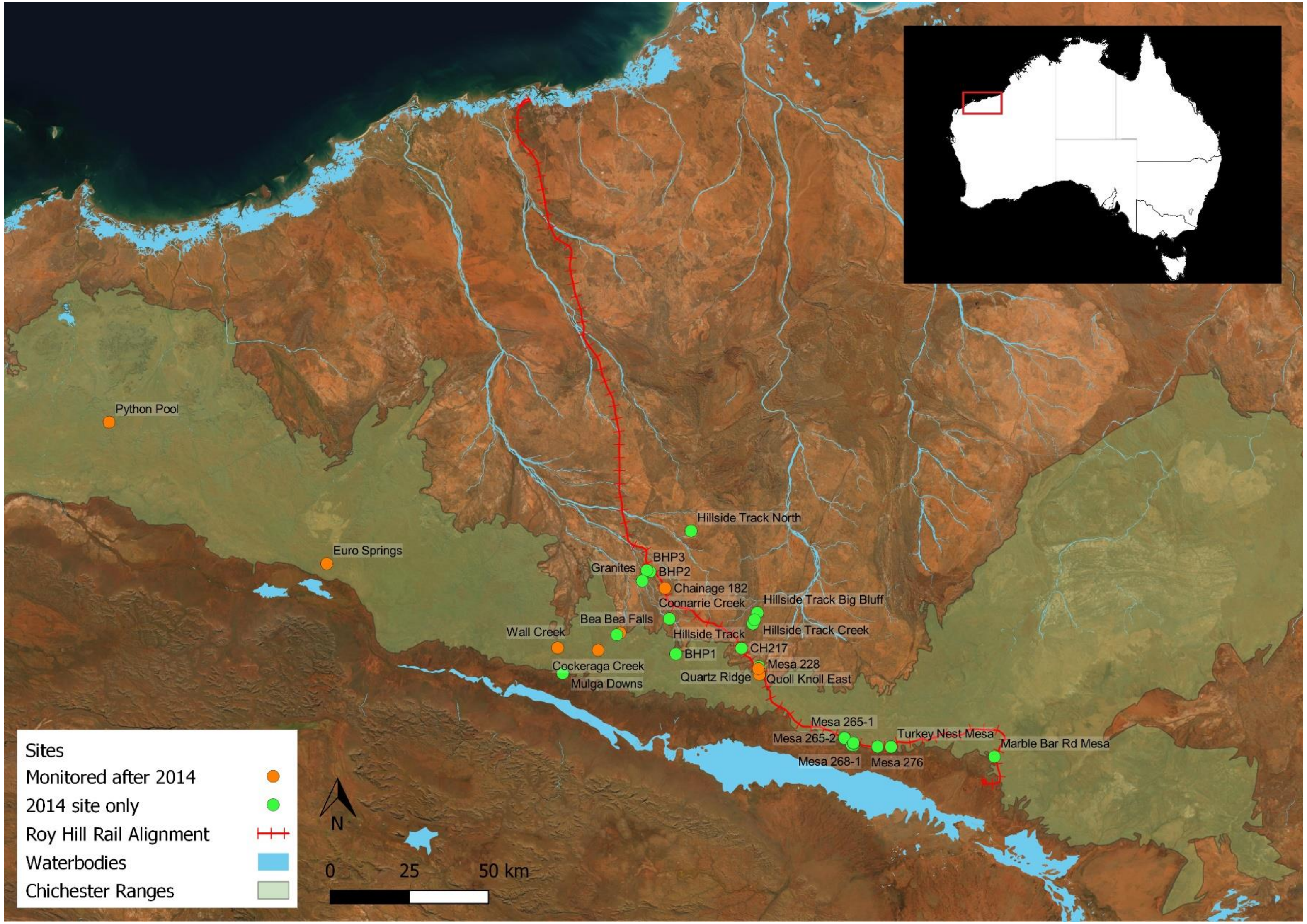

Figure 2: Site history for northern quoll surveys in the Chichester Ranges, Pilbara WA.

2.1 Monitoring sites

2.1.1 Euro Springs

Euro Springs is a complex rocky gorge system running east to west with shallow permanent pools of water, located approximately 100km south-east of Millstream-Chichester National Park, on Mt Florance station. Euro Springs is located on the southwestern edge of the Chichester Ranges. The western side of the system has a sandy riverbed substrate and is densely vegetated with *Melaleuca* sp. and loose rocky walls on either side. Progressing east, the gorge floor becomes solid rock and is interspersed with permanent shallow water pools lined with sedges. The surrounding vegetation is open *Triodia* grassland. Euro Springs has been monitored from 2014 to 2019 with cage traps (2014-2016) and camera traps (2017-2019).

2.1.2 Wall Creek

Wall Creek on Hooley Station is a 2 km long rocky gorge running approximately north-south, eventually feeding into the Yule River to the north, and is in the central west of the Chichester Ranges. The gorge is shallower at the southern end and becomes deeper and more complex to the north. The habitat consists of a scree slope of weathered rocky basalt with numerous permanent pools of water in a creek line at the base of the slope, with a mixed vegetation complex consisting of *Triodia* sp., *Eucalyptus* sp., *Acacia* sp., *Melaleuca* sp., and other shrub species. The upper slopes of the gorge consist of open woodland of *Triodia* sp. and mulga (*Acacia aneura* and related *Acacia* spp.). Wall Creek is recognised to have both ecological and Aboriginal significance and was prioritised to remain undisturbed during the FMG rail construction (Fortescue Metals Group, 2010). Wall Creek was investigated with camera traps in 2014, before being monitored with cage traps (2015-2016) and camera traps (2017-2019) more intensively.

2.1.3 Mesa 228

Mesa 228 (approximately 1.5km south from Quoll Knoll) is a lateritic mesa, about 1 km long with several caves and crevices located along its ridge. This mesa is in the central north of the Chichester Ranges. Vegetation on Mesa 228 includes shrubs and small trees of *Acacia*, *Eremophila*, and *Eucalyptus*, with an open *Triodia* grass layer. Slopes are comprised of *Triodia* grassland with *Eucalyptus brevifolia* and tall shrubs of *Acacia* and *Senna* spp. Mesa 228 has been monitored with cage traps (2014-2016), and camera traps (2017 & 2019), with no monitoring occurring in 2018. Mesa 228 was a component in an Honours research project in 2014 investigating the effects of mining infrastructure on the movement of northern quolls (Henderson, 2015).

2.1.4 Quoll Knoll

The rocky knoll dubbed "Quoll Knoll" is near Chainage 225, situated between the Roy Hill rail line and a light vehicular access track (Figure 3). Quoll Knoll is a small (200m × 100m) lateritic outcrop of very large boulders, bounded by the railway cutting on eastern side, and a vehicular track (Roy Hill rail service track) on the western side. This vehicular track lies between Quoll Knoll outcrop and a separate rocky ridge located to the south-west. Quoll Knoll is approximately 3km to the north of Mesa 228 and is in the central north of the Chichester Ranges. Vegetation includes *Triodia* spp. and other shrub species, with a creek line at the base of the two outcrops containing a mixed vegetation composition including dominant Acacia species.

Located not far from Quoll Knoll is the West Shaw River Bridge. The West Shaw River Bridge is a Roy Hill railway overpass with two large granite rock armouries less than 500 m from Quoll Knoll (Figure 3). The overpass crosses the seasonal Western Shaw River and is surrounded by *Acacia* and *Triodia* habitat. Construction on the overpass began in 2013 and finished in 2015. A quoll latrine site was identified here in 2016 (Dunlop and Johnson, 2016, Aussie Feral Pests, 2016).

Quoll Knoll and the hinterland has been subject to long term monitoring since 2014 via multiple programs and methods and was a component of two Honours research programs (Cowan et al., 2020c, Henderson, 2015). Quoll Knoll has been monitored by targeted annual cage trapping by DBCA (2014-2017, 2019) and permanent Roy Hill or annual DBCA camera trapping (2014-2019), as well as targeted for regular feral animal control by Animal Pest Management Services (from 2014 to 2016), and Aussie

Feral Pests (from 2016 to present) on behalf of Roy Hill (up to three times per year). Six permanent cameras remained in place at Quoll Knoll between 2014 and 2019. The capture of non-targets (i.e. quolls) during the feral animal control events has provided additional information on the presence and persistence of this species at this site.

Figure 3: Photos of monitoring sites near Roy Hill Rail: a) the small rock outcrop referred to as Quoll Knoll, and b) the West Shaw Bridge.

2.1.5 Chainage 182

Chainage 182 is a granite outcrop, approximately one kilometre wide, with a complex rocky habitat that has been identified as a potential location for quolls. This site is located immediately to the east of the Roy Hill rail alignment and lies just north of the Chichester Ranges. Previous reconnaissance and desk top surveys had identified this area as a potential monitoring site for quolls along the Roy Hill rail alignment, however access was restricted during construction activities, and the site was not subject to camera trap monitoring until 2018. The habitat type is similar to granite outcrops south of Port Hedland that have high populations of northern quolls consistently present (Dunlop et al., 2018). Chainage 182 has been monitored by camera traps only (2018-2019).

2.1.6 Python Pool

Python Pool is nestled in the far northwest of the Chichester Ranges at the base of a seasonal waterfall within the Millstream-Chichester National Park. The western end has a permanent pool surrounded by sheer basalt cliffs and runs along the bed of a small tributary for 1.2 km. The creek bed is lined by four-metre-high tumbledown basalt walls which becomes less deep and complex to the east. The creek line has a mixed vegetation complex with *Eucalyptus camaldulensis* and sheoaks around the pool transitioning to wattles and *Melaleuca* spp. through the sandy creek bed. The surrounding vegetation is a mix of *Triodia* grassland and marbled gum (*Eucalyptus gonglyocarpa*). During the summer of 2014/15 a large wildfire burnt through Python Pool and a large proportion of the surrounding area. This site was monitored from 2014 to 2019 using primarily cage traps.

2.1.7 Bea Bea Creek

Bea Bea Creek is a weathered rocky basalt outcrop with a waterfall and permanent pools of water in the creek line at the base of the outcrop. This site is in the central northwest of the Chichester Ranges. Vegetation includes *Triodia* spp., *Eucalyptus* spp., *Acacia* spp., *Melaleuca* spp., and other shrub species. Monitoring took place in 2014 and 2019 using camera traps while scat searches took place in 2015.

2.1.8 Cockeraga Creek

Cockeraga Creek is a scree slope of weathered rocky basalt with permanent pools of water in the creek line at the base of the slope, mixed vegetation complex with *Triodia* sp., *Eucalyptus* sp., *Acacia* sp., *Melaleuca* sp., and other shrub species. This site is in the central southwest of the Chichester Ranges. Monitoring took place in 2014 using cage traps and 2019 using camera traps, while scat searches took place in 2015 and 2016. This site was monitored by several consultancies for FMG between 2014 and 2019. This data was not included in this report unless included in annual DBCA reports.

2.1.9 Other 2014 survey sites

Sites that were monitored in 2014 include Hillside Track, Mesa 265, Mesa 268, Mesa 276, Marble Bar Road Mesa, BHP 1, 2, & 3, Granites, Mulga Downs, Quartz Ridge, Turkey Nest Mesa, CH217, and Coonarrie Creek (Table 1, Figure 2). Based on the results at these sites, they were not monitored further — except for Coonarrie Creek where scat searches took place in 2016 (Table 1).

2.2 Cage trapping

Annual live trapping was conducted for the DBCA Pilbara Northern Quoll Regional Monitoring Project at various sites as outlined in Section 2.1, from 2014 until 2019. Trapping routines and trap nights are outlined in Table 1. Live trapping was undertaken using the wire-mesh traps (45cm x 17cm x 17cm, Sheffield Wire Co, Welshpool WA) generally set 50m apart in two 25m transects, baited with peanut butter, oats and sardines (Figure 4). Each individual quoll was microchipped, weighed and measured, body condition was assessed, and tissue samples taken for genetic analysis.

Targeted feral cat trapping also occurred along the Roy Hill SRL near Quoll Knoll at various stages since 2016 (Table 3). This feral animal control program was conducted by Animal Pest Management Services (APMS) from 2014 until 2016 (Eaton, 2016a), and by Aussie Feral Pests (AFP) from 2016 to (and including) 2019 (Aussie Feral Pests, 2019). This program was conducted twice in 2014, once in 2015, and three times per year from 2016 to 2019. Up to 35 large cage traps baited with chicken and/or tinned cat food were strategically placed in likely cat habitat or where cat tracks were observed, for five nights. Traps were repositioned as new cat tracks were discovered. Any northern quolls incidentally captured in cat traps were either scanned for a microchip or had one inserted if not present, tissue taken, measured and released, with data provided to DBCA. Traps were checked daily and captured feral species were relocated offsite where they were euthanized.

Figure 4: Northern quoll caught in a wire cage trap.

2.3 Camera trapping

While live trapping using wire cages is useful for obtaining demographic data or collecting samples, such as tissue for DNA analysis, it is generally both expensive and time consuming, with trapping sessions running for a minimum of four days at a time (Dunlop et al., 2014). Outward-facing camera traps were deployed throughout the six-year monitoring program, where cameras were fixed to a tripod and located in a sheltered position such as rock overhang, rock crevice, or cave (Figure 5), or placed on the ground facing a rock crevice or similar feature. This allowed for species identification at each site as well as determining the presence of northern quolls and feral species (i.e. feral cats).

Camera trap use, where individuals can be recognised via unique markings or spot patterning, can estimate demographic parameters such as relative abundance. This method can be a cost-effective alternative to current live trapping efforts for monitoring population density. To facilitate individual identification, from 2018, Reconyx PC900 Hyperfire cameras were attached to a wooden stake 1.5 metres above the ground and orientated in a downward-facing position (Figure 5). Given that spot patterning used to identify individual quolls is located on the animal's dorsal surface, a downward-facing orientation will most consistently capture images suitable for individual identification and allow for size comparison between animals. Cameras were set to record activity at all times of the day and night with three or five consecutive photographs per trigger, except for 2014, where cameras were set to record from dusk to dawn (1800 and 0600 hrs) with three consecutive photographs per trigger (for camera trapping details see Table 1). A scent lure consisting of peanut butter, oats, sardines and fish oil in an inaccessible ventilated pod was secured to the base of the camera post. Cameras were set approximately 200m apart in order to spread detections across as many home ranges (usually delineated by females) as possible. Outward-facing cameras were paired with several top-down cameras in order to validate that species were not missed by the downward facing setup.

Analysis of all photographs was done through importing photos into CPW Camera Warehouse (CPW) for species identification as well as identification of individual quolls through unique pelage marks. To determine individual identification, each quoll detection event needed to be determined, which was defined as a series of photographs with no more than a 15-minute interval between successive photographs of a quoll (Diete et al., 2016). All detection events were examined to confirm that only one individual was captured on the series of photographs assigned to the event; if a second individual was found to be within the event then photographs were split and assigned their own event. Once all quoll detections were defined appropriately, top down images of all northern quoll photos were compared against each other using Wild ID to determine individuals at each location with each new individual given a unique identifying ID (Bolger et al., 2012).

APMS and AFP also utilised camera traps during targeted feral species trapping as well as accessed images from cameras deployed by DBCA and Roy Hill to locate or confirm the presence of feral species (i.e., feral cats).

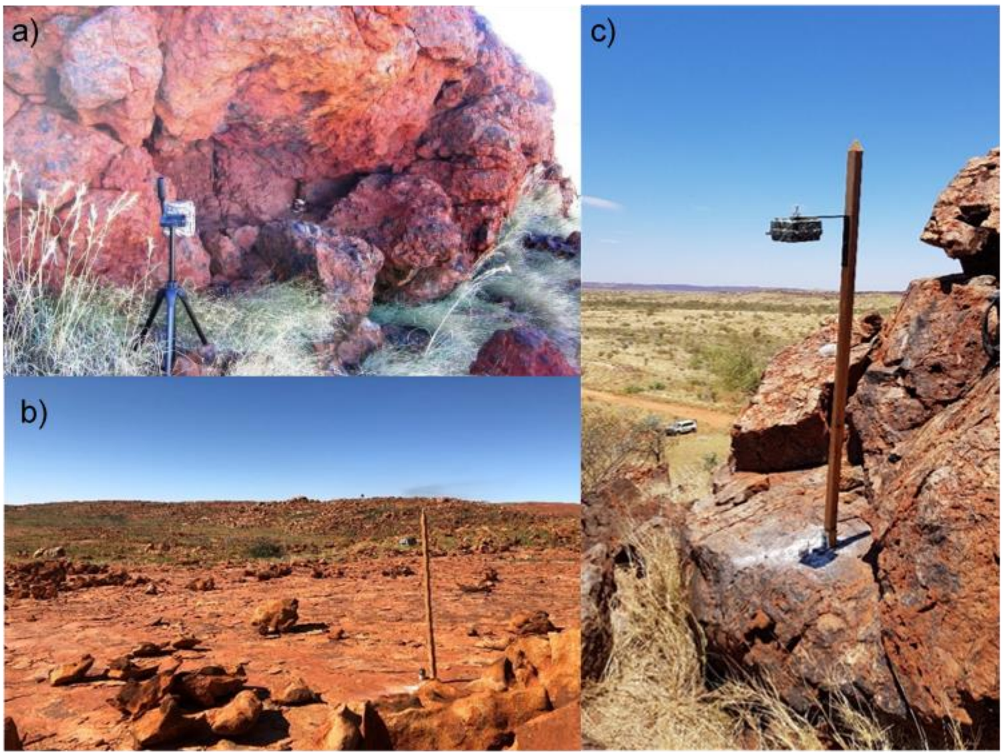

Figure 5: Examples of camera set ups: a) a forward-facing camera on a tripod, b) a downward-facing camera set up at Chainage 182 on a wooden stake, and c) a downward-facing camera set up at Quoll Knoll.

Table 1: Sites monitored from 2014 to 2019 by DBCA.

Site	2014	2015	2016	2017	2018	2019
Quoll Knoll	Yes	Yes	Yes	Yes	Yes	Yes
Mesa 228	Yes	Yes	Yes	Yes		Yes
Cockeraga Creek	Yes					Yes
Bea Bea Creek	Yes					Yes
Wall Creek	Yes	Yes	Yes	Yes	Yes	Yes
Euro Springs	Yes	Yes	Yes	Yes	Yes	Yes
Python Pool	Yes	Yes	Yes	Yes	Yes	Yes
Chainage 182					Yes	Yes
Hillside Track	Yes					
Mesa 265	Yes					
Quartz Ridge	Yes					
Mesa 268	Yes					
Mesa 276	Yes					
Marble Bar Road Mesa	Yes					
Turkey Nest Mesa	Yes					
BHP 1-2-3	Yes					
Granites	Yes					
Mulga Downs	Yes					
CH217	Yes					
Coonarrie Creek	Yes					

Table 2: Cage trapping and camera trapping methods used to monitor all sites between 2014 and 2019.

	2014	2015	2016	2017	2018	2019
No. of Cameras	80	NA	33	20	16	24
Camera Trap Nights *	334	84	836	2240	1728	1676
No. of Cage Traps	58	110	110	10	50	15
Cage Trap Nights	202	440	440	40	200	60
Plus, six permanent Quoll Knoll cameras	Yes	Yes	Yes	Yes	Yes	Yes

* The number of cameras and camera trap nights in this table do not include the six permanent camera traps located at Quoll Knoll, which were deployed from April 2014 ongoing. The six Quoll Knoll permanent cameras accounted for an extra 1644 camera trap nights in 2014, 2190 camera trap nights in 2015, 2017, 2018, and 2019, and 2191 camera trap nights in 2016 due to it being a leap year.

Table 3: Northern quolls and feral cats captured during targeted feral cat cage trapping at Quoll Knoll.

Date	Cats	Quolls	No. of traps	Trap nights
September 2014	0	1	25	125
December 2014	0	1	25	125
June 2015	1	1	25	125
March 2016	1	1	25	125
August 2016	1	0	25	125
November 2016	0	1	35	175
April/May 2017	0	0	35	175
September 2017	1	1	35	175
December 2017	0	0	35	175
April 2018	0	3	35	175
July 2018	3	4	35	175
November 2018	1	1	35	175
April 2019	0	2	35	175
July 2019	4	1	35	175
November 2019	3	0	35	175

2.4 Climatic data

Climatic data was collected from the nearest BOM weather station, Wittenoom (station 005026), located 38km from Wall Creek, 95km from Mesa 228, and 190km from Python Pool. The region received higher than average mid-summer rainfall between 2014 and 2019, and less than average rainfall at the beginning and end of summer—particularly during February (Figure 6). Most years, rainfall would decrease around February, except for 2017 where it increased, but then dropped over the next three months and did not rain again until November (Figure 7). 2014 had the second highest January rainfall, but the lowest February rainfall, while 2015 had the highest rainfall during autumn, but the lowest rainfall during summer (Figure 7). Rainfall was similar to 50-year averages for the other months, with very little rainfall occurring from August to October. Temperatures between 2014 and 2019 were quite similar to 50-year averages, however were slightly warmer during spring and early summer (September to December; Figure 6).

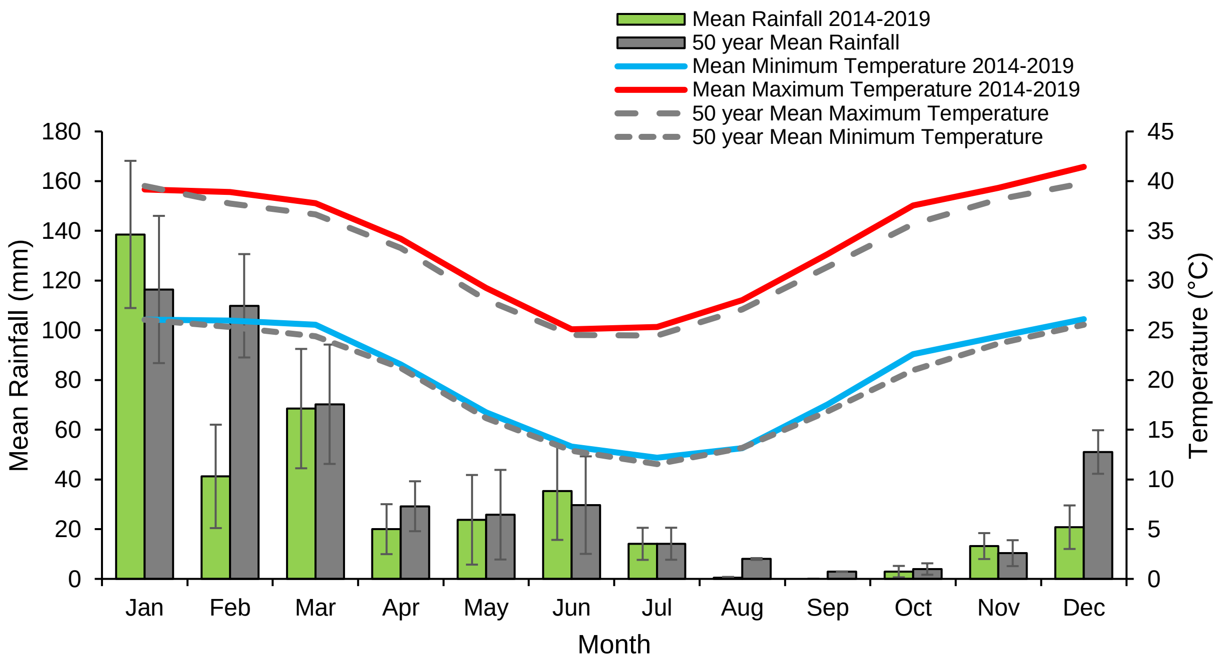

Figure 6: Climate data for the nearest Bureau of Meteorology weather station, Wittenoom (station 005026).

Error bars indicate the standard error of the mean.

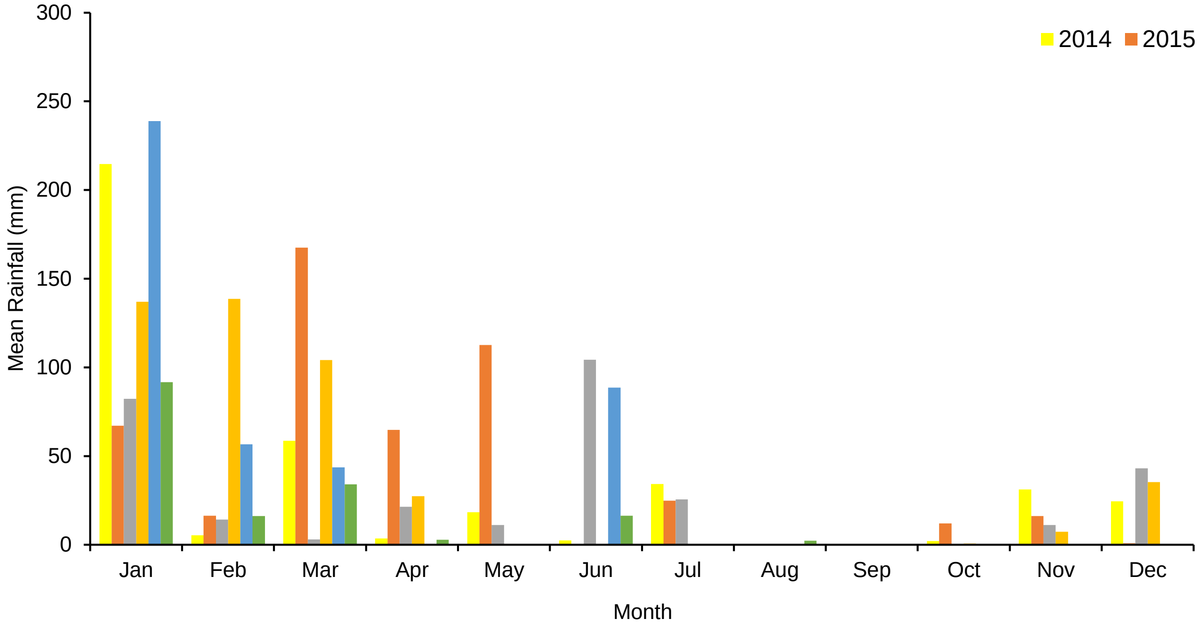

Figure 7: The mean monthly rainfall for each monitoring year (2014 - 2019).

3 Results

3.1 Chichester Range Surveys

Northern quoll abundance in the Chichester Ranges was not consistent over time at the monitoring sites between 2014 and 2019. Yearly fluctuations in northern quoll abundance were identified at most of the sites: A total of 19 sites were visited in 2014 as reconnaissance surveys to determine northern quoll presence in the Chichester Ranges, and where further monitoring should take place (Johnson and Anderson, 2014). This reconnaissance project focused primarily on the south-eastern extent of the Chichester Ranges, however most of the southern sites had minimal or no northern quolls recorded and annual monitoring was not recommended to be undertaken at the majority of these sites (Johnson and Anderson, 2014). Using the species distribution model (SDM) devised by Molloy et al. (2017), we identified areas within the Chichester subregion with the highest northern quoll density. Figure 8 provides a visual representation of this distribution in combination with northern quoll records obtained from the monitoring programs conducted from 2014 to 2019.

These combined records show that the southern area of the Chichester Ranges has a low likelihood of northern quoll presence, with most sites within this area having a yearly average of less than three northern quolls recorded—with most sites monitored in 2014 having no northern quolls recorded. Quoll Knoll was the only southern site with a yearly average of three northern quolls—the highest for this area. Westerly sites within the Chichester Ranges (Python Pool, Euro Springs) had yearly averages of three and six northern quolls respectively and were in areas with a higher likelihood of northern quoll presence. Areas of the Chichester subregion to the north of the Chichester Ranges have the highest likelihood of northern quoll, but no sites were monitored under the Roy Hill research program in this northern region as this area lies outside the Chichester Ranges footprint. The low likelihood of northern quoll presence in the south of the Chichester Ranges as indicated via Molloy et al. (2017), and with five monitoring sites having a yearly average of one or more northern quolls recorded per year, shows that some low density populations persist in this area. The northern areas with highest likelihood of northern quoll presence lie close to sections of the Roy Hill Special Rail Lease between Chainage 50 and Chainage 100 (i.e. 50 and 100 km south of Port Hedland respectively).

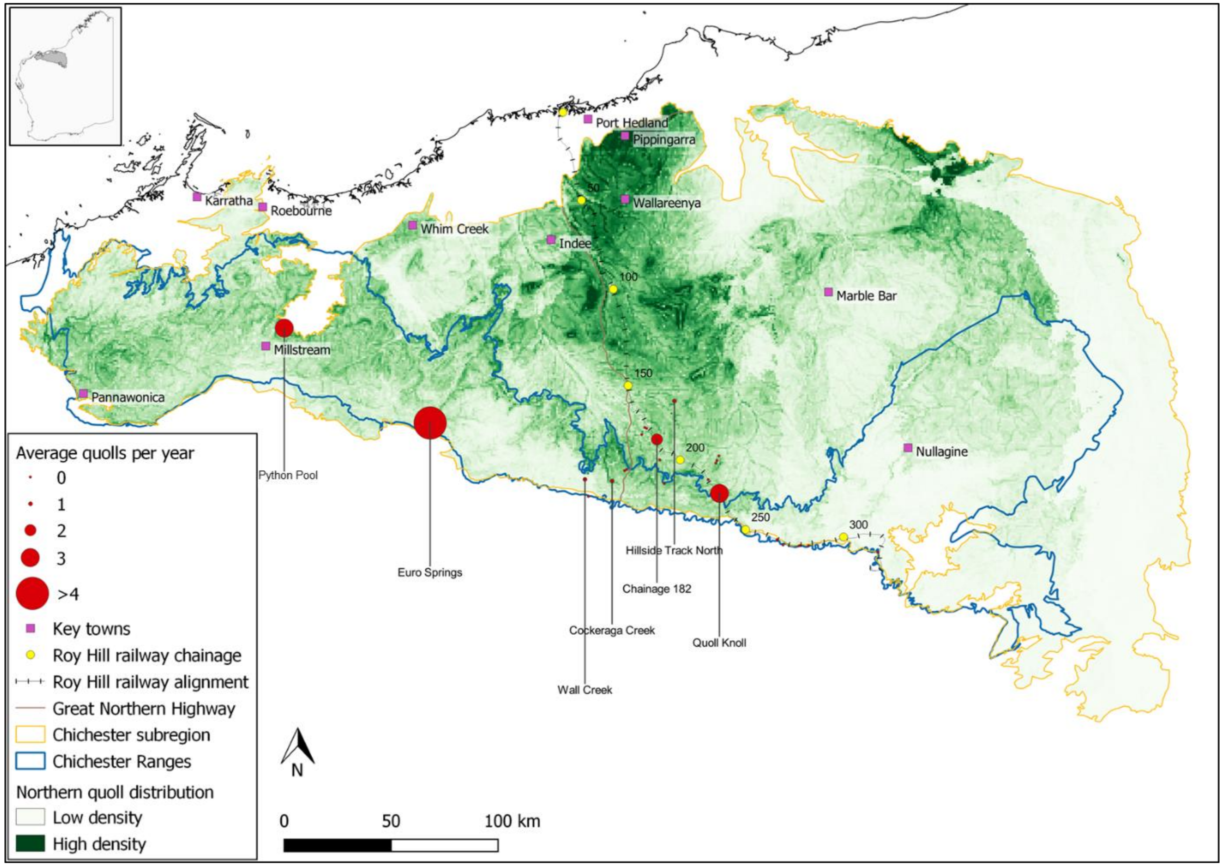

Figure 8: A heat map of northern quoll records within the Chichester Subregion*.

*The species distribution model (SDM) devised by Molloy et al. (2017), is depicted in green with the darker the green, the higher the density of northern quoll records. The red dots are the Roy Hill/DBCA monitoring sites and the size of the dots determines the average number of northern quolls captured per monitoring year either in a trap or on a camera trap between 2014 and 2019. The larger red dots are sites with a higher average number of quolls and the smaller red dots had a smaller average number of quolls captured per monitoring year. Labelled sites are those with a yearly average of more than one northern quoll. Unlabelled red dots are all other sites (including those surveyed in 2014 but not monitored further), which all had no quoll presence or an average number of quolls less than one per year.

Table 4, below, provides data on each site subject to monitoring from 2014–2019, the number of detections or the number of animals cage trapped, and the trap nights at each site for each monitoring year.

For the sites where annual monitoring was conducted over the six-year period, Euro Springs maintained generally higher numbers of northern quolls compared to other sites, peaking in 2017 and declining towards 2019 where the number of individual quolls was lowest for this site). This decline in quoll numbers coincided with decreasing detections of rock rats and increasing detections of feral cats—with feral cats not sighted until 2018.

Northern quoll activity has been recorded at Wall Creek since 2017, when camera traps replaced the previous cage trapping arrays.

Mesa 228 had a single detection of a northern quoll in 2015 and then no detections up to and including 2017 when annual monitoring ceased at the site. However, when monitoring recommenced in 2019, there were 106 detections of northern quolls from 360 camera trap nights. Rock rat detections also increased in 2019 from previous monitoring periods at this site. There were two detections of feral cats in 2019 and three feral cat detections in 2017.

Quoll Knoll maintained a similar abundance of northern quolls over the full monitoring period, with northern quolls recorded each year from 2014 to 2019. At least 2 northern quolls minimum were recorded each year, with the maximum number recorded being five in 2018. Most recently in 2019, rock rat detections increased from zero to 65, while feral cat detections in 2019 reduced by half compared to 2018

Chainage 182 was monitored for only two years from 2018 and had one and two individual quolls recorded in 2018 and 2019 respectively. Rock rats were not detected in 2019, and feral cats were present in both years.

Python Pool had the most northern quolls detected of all sites (9) in 2014, however, numbers dropped dramatically the following year and have not returned to similar numbers since. One feral cat was recorded at Python Pool in 2016 and there were regular detections and signs of feral cats over the six-year period.

Bea Bea Creek and Cockeraga Creek were searched for scat for most of the monitoring years, however DBCA only undertook cage or camera trapping at these sites in 2014 and 2019. Northern quolls were present at Cockeraga Creek in 2014, but the site was not recommended for monitoring by DBCA as it was subject to annual monitoring by a consultant agency for Fortescue Metals Group (FMG). This data was not used unless contained within DBCA annual reports. Despite this, scat searches were undertaken by DBCA during both 2015 and 2016. When DBCA monitoring recommenced in 2019 at both sites, neither Bea Bea Creek nor Cockeraga Creek recorded northern quolls, while Bea Bea Creek had 14 detections of feral cats).

Due to the number of rock rats being captured in cage traps during all DBCA northern quoll trapping programs for the period from 2014–2018, a rock rat enclosure was introduced into cage traps in 2019, to protect them from predators (i.e., quolls, cats), that can still predate upon rock rats through the wire cage mesh openings. This proved successful with evidence of rock rats using enclosures after being trapped in the cage (Figure 9). All sites that switched from cage trapping to camera trapping (excluding Mesa 228) in 2017, recorded higher numbers of northern quolls.

Table 4: Species detection history for eight sites monitored by DBCA (excluding the initial 2014 survey sites).

Site	Captures	2014	2015	2016	2017	2018	2019
Euro Springs	Quoll	6	5	3	12	8	2
	Rock rat	2	2	2	91	27	24
	Cat	0	0	0	0	1	2
	Trap Nights	*200*	*200*	*200*	*510**	*679**	*345**
Wall Creek	Quoll	0	0	0	3	1	2
	Rock rat	0	1	3	34	134	12
	Cat	1	0	0	0	5	2
	Trap Nights	*6**	*200*	*200*	*1010**	*641**	*345**
Mesa 228	Quoll	0	1	0	0	-	106 detections
	Rock rat	4	17	18	1	-	29
	Cat	0	0	0	3	-	2
	Trap Nights	*80*	*200*	*200*	*1230**	*-*	*360**
Quoll Knoll #	Quoll	3	3	2	2	5	4
	Rock rat	0	0	1	0	0	65 detections
	Cat	1	1	2	1	8	7
	Trap Nights	*32*	*40*	*40*	*40*	*827**	*1405**
Chainage 182	Quoll	-	-	-	-	1	2
	Rock rat	-	-	-	-	4	0
	Cat	-	-	-	-	2	3
	Trap Nights	-	-	-	-	*408**	*350**
Python Pool	Quoll	9	1	1	3	0	1
	Rock rat	5	19	7	0	3	6
	Cat	0	0	1	0	0	0
	Trap Nights	*200*	*200*	*200*	*200*	*200*	*150*
Bea Bea Creek	Quoll	0	-	-	-	-	0
	Rock rat	0	-	-	-	-	3
	Cat	0	-	-	-	-	14
	Trap Nights	*18**	-	-	-	-	*138**
Cockeraga Creek	Quoll	2	-	-	-	-	0
	Rock rat	0	-	-	-	-	0
	Cat	1	-	-	-	-	2
	Trap Nights	*90*	-	-	-	-	*138**

Quoll Knoll includes data supplied by APMS and AFP.

* Refers to camera traps rather than cage traps. For camera traps, northern quoll totals for those years are for individuals recorded (except for quolls at Mesa 228 in 2019), while other species camera trapped are the total detections separated by at least 60 minutes. For years where cage traps were deployed, totals provided is for individuals trapped.

- Cells with this symbol denote years were cage trapping or camera trapping did not occur.

Figure 9: A common rock rat using a rock rat enclosure (PVC pipe) inside a cage trap used to target northern quolls.

Presence or absence of northern quolls and feral cats at Quoll Knoll was determined using records from DBCA Chichester Range reports from 2014 to 2019, the DBCA northern quoll trapping database, Animal Pest Management Services Reports from September 2014 to March 2016, and Aussie Feral Pests reports from August 2016 to November 2019 at Quoll Knoll. Presence of an animal was confirmed if the animal was captured (in a cage trap or on a camera trap), therefore the presence of scat was not used to determine presence.

Presence on a certain date is represented in Figure 10 by coloured areas in the graph with the height of a coloured area not depicting the number of animals but allows comparisons to be made between when northern quolls and feral cats were present at this site. Gaps between coloured areas signify no record of a northern quoll or feral cat for these dates.

Northern quolls were not consistently present at Quoll Knoll between 2014 and 2019. Figure 11 shows the monthly data for this site for the full 2014-2019 period. There were thirty months (out of 69 total months) where monitoring took place at Quoll Knoll and northern quolls were absent (refer to Appendix 1). These absences were common within the months of January, February, March, and October (Figure 11). Quolls were consistently recorded in July, being detected in this month in all six years. Other long-term sites showed similar trends, including Euro Springs, Wall Creek, and Mesa 228 (Appendix 1). Bea Bea Creek and Coonarrie Creek—not monitored to the same extent as Quoll Knoll —showed no recorded presence of northern quolls either captured by a cage trap or camera trap in any month or any year (Appendix 1). Northern quolls had a more stable presence at Quoll Knoll than feral cats (i.e., 39 months of quoll presence compared to 18 months of feral cat presence).

Feral cat presence was not consistent at Quoll Knoll. Feral cats were recorded at Quoll Knoll by APMS in September 2014—the first month of the targeted feral cat trapping program (Aussie Feral Pests, 2016), with cats absent for 51 months of the 69 months Quoll Knoll was monitored (Appendix 2). There were 15 months where northern quolls and feral cats were recorded within the same month (Figure 10). These overlapping periods were quite sporadic with no trends or standout months. There were some detections of both quolls and cats on the same camera traps within a short duration at Quoll Knoll (Figure 12), and AFP found evidence of northern quolls in the stomach contents of a captured feral cat in 2016 (Aussie Feral Pests, 2016).

Of the 15 cat trapping events at Quoll Knoll, feral cats were only identified four times in the month after trapping (Figure 10). Of the seven trapping events which did not successfully catch a feral cat, only one saw feral cat presence in the month before and after (September 2014), and only one saw feral cat presence in the month after (April 2019). Of the eight successful cat trapping events, six saw feral cat presence in the month before trapping but no presence in the month after trapping (Figure 10). Northern quolls were recorded in the month following successful feral cat trapping on six occasions, although northern quolls were present during the month before successful feral cat trapping on all but one occasion. Northern quolls were recorded in the month following unsuccessful feral cat trapping on three occasions. Feral cat trapping was most successful around the month of July and least successful around October (Figure 10).

There was also definitive evidence of quolls breeding at Quoll Knoll, with one adult female being photographed with young still attached to the pouch in November 2018 (Figure 12), and a female and its young trapped in subsequent years (July 2015 and March 2016) (Henderson, 2015, Eaton, 2016b). This indicates that Quoll Knoll was used as a denning location for breeding female northern quolls in 2015 and 2018. A later image from the cameras installed to monitor dens showed one independent subadult northern quoll in January 2019 (Figure 12), giving further support that this site is an important and successful breeding location for northern quolls.

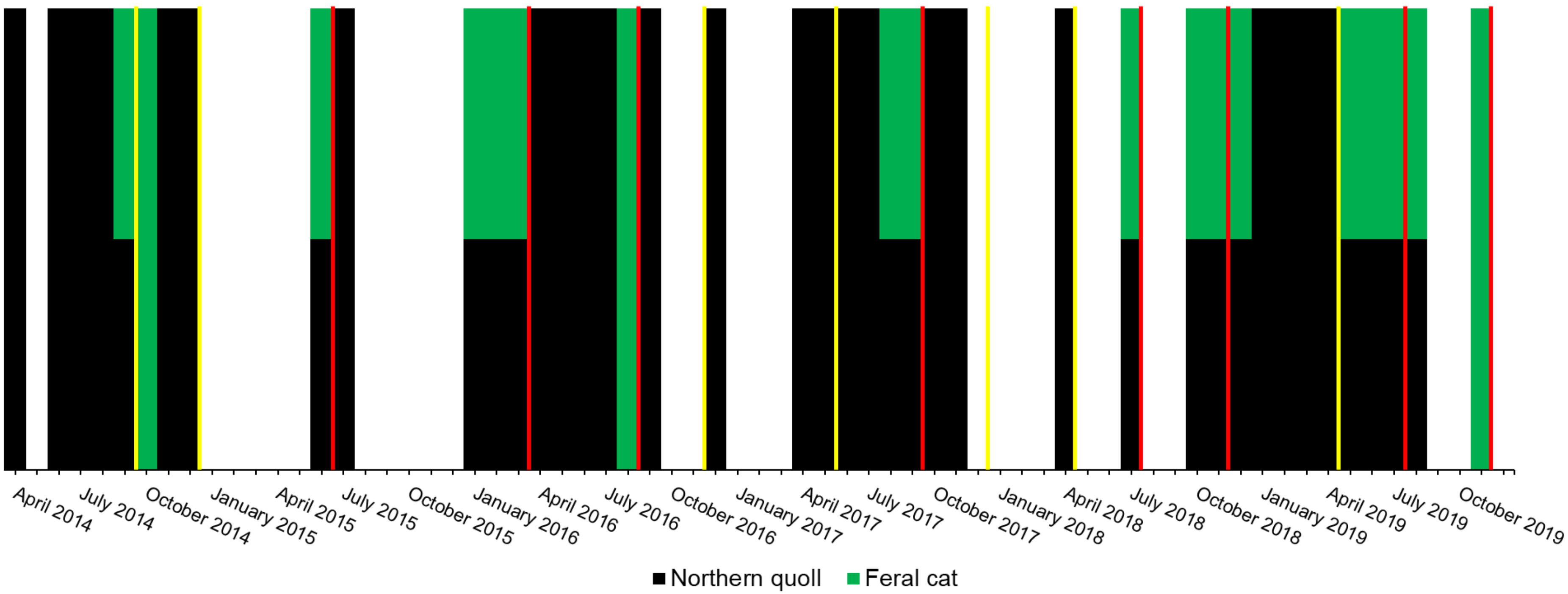

Figure 10: Presence* of northern quolls and feral cats at Quoll Knoll from 2014 to 2019.

*Presence on a certain date is represented by coloured areas in the figure—height of a coloured area has no significance but allows comparisons to be made between northern quolls and feral cats. Gaps between coloured areas signify no record of a northern quoll or cat on these dates. Presence of an animal was confirmed if the animal was captured (in a cage trap or on a camera trap), therefore the presence of scat was not used to determine presence for this figure. Red lines denote the end of the month when targeted cat trapping occurred and was successful in removing at least one cat. Yellow lines denote the end of the month when targeted cat trapping occurred and was not successful in removing at least one cat.

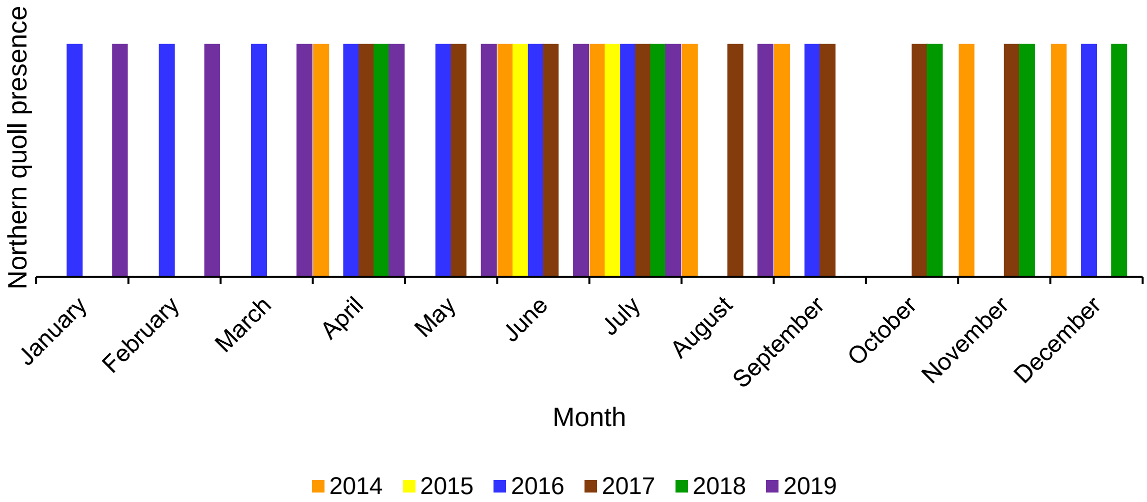

Figure 11: The presence* of northern quolls at Quoll Knoll per month.

*A coloured bar signifies that northern quolls were recorded during that month of that year. Each colour represents a different year.

Figure 12: Examples of (top and bottom left panels) a northern quoll and a feral cat active at the same Quoll Knoll camera only two hours and 17 minutes apart in May 2019, (top right panel) a female northern quoll with pouch young attached in November 2018, and (bottom right panel) an independent subadult northern quoll at Quoll Knoll in January 2019.

DBCA developed an annual timeline in relation to reproduction and dispersal patterns of northern quolls, in order to inform management actions in the Chichester Ranges (Table 5) (Dunlop et al., 2018). This shows that northern quolls undertake reproductive or maternal actions for almost the entire year. Therefore, it is important to target feral cat control activities at the times when northern quolls are most susceptible to predation. To maximise bait uptake and trap success, cat control should take place when there is low prey available for feral cats (i.e., June to August) (Table 5). This period is also when young northern quolls are prone to be taken as prey by feral cats, because they are either in the early stages of pouch young, or the previous generation is in the later stages of emerging from their den and beginning to find mates (Table 5). Trapping during the period around July is supported by the fact that most of the successful targeted feral cat trapping and northern quoll presence occurred around this period. Feral cat trapping has shown to be successful in reducing the detections of feral cats, with 75% of successful cat trapping events resulting in no detections of feral cats the following month.

Table 5: Months of northern quoll and feral cat activity to inform management actions. Shaded cells denote active months.

Activity	Months (may vary between years according to season)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern quoll pouch young								■	■	■		
Northern quoll denning young	■	■									■	■
Northern quoll young dispersal		■	■	■								
Northern quoll mating						■	■	■				
Low prey availability for feral cats						■	■	■				
Feral cat trapping		■	■			■	■	■		■	■	
Feral cat baiting						■	■	■				

4 Discussion

Southern sites in the Chichester Ranges that appeared to meet the requirements for suitable quoll habitat were determined from reconnaissance surveys conducted in 2014 to have little or no quoll presence and hence were not included in a long-term monitoring program. Of the sites that showed northern quoll presence—primarily further to the west or north from the southern Chichester boundary—monitoring was conducted over the next six years. Other central-northern sites (e.g. Chainage 182) were opportunistically included as the program progressed and information was gathered. Monitoring of these long-term sites in the Chichester Ranges shows that the central extent of the Chichester Ranges contains small, disjunct quoll populations, separated by several kilometres of unsuitable habitat, and that northern quolls have a dynamic and intermittent presence in the landscape, likely influenced by predation, climate, and environment. Western sites showed similar trends but not to the same extent and were far more stable than central or southern sites with higher averages of northern quolls recorded per year. For sites where northern quolls were recorded, the presence of quolls, feral cats, and common rock rats fluctuated over the six years, and there was evidence of breeding, predation, and immigration at many sites, particularly Quoll Knoll.

Feral cats are implicated in the extinction of 63 species worldwide (Doherty et al., 2016), and are believed to restrict northern quolls to rocky areas in the Pilbara, while cats tend to prefer open, flat habitats (Hernandez-Santin et al., 2016). However, habitat overlap does occur, and there was evidence of a northern quoll inside the stomach of a captured feral cat at Quoll Knoll during 2016 (Aussie Feral Pests, 2016). Northern quoll and feral cat activity at Quoll Knoll often coincided, with quoll absences mainly falling around February or August—the times when sub-adult young would be dispersing (February), northern quolls would be mating (August), and prey availability for feral cats (and quolls) would be low (August). Temperatures were also warmer (February), and rainfall was lower (August) at these times of the year. A lack of prey due to low rainfall may cause feral cats to move into rocky habitats to look for food, as they were often present at Quoll Knoll during August. Feral cats can have a higher activity overlap with northern quolls in areas where quolls are denning (Cowan et al., 2020c).

Northern quoll persistence relies heavily on juvenile survival, and successful dispersal from maternal dens to other landscapes is critical to support genetic variation and quoll populations long term (Moro et al., 2019). There is evidence that Quoll Knoll and the surrounding area can support northern quolls over short and long periods of time, with evidence of the same female trapped a year apart (Henderson, 2015), a young quoll being raised to a sub-adult in 2018 (Cowan et al., 2020c), and a male northern quoll captured in 2018 during April and November at both Quoll Knoll and the West Shaw Bridge. It had gained ~245g in weight between captures (Aussie Feral Pests, 2018). Northern quolls were detected in the month after successful feral cat trapping on 75% of occasions. In comparison, feral cats were not detected in the month after targeted feral cat control events on 75% of occasions. This suggests that current feral cat control is successful in removing feral cats from the landscape for a short period and when strategically targeted at the time of year when quolls are most vulnerable, may assist in reducing mortality of northern quolls from feral cat predation (Moro et al., 2019). Feral cat trapping was most successful around July, and feral cat control in the arid zone (like the Pilbara) is generally most effective during the winter months (Lohr and Algar, 2020, Algar et al., 2013). Northern quoll survival is high during *Eradicat®* baiting (Cowan et al., 2020a). This method as well as automated feral cat grooming traps (Felixers™) may be useful tools to complement existing feral predator management, while also being safe for native species (Dunlop et al., 2020).

Feral cat presence at Quoll Knoll was identified every year using camera traps or targeted feral cat trapping. After northern quoll cage trapping switched to primarily the use of camera traps at most sites, the number of species detections generally increased. The use of camera traps, and particularly top-down camera setups instead of the more labour-intensive cage trap arrays is a cost-effective monitoring method for both northern quolls and other species (i.e., feral cats, rock rats) (Moore et al., 2020b, Moore et al., 2020a). Northern quolls, feral cats, and other species (i.e. Perenties *Varanus giganteus*) can be identified using camera traps without the need for live-trapping and animal handling (Moore et al., 2020b, Hohnen et al., 2013, Moore et al., 2020a). Another benefit to this technique over live trapping is the length of deployment time allowing for a greater chance of detections in more sparsely populated areas such as Wall Creek and Mesa 228. Top-down cameras should be paired with outwardsfacing cameras in order to best capture the presence of northern quolls and their predators (i.e. feral cats; Moore et al., 2020b), and can be used to identify individuals.

Northern quolls (particularly males) can travel long distances when mating and dispersing (Oakwood, 2002). Many Chichester Range sites are separated by several kilometres of unsuitable habitat (i.e., spinifex sandplain), and movement between rocky outcrops may be dangerous if feral cats are present in the more open landscapes, where they are more successful hunters (McGregor et al., 2015). The times when northern quolls are dispersing or breeding are when they are at their most vulnerable, and therefore feral cat control is critical to lessen predation pressure on northern quolls and their young (Dunlop et al., 2018).

Cane toads have devastated northern quoll populations across northern Queensland and the Northern Territory (Ibbett et al., 2018, Moore et al., 2019), and large intense fires followed by feral cat predation can be equally as destructive (Woinarski et al., 2004, Stobo-Wilson et al., 2020). The potential influence of threatening processes on northern quoll populations is demonstrated at the Python Pool monitoring site. At this site, several northern quolls were detected in 2014. However, during the summer of 2014/15, a large wildfire swept the monitoring site and quolls struggled to recover to similar numbers in the following years. The initial quoll population decrease at Python Pool is likely attributed to the wildfire reducing vegetation, food, and habitat cover (Woinarski et al., 2004). The slow recovery by northern quolls at this site may be due to a lack of prey species and enhanced predation pressure in the disturbed landscape. As majority of the detections at Python Pool were during the mating season, it is possible that the movement in and out of the area was due to quolls searching for mates. Feral cats are more successful hunters in open habitat (McGregor et al., 2015), and often prefer burned and disturbed landscapes, so would pose a higher threat to northern quolls moving through the landscape (Davies et al., 2020).

Northern quolls have been recorded using a number of man-made structures, including, rail culverts beneath the rail line (Turner, 2018), and artificial refuges (Cowan et al., 2020c). However, these structures have also been exploited by feral cats, and monitoring along with adaptive management is key to ensure the safety of northern quolls using these structures (Cowan et al., 2020c). Suitable refuge habitat for northern quolls in the south-eastern Chichester Ranges appears to be widely dispersed throughout the landscape, making northern quolls vulnerable to predation when moving between them, or dispersing following recruitment. Expanding or replacing existing monitoring sites with other sites further north within the Chichester subregion where northern quolls are in higher densities (i.e. Dolphin Island, Mesa behind Rail Camp 1; Davie, 2019), is likely to provide more useful information to understand population trends. Parts of the northern Chichester subregion with the highest likelihood of northern quoll presence are suggested for future monitoring and may be more viable as populations are more stable.

5 Recommendations

- Remove some central Chichester locations monitored from 2014 to 2019 (Chainage 182, Wall Creek, Bea Bea Creek, Cockeraga Creek) from the long-term monitoring program due to the intermittent presence of a small number of northern quolls.
- Establish new monitoring sites within the Pilbara region in areas with high densities of northern quolls (e.g., areas between Chainage 50 and Chainage 100 in the northern Chichester subregion, and Dolphin Island). Reconnaissance surveys should also be conducted across the Pilbara to identify populations suitable for further monitoring.
- Due to practicality and improved monitoring methods, transition annual quoll monitoring at both Quoll Knoll and Mesa 228 to cameras only for extended time periods. This should commence in 2021. This will be to trial a new camera arrangement based on findings by Moore et al. (2020b). The aim is to test and develop a robust method that can be used across the Pilbara for comparative purposes with this location being one site for this Pilbara-wide project. These sites do not satisfy the criteria to be long-term trapping sites, however, both locations have provided valuable data and are prime candidates for continued annual camera monitoring. Given that feral cat control is being conducted at this location as per DBCA recommendations, and has been shown to be effective in enabling northern quoll persistence and breeding success (albeit in small numbers), it is also a good opportunity to use this new camera array at this site. Use of the current camera array set up at Quoll Knoll can be leveraged, whereas new cameras are to be installed at Mesa 228. DBCA can provide detail on the location, number of cameras to be set up and deployment term for these two locations that are sited 3 km apart. Image data to be analysed annually.
- Continue to undertake feral cat and fox control via feral animal control trapping events in the Quoll Knoll area to help protect northern quolls present in this area. Control should be undertaken three times per year during February/March, June/August, and October/November. Control during the period around July has been shown to be particularly effective (Lohr and Algar, 2020). Feral cat cage trapping results and camera trapping data for the

presence of northern quolls and feral cats to be added to the current database and ongoing data analysis is to be conducted to ascertain the effectiveness of the feral cat control program.

- DBCA, Roy Hill, and FMG continue the trials of the Felixer™ feral cat grooming trap, subject to APVMA and other approvals, with the future intent of a trap being located at Quoll Knoll.
- Explore the suitability and potential effectiveness of *Eradicat*™ baiting in the Quoll Knoll area (baiting should occur in an area of 20,000 ha minimum to sufficiently control feral cats (e.g., Cowan et al., 2020a).
- Any northern quolls trapped accidentally during a feral cat control program be processed, photographed, and data provided to DBCA. Images of quolls and feral predators taken from the passive camera array at Quoll Knoll be provided to the feral pest contractor prior to each feral animal control event, to enable a targeted program.
- Based on the results of northern quoll presence for the Chichester Ranges for the period 2014-2019, DBCA recommend a review of the current approved Roy Hill Northern Quoll Research Plan to transfer the focus from the Chichester Ranges and redirect research effort towards remaining knowledge gaps that benefit the conservation of northern quolls.

Appendices

Appendix 1. Presence and absence of northern quolls at all sites monitored in the Chichester Ranges from 2014 to 2019. Yellow highlighted cells represent months where cage trapping or camera trapping occurred. The letter 'Y' represents a positive presence of northern quolls in that month. Quoll presence or absence was determined using records from DBCA Chichester Range reports from 2014 to 2019, the DBCA northern quoll trapping database, Animal Pest Management Services reports from September 2014 to March 2016, and Aussie Feral Pests reports from August 2016 to November 2019 at Quoll Knoll. Presence of an animal was confirmed if the animal was captured (in a cage trap or on a camera trap), therefore the presence of scat was not used to determine presence.

Euro Springs	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
																	Y						
	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
			Y																				
	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
				Y	Y	Y	Y											Y	Y	Y			
Wall Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
					Y	Y								Y	Y			Y					
	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
					Y													Y	Y				
Mesa 228	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
															Y								
	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
																		Y	Y	Y			
Quoll Knoll	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
	Y		Y	Y	Y	Y		Y	Y						Y	Y						Y	Y
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Cockeraga Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Coonarrie Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Appendix 2. Presence and absence of feral cats at all sites monitored in the Chichester Ranges from 2014 to 2019. Green highlighted cells represent months where targeted feral cat trapping or camera trapping occurred. The letter 'Y' represents a positive presence of feral cats in that month. Cat presence or absence was determined using records from DBCA Chichester Range reports from 2014 to 2019, Animal Pest Management Services reports from September 2014 to March 2016, and Aussie Feral Pests reports from August 2016 to November 2019 at Quoll Knoll. Presence of an animal was confirmed if the animal was captured (in a cage trap or on a camera trap).

Euro Springs	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
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Wall Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Mesa 228	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
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Quoll Knoll	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Chainage 182	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Python Pool	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Bea Bea Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Cockeraga Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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Coonarrie Creek	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16
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