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Biodiversity and Conservation Science

# Northern quoll targeted surveys in the Chichester Ranges

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Report prepared for Roy Hill Pty Ltd

November 2019

GOVERNMENT OF WESTERN AUSTRALIA

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Cover image: Granite outcrop habitat in the Pilbara. Judy Dunlop

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## Acknowledgments

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## Summary


- Monitored northern quoll populations have fluctuated over time but reduced feral cat numbers appears to improve northern quoll persistence. This is supported by the results of the PhD study showing that feral cat presence is the most important predictor of northern quoll occupancy.
- Monitoring locations with feral cats, particularly in combination with removal of cover by clearing or wildfire suffered temporary local extinctions of northern quoll populations. These included Quoll Knoll and Python Pool sites.
- Monitoring via top-down cameras appears to be an effective technique of identifying individuals and can be used for a much longer period than trapping.
- Quoll Knoll was shown to be occupied again in 2018, with evidence of successful breeding over the 2018-2019 summer. At least one pouch young were raised to independence.
- Northern quolls are exhibiting choices on the physical parameters of denning locations, relating to surrounding habitat characteristics, size of entrances and depth of the den. These characteristics are likely to be driven by temperature and humidity preferences, as well as protection from predators, and prey availability at sites.
- Felixer feral cat grooming traps are likely to be a useful complementary tool for managing feral cats. There have been no non-target issues with native Pilbara species (including northern quolls) from a 6-month non-toxic trial. Trials are continuing at a secure site with the view to progress to toxic mode in 2019.

# 1 Introduction

This report details the northern quoll research undertaken by the Department of Biodiversity, Conservation and Attractions (DBCA) for Roy Hill, as well as the collaborative research projects with Charles Sturt University students and Fortescue Metals Group in 2018. This research is focused on northern quoll (*Dasyurus hallucatus*) 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. This work conducted in 2018 is a continuation of previous survey efforts throughout the area (Johnson and Anderson, 2014; Dunlop *et al.*, 2015b; Dunlop and Johnson, 2016; Dunlop *et al*., 2017). The results of this and previous surveys are summarised and discussed.

## 1.1 Northern Quoll

The northern quoll is a medium-sized omnivorous marsupial, the smallest of Australia's four species of *Dasyurus* (Oakwood, 2002a). 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 (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). In particular, 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.

Several other ecological factors are contributing to the decline of quolls and other medium-sized mammal fauna, including predation by feral cat (*Felis catus*), wild dogs (*Canis lupus*), 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; Hill and Ward, 2010; Woinarski *et al.*, 2014). 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 dispersing phase by removal of threats (feral predators) or preservation of habitat corridors by burning outside of 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 primarily on more complex rocky habitat (Molloy *et al.*, 2017) than northern quolls in the Northern Territory or Queensland, where tree hollows and logs are common (Oakwood, 1997). The ridges and mesas of channel-iron deposits and banded iron formations are often the primary focus of iron-ore extraction in the Hamersley Province

(Morris and Ramanaidou, 2007), 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 they are 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, 2002b). The species is the largest animal in the world to undergo suicidal reproduction (semelparity), whereby males experience immune system collapse and eventual death, usually in the first year, after an intense mating period (Oakwood *et al.*, 2001; Fisher *et al.*, 2013). This enables females to drive intense competition between males, and allow females 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, 2002a).

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, 2002b) and to a lesser extent in the Kimberley (Cook, 2010; How *et al.*, 2009; Schmitt *et al.*, 1989), few studies have been undertaken on northern quolls in the Pilbara. Due to the limited evidence available to allow for the creation of ecologically equivalent offsets (Department of Sustainability, 2011) for the northern quoll in the Pilbara, 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 Infrastructure Pty Ltd (Roy Hill) has Commonwealth and WA Office of Environment Protection Authority approval for the Roy Hill Rail and Associated Infrastructure Project (the Rail Project) which comprised the construction and operation of a recently completed 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 such as a permanent access road running the length of the rail alignment, additional construction roads, bridges, passing sidings, workshops, borrow and ballast areas, lay down areas and four temporary construction workforce camps. Since construction was completed in late 2015 and operations have started, camps, borrow pits and other temporary construction sites have been decommissioned, with all these temporary areas 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).

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

- 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;
- To inform management for the conservation of northern quoll populations in and around mining sites and other developments in the Chichester Ranges; and
- To help clarify the genetic and conservation status of the Chichester Ranges northern quoll population.

## 1.3 Previous Surveys

Records of northern quolls in the Pilbara have increased substantially along with the interest in exploration of the area by industry (See Appendix 1). Significant effort has been made in recent years to determine the presence and extent of northern quolls within the Pilbara region, including the target area of the Chichester Ranges (Biota Environmental Sciences, 2005; Davis *et al.*, 2005; Ecologia Environment, 2008). Prior to 2000, there were 46 unique records of northern quolls on NatureMap, compared to 1377 records from 2001 onwards. Regular surveys for threatened species are undertaken at nearby sites relevant to the Fortescue Metals Group (Spectrum Ecology, 2018), so data for those are used for comparison here.

Previous surveys and species distribution models (Molloy *et al.*, 2017) indicate that northern quolls are most likely to occur in granite outcrops in the Abydos plains, and in the north-western edge of the Hamersley Ranges. Populations of northern quolls in the eastern part of the Chichester Ranges appear to be highly fragmented with small breeding colonies occupying relatively isolated islands of suitable refuge and foraging habitat. This is supported by population genetics work that shows high rates of dispersal and genetic mixing, presumably by male animals, across the landscape (Spencer *et al.*, 2013). This level of heterogeneity in the population is such that the entire Pilbara population appears to be one genetic unit; that is, quolls from different areas of the Pilbara cannot be genetically differentiated.

Some sites in the southern Pilbara that appeared to meet the requirements for suitable quoll habitat (substantial complex rocky habitat with prey resources available) were determined to have no quoll presence during previous surveys (Johnson and Anderson, 2014). It is likely that predation pressure is limiting the dispersal of northern quolls into these suitable habitats. Quoll populations appear to increase in number and distribution further north and west of this study area (Coffey Environments, 2012; Rapallo, 2012). DBCA established two long-term monitoring sites at more westerly Chichester Range sites, Mt Florance and Python Pool, in 2014. Monitoring at these sites has indicated that populations are subject to environmental variation; a large fire at Millstream National Park in the summer of 2014/15 went through the trapping site which reduced the number of quolls trapped post-fire, and there is no indication that the local population has been able to recover to pre-fire levels.

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 actions.

The northern quoll population at Quoll Knoll is considered significant due to the low density and sparse spread of quoll populations in south-eastern Pilbara (see Ecoscape, 2017; Molloy et al., 2017). This population is close to the south-eastern limit of known quoll records and appears to be self-sustaining, with evidence of breeding and immigration. Feral animal management should continue to be of high priority to protect this small population.

# 2 Methods

Quoll records from the Chichester Ranges have been opportunistically added to the Northern Quoll Regional Monitoring undertaken by DBCA. Since 2014, several new locations of intermittent occupancy have been identified in this region. Unlike core parts of the northern quoll's habitat in the Pilbara, such as the granite outcrops south of Port Hedland (Red Rock), or the western edge of the Hamersley Range (Pannawonica region), northern quolls are not in high numbers and are not consistently present at these Chichester Ranges locations. The areas that have been surveyed by DBCA are shown in *Figure 2*.

## 2.1 Climatic Data

Climatic data were collated from the nearest BOM weather station (Wittenoom station 005026), Wittenoom, located 38km from Wall Creek, 95km from Mesa 228, and 190km from Python Pool. The monthly averages of rainfall and temperature from 1951 to 2017 are shown in Figure 1. The Pilbara experiences much of its rainfall during monsoonal rainfall events over summer, with cool and dry winters. The region received higher than average summer rainfall In January 2018, and significantly less than average between February and May. In June 2018 there was an unseasonal 88mm of rain followed by well below average rain for the rest of the calendar year. There was little difference in 2018 minimum and maximum temperatures when compared to the long-term averages.

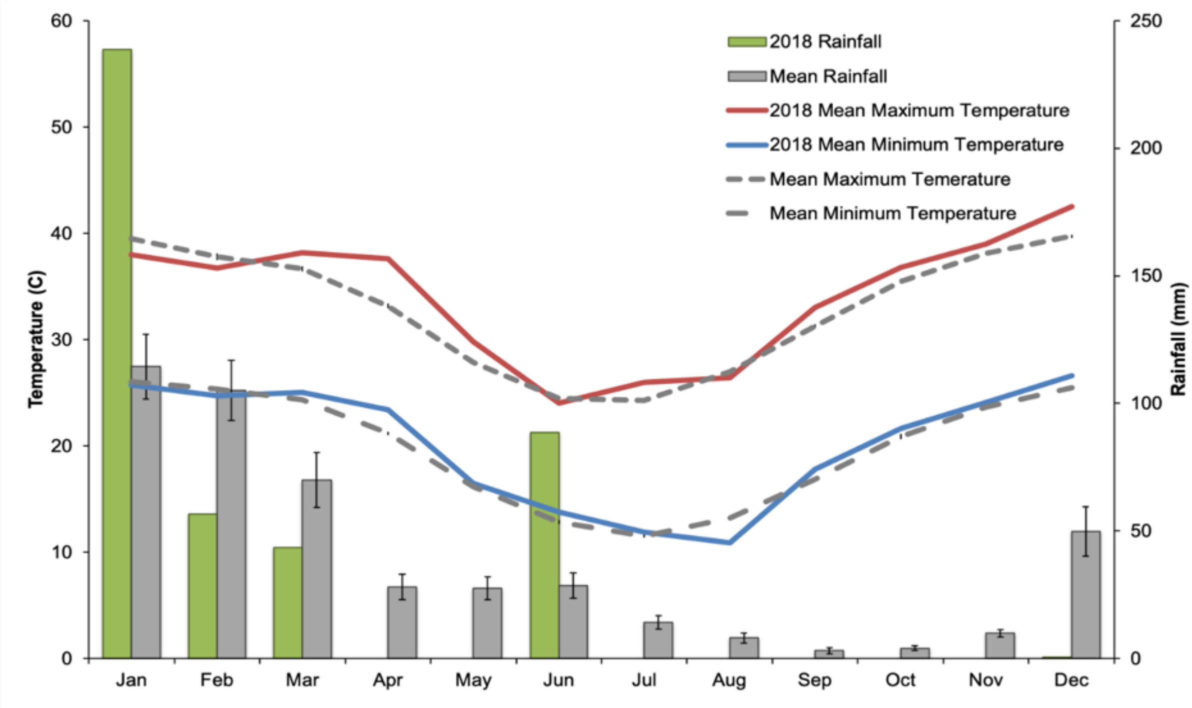



*Figure 1.* Climate data for the nearest Bureau of Meteorology weather station, Wittenoom station (005026). Grey columns indicate the 50-year mean monthly rainfall, grey lines indicate the 50-year mean monthly minimum and maximum temperatures, and coloured columns and lines are 2018 data for comparison.


*Figure 2.* Map of the 2018 Roy Hill northern quoll camera and cage trapping sites (Wall Creek, Chainage 182 granite outcrop and Quoll Knoll) in the context of the Pilbara, showing Roy Hill Railway and other relevant quoll DBCA monitoring sites.

## 2.2 Cage trapping

Annual live trapping was conducted by the Pilbara Northern Quoll Regional Monitoring Project at Python Pool in August of 2018. Live trapping employs the standardised method of two transects of 25 wire-mesh traps (45cm x 17cm x 17cm, Sheffield Wire Co, Welshpool WA) set 50m apart, opened for four consecutive nights for a total of 200 trap nights per session, baited with peanut butter, oats and sardines. Each individual quoll is microchipped, weighed and measured, body condition is assessed, and tissue samples taken for genetic analysis.

Targeted feral cat trapping also occurred along the Roy Hill SRL near Quoll Knoll, in April, July and November 2018. This feral animal control program was conducted by Aussie Feral Pests (AFP). 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 are discovered. Any northern quolls incidentally captured in cat traps were scanned for a microchip, tissue taken, measured and released, with data provided to DBCA.

## 2.3 Camera Trapping

Live trapping using wire cages currently exists as the primary means of assessing quoll population size as part of the Pilbara northern quoll monitoring program. While useful for obtaining demographic data or collecting samples such as tissue for DNA analysis, live trapping is both expensive and time consuming, with trapping sessions running for a minimum of four days at a time (Dunlop *et al*. 2014). Remote camera 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.

Reconyx PC900 Hyperfire cameras were attached to a wooden stake 1.5 metres above the ground, orientated in a downward-facing position. Given 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 day and night with five consecutive photographs per trigger. 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. We paired several top-down cameras with outward-facing cameras in order to validate that species were not missed by the downward facing setup.

Five top down cameras were placed at Wall Creek (24 May – 23 August; 641 camera nights) and Euro Springs (24 May – 29 August; 679 camera nights) respectively and two more downward facing cameras were deployed by Roy Hill on Quoll Knoll (9 October – 14 February; 256 camera nights). Four cameras were deployed at Chainage 182 from 12 Oct 2018 – 22 Jan 2019, totalling 408 camera nights (Table 1).

*Figure 3.* Installing downward-facing cameras in quoll habitat at Wall Creek.

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, this was defined as a series of photographs with no more than a 15-minute interval between successive photographs of a quoll (Diete *et al.*, 2015). 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).

*Table 1.* Site locations and survey effort for the 2018 field season.

| | Latitude | Longitude | Trap Nights | Camera Nights | Set Date | Retrieval Date |
|---|---|---|---|---|---|---|
| Wall Creek | -22.03 | 118.63 | - | 641 | 24/05/2018 | 23/08/2018 |
| Ch182 | -21.85 | 118.95 | - | 408 | 12/10/2018 | 22/01/2019 |
| Euro Springs | -21.77 | 117.92 | - | 679 | 24/05/2018 | 29/08/2018 |
| Python Pool | -21.33 | 117.24 | 200 | - | 28/08/2018 | 31/08/2018 |

# 3 Chichester Range surveys

Since 2014, DBCA and Roy Hill have been monitoring several sites through the Chichester Range in order to learn more about northern quoll populations in this habitat. The density of quolls is variable between the sites, and not consistent between years. Each site is discussed in detail below.

*Table 2.* Species detection history for five sites. Captures during the three-year period included northern quolls (*Dasyurus hallucatus*), Common rock rats (*Zyzomys argurus*) and House mice (*Mus musculus*). Trap nights with an asterisk* refer to camera traps rather than cage traps.

| | Captures | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Euro Springs | Quoll | 6 | 5 | 3 | 12 | 8 |
| | Rock rat | 2 | 2 | 2 | 91 | 27 |
| | House mouse | 0 | 0 | 0 | 0 | 0 |
| | *Trap Nights* | *200* | *200* | *200* | *510** | *679** |
| Python Pool | Quoll | 9 | 1 | 1 | 3 | 0 |
| | Rock rat | 5 | 19 | 7 | 0 | 3 |
| | House mouse | 0 | 0 | 0 | 0 | 0 |
| | *Trap Nights* | *200* | *200* | *200* | *200* | *200* |
| Wall Creek | Quoll | - | 0 | 0 | 3 | 1 |
| | Rock rat | - | 1 | 3 | 34 | 134 |
| | House mouse | - | 1 | 0 | 0 | 0 |
| | *Trap Nights* | *-* | *200* | *200* | *1010** | *641** |
| Mesa 228 | Quoll | - | 1 | 0 | 0 | - |
| | Rock rat | - | 17 | 18 | 1 | - |
| | House mouse | - | 0 | 0 | 0 | - |
| | *Trap Nights* | *-* | *200* | *200* | *1230** | *-* |
| Quoll Knoll | Quoll | - | 3 | 0 | 2 | 4* |
| | Rock rat | - | 0 | 1 | 0 | - |
| | House mouse | - | 0 | 0 | 1 | - |
| | *Trap Nights* | *-* | *40* | *40* | *40* | *-* |

## 3.1 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 4). Quoll Knoll is a small (200m x 100m) lateritic outcrop of very large boulders, bounded by the railway cutting on one side, and with a vehicular track running between two separate rocky areas. Vegetation includes *Triodia* sp. and other shrub species, with a creek line at the base of the outcrops containing a mixed vegetation composition including dominant *Acacia* species (Phoenix Environmental Sciences, 2011).

Three individuals were trapped by DBCA in September 2014 as part of a targeted northern quoll survey in the central and eastern Chichester Ranges (Johnson and Anderson, 2014).

Monitoring using cage trapping and camera traps has confirmed occupation and breeding at the Quoll Knoll complex most years. A total of five individuals were trapped during this time; two females and a male initially caught in 2014, one new male and one new female caught in 2015 with only one female recapture from the previous year.

During the 2016 monitoring survey, no quolls were trapped over the 40 trap-night effort, however a large male feral cat was subsequently trapped and euthanised with gut contents determined to consist entirely of northern quoll. It was presumed that this predation event caused the local extinction of the small population, with the last evidence of quolls occupying Quoll Knoll captured on the 8th of July 2016 by Roy Hill staff on one of the four permanent camera trap stations deployed at Quoll Knoll and its surrounds (Dunlop and Johnson, 2016). Monitoring via camera traps indicated that Quoll Knoll was recolonised in 2017, and DBCA trapped two individuals at the site in April 2017.

In addition to the two top down cameras deployed by Roy Hill at Quoll Knoll, there are four permanent (since April 2014), unbaited camera traps set at Quoll Knoll and on the two smaller knolls to the west of the LV track (Knoll 2 and Knoll 3), plus a camera located at a quoll latrine site under the West Shaw River rail bridge. Quoll Knoll was also one of the "natural den" sites used in the artificial denning honours project, see Section 4 (page 18) for further detail.

The nearby Mesa 228 (*Figure 2*, approximately 1.5km south from Quoll Knoll) was chosen to be included as a survey site due to its proximity to the Quoll Knoll population, size of suitable habitat and complexity of breakaway habitat. One individual male northern quoll was captured at Mesa 228 in 2015, but there have been no further records in two years of monitoring (either by cage traps or by cameras) conducted in 2016, 2017, and this site is no longer part of the long-term monitoring program.

*Figure 4.* The small rock outcrop referred to as Quoll Knoll. It lies directly between the Roy Hill rail line and Rail Service Track used by light vehicles.

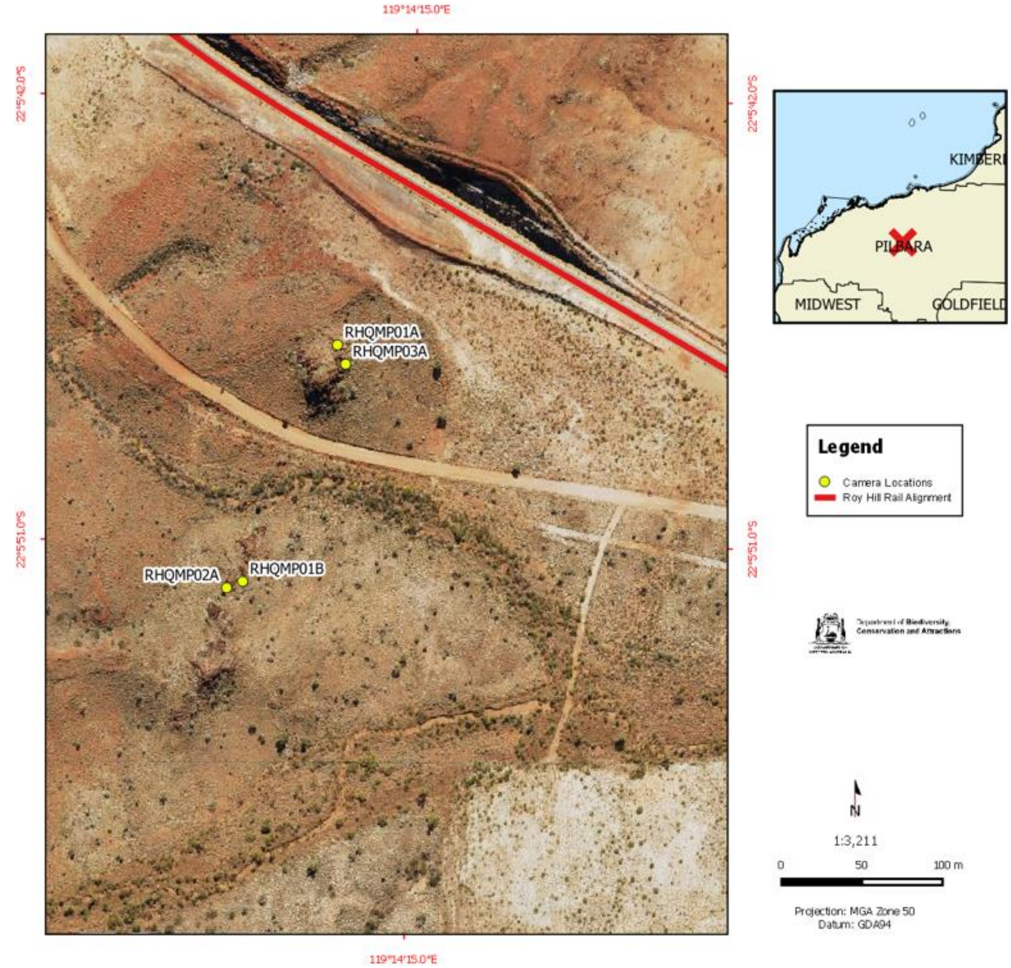



*Figure 5.* Map of Quoll Knoll, showing the rail line, light vehicle track and permanent monitoring camera locations.

The permanent unbaited cameras placed around Quoll Knoll and its surrounds identified at least four individual quolls from approximately 100 occasions. There was evidence of breeding at Quoll Knoll in 2018, with one adult female being photographed with young still attached to the pouch (*Figure 6*). This indicates that Quoll Knoll is again being used as a denning location for breeding female northern quolls. A later image from the cameras installed to monitor dens showed one independent subadult northern quoll (*Figure 6*). Other species detected included two occasions of common rock rats, 21 occasions of euros and 29 detections of perentie (*Varanus giganteus*). There were eight detections of feral cats, but no evidence of any other species of feral predator detected. Pilbara grasswrens, a recently identified unique species (formerly striated grasswren) were detected regularly at Quoll Knoll, suggesting there is a resident population of this cryptic, ground-dwelling species.

Non-target capture of quolls through feral cat management resulted in the capture of five quolls over approximately 525 trap nights (three trap sessions, 35 cage traps over five nights) between April 2018 and November 2018. Three new individuals were caught in the April session (two males, one female), two new individuals were captured (one male, one female) in the July session and two recaptures from April were also recorded (two males). No new individuals were caught in the November session, but one male initially caught in April was recaptured, and had gained approximately 245g in weight as it matured (685g to 930g).


*Figure 6.* Evidence of successful breeding at Quoll Knoll: (top) Female northern quoll with large young attached in November 2018, (bottom) Independent subadult northern quoll in January 2019.

## 3.2 Wall Creek

Wall Creek on Hooley Station (*Figure 2*) is a 2 km long rocky gorge running approximately north-south, eventually feeding into the Yule River to the north. 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* species). It is recognised to have both ecological and Aboriginal significance, and was prioritised to remain undisturbed during the FMG rail construction (Fortescue Metals Group, 2010).

*Figure 7.* Weathered rocky basalt scree slope with mixed vegetation complex at Wall Creek, Hooley Station.

The gorge at Wall Creek (*Figure 7*) was chosen as a monitoring site due to the presence of good northern quoll habitat parameters including permanent water, complex breakaway gorge walls, minimal disturbance from industry or grazing, and generally intact vegetation. However, no individuals were captured in 2015 or 2016 (Dunlop *et al.*, 2016). From 828 camera nights, only one photo of a single individual at Wall Creek was captured in 2016, while there were 8 detections of feral cats. Cameras were again deployed at Wall Creek in 2017 for a total of 1010 trap nights, where during this time three individual quolls were detected, two of which were consistently in the area for two months. Feral cats were not detected at this time. Evidence of quolls have been recorded through scat searches in 2014 at other nearby sites including Coonarrie Creek, Bea Bea Creek and Cockeraga creek, located at 36.5 km, 19 km and 12.4km from Wall Creek respectively (*Figure 2*).

The array at Wall Creek in 2018 (*Figure 8*) detected one individual quoll from three detections over the 641-camera night deployment. All three detections were in June over a five-night period (25 June – 30 June), with no other quoll detections during the deployment. At least 16 species were detected at Wall Creek, with five detections of cats, 134 detections of common rock rats, and 46 detections of Rothchild’s rock wallaby (*Petrogale rothchildsi*). Other species identified were three reptiles, and six bird species (Table 5).

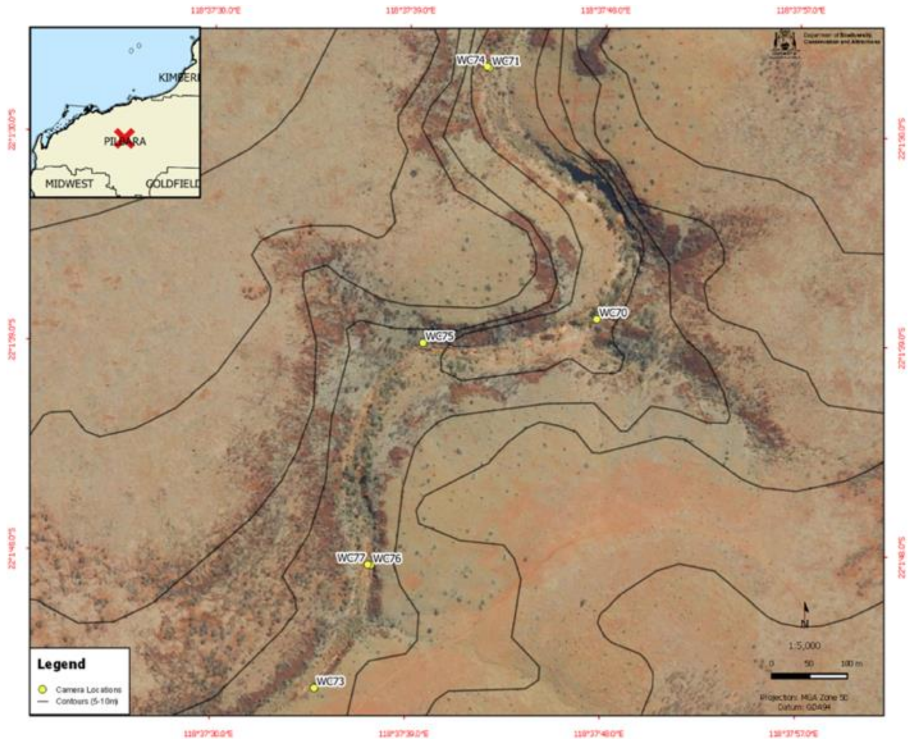



*Figure 8.* Camera trap deployment at Wall Creek, Hooley Station

## 3.3 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 (*Figure 9*). Previous surveys had identified this area as a potential monitoring site for quolls along the Roy Hill rail alignment, but access was restricted. 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).

Quoll presence was confirmed at the Chainage 182 granite outcrop, with a single detection of one individual from 408 camera nights. A further 11 species were detected during the deployment, including four detections of rock rats, three detections of euros (*Osphranter robustus*), one detection of a short-beaked echidna (Tachyglossus aculeatus), 12 detections of Pilbara grasswrens (*Amytornis* white)i and one detection of a spiny-tailed monitor (*Varanus acanthurus;* Table 5).

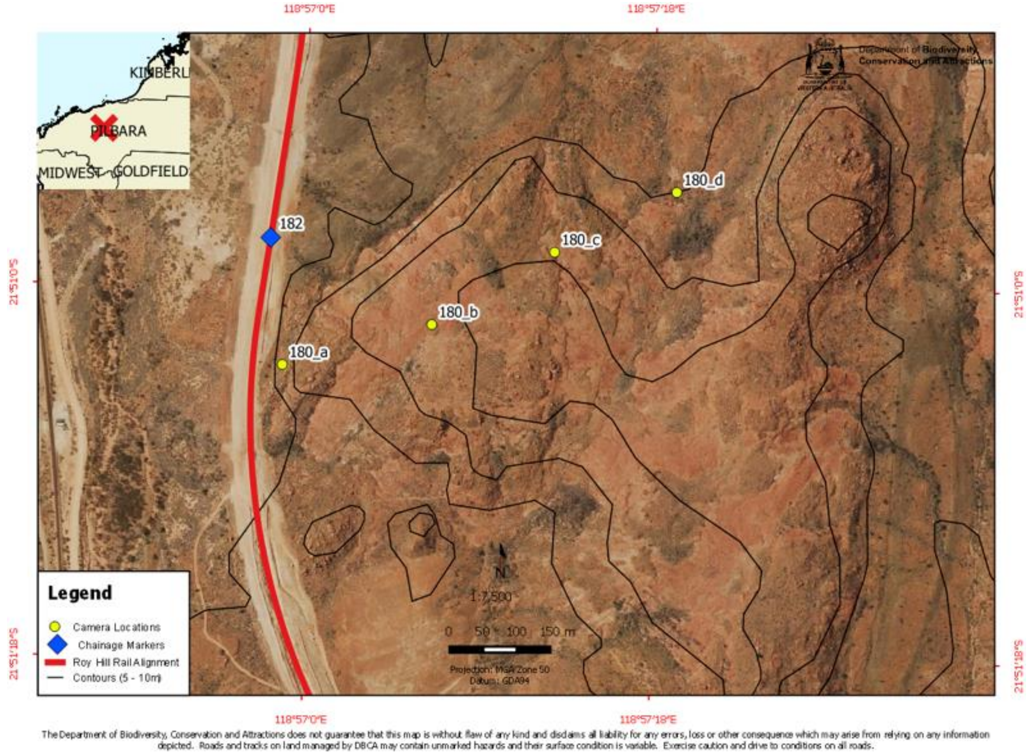



*Figure 9.* Camera trap set along the granite outcrop at Chainage 182 in the Chichester Ranges.

## 3.4 Mt Florance

Euro Springs located approximately 100km south-east of Millstream-Chichester National Park, on Mt Florance station, is complex rocky gorge system running east to west with shallow permanent pools of water along the gorge. The western side of the system has a sandy riverbed substrate and is densely vegetated with Melaleuca 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 sp.* grassland.

Euro Springs was initially part of the live trapping (2014-16) program but then changed to camera monitoring (2017-18). Live trapping resulted in six, five and three individuals captured respectively in three years. Remote cameras were deployed in 2017 for a total of 510 camera nights. Through spot pattern identification at least 12 individuals were identified over the deployment period.

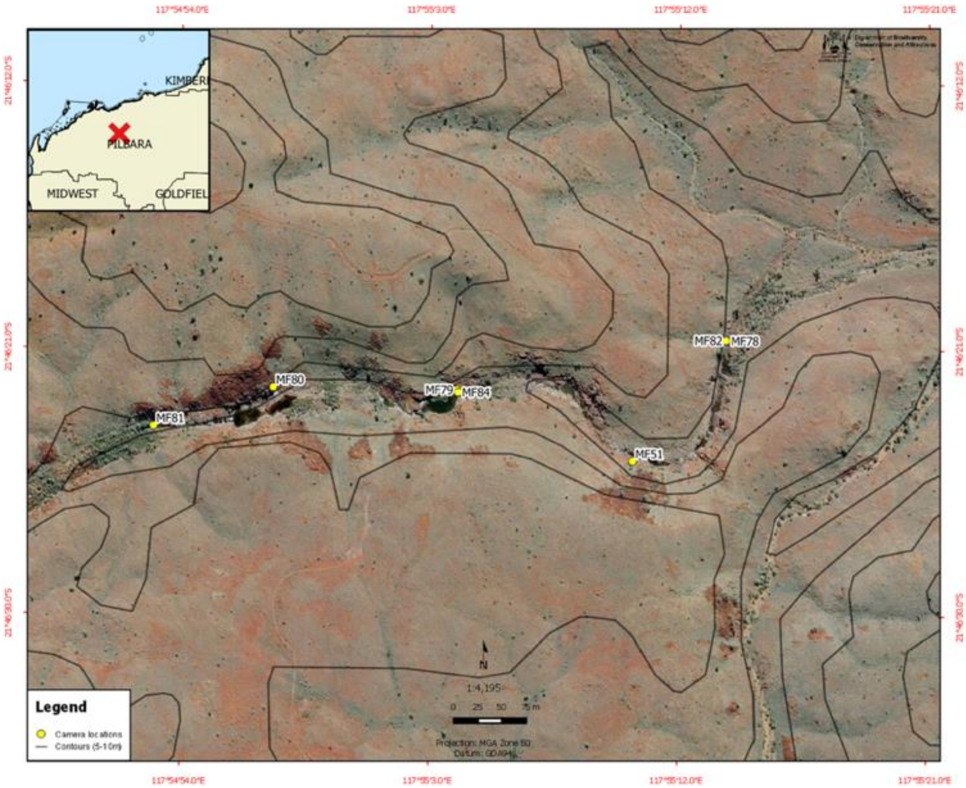



*Figure 10.* Camera trap locations within Euro Springs on Mt Florance station, in the Chichester Ranges.

Five downward-facing cameras, and two outward-facing cameras were set at Euro Springs from May to August 2018, totalling 679 camera trap-nights (*Figure 10*). At least eight individuals were identified from 46 detection events. A total of 11 species were detected during the deployment period, most notably one detection of a cat and three detections of juvenile wild dogs. Other detections include 27 occasions of common rock rats, 33 Rothchild’s rock wallaby and two detections of euro  as well as three bird species and two reptiles (Figure 11)

| | May | Jun | Jul | Aug |
|---|---|---|---|---|
| **MF017** | | 6 | 1 | 1 |
| **MF018** | 1 | 12 | 1 | |
| **MF019** | 1 | 3 | 2 | |
| **MF020** | | 1 | | 1 |
| **MF021** | | 2 | | |
| **MF022** | | | 1 | |
| **MF023** | | 1 | | |
| **MF024** | | | | 1 |
| **Individuals** | 2 | 6 | 4 | 3 |

*Figure 11.* Detection history of individual northern quolls at Euro Springs over the 2018 deployment period. Numbers inside each cell indicate the number of times an individual was detected in each month. A total of eight different individuals passed through Euro Springs over the four-month deployment.

## 3.5 Python Pool

Python Pool trapping site is nestled in the Chichester Range 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 1.2km. 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 and transitioning to wattles and Melaleuca through the sandy creek bed. The surrounding vegetation is a mixed *Triodia sp.* and marbled gum (*Eucalyptus gonglyocarpa*) open grassland.

Python Pool, located within Millstream-Chichester National Park, is the most westerly long-term survey location of the northern quoll project. Annual live trapping has been conducted since 2014 and has indicated a low abundance of quolls at this location. Initial trapping in 2014 show nine individual captures. However, during the summer of 2014/15 a large wildfire burnt through Python Pool and the surrounding area, which has negatively affected the quoll population at this site. 2015 and 2016 annual trapping resulted in only one individual captured each year. 2017 showed an improvement in numbers with three individuals captured.

Cage trapping at Python Pool in 2018 resulted in no quoll captures from 200 trap nights, and five individual common rock rats from six captures over the trapping session. Feral cat sign was commonly detected and coupled with a lack of cover over a large area following the 2014-15 fire, may explain the lack of northern quolls in this location.

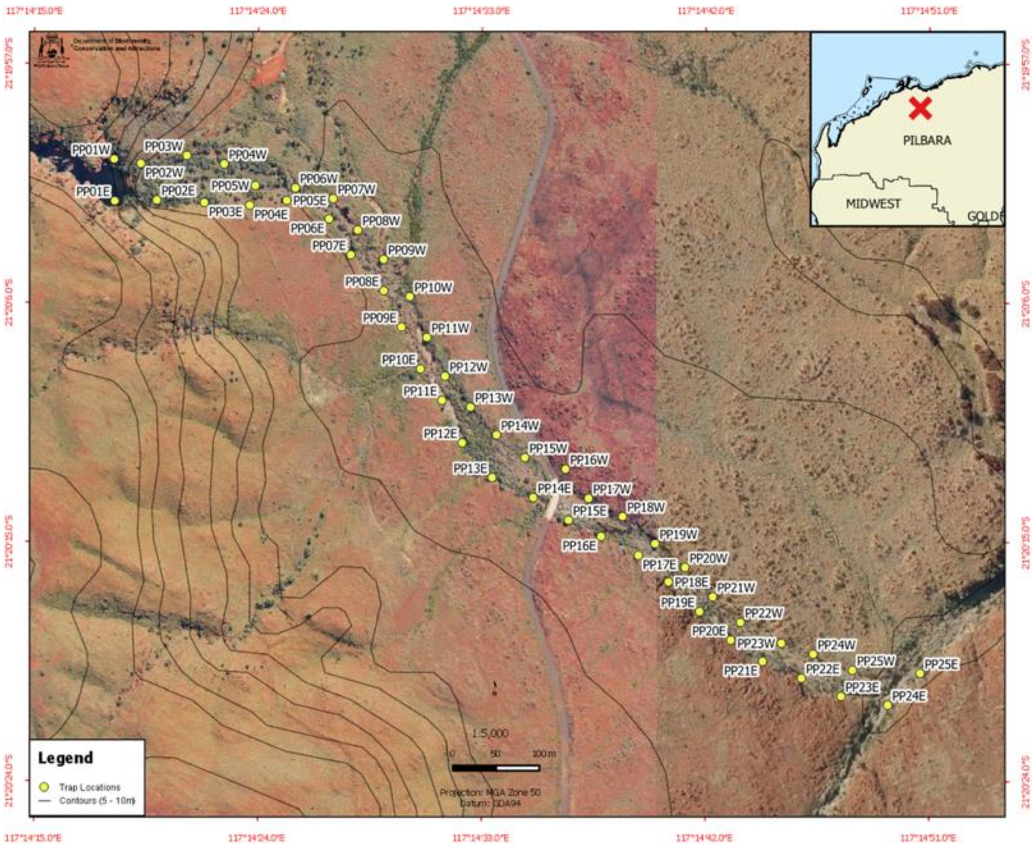



*Figure 12.* Regional monitoring site Python Pool, in the Millstream-Chichester National Park in the Chichester Ranges.

# 4 PhD and Honours research contributions

Roy Hill have been assisting in-kind and financially with two collaborative research projects between Charles Sturt University and DBCA that address the research priorities outlined in Cramer *et al.* (2016). Harry Moore (a collaborative PhD project between Charles Sturt University, DBCA, The University of Western Australia and Deakin University) has been examining fine-scale habitat use, as a follow on from broad scale habitat mapping undertaken by Molloy *et al.* (2017), as well as determining the interactions between feral cats, wild dogs/dingoes and northern quolls in different habitats. This PhD project is in its second year of research, with the majority of field studies completed. Mitch Cowan is an honours student researching the physical and thermal properties of the dens used by female northern quolls in the breeding season. His work has compared natural and artificial den sites at several Pilbara locations. Updates on both of these projects are outlined here.

## 4.1 Fine-scale habitat use

Better definitions of habitat attributes favoured by northern quolls is required to advance both species distribution models, as well as the development of predictive site-based habitat modelling (Cramer *et al.* 2016). Fine scale data detailing how northern quolls use habitat may be gained from the association of habitat features with the presence of quolls as determined by tracking using Global Positioning System (GPS) receivers (Gaillard *et al*. 2010). GPS technology has become an important tool in wildlife research and offers a number of major advantages over traditional techniques such as VHF radio tracking. These include their capacity to collect much larger volumes of locational data, with greater accuracy and at a lower cost than VHF transmitters. With the availability of this data comes the potential to conduct much finer scale analysis of animal behaviour than what has previously been achievable. However, there are no published studies to date investigating the use of GPS telemetry systems to study northern quolls (but see unpublished works by Henderson 2015; Hernandez-Satin 2016). This absence within the literature is likely an artefact of weight restrictions imposed on the application of GPS devices on small to medium-sized animals (total collar weight must be <5% of total animal weight) as well as cost limitations. However, recent advances in technology (availability of affordable light weight devices) have recently made GPS telemetry a viable technique with which to study northern quoll movement patterns.

This study aims to expand on our limited understanding of quoll habitat use through GPS telemetry.

**Outcomes to date**

In 2018, we attached GPS collars to 12 northern quolls across three separate sites on Indee station. Collars were set to a high fix rate – attempting a fix every 1-5 minutes and only attempting between 5pm and 7am. These remained attached to the animals for an average of 9 days. Collars collected an average of 566 locational data points each, totalling almost 7000 locational data points. In future analyses, this data will be used to track the fine scale movement of northern quolls, to determine which features of the landscape are most important while foraging.

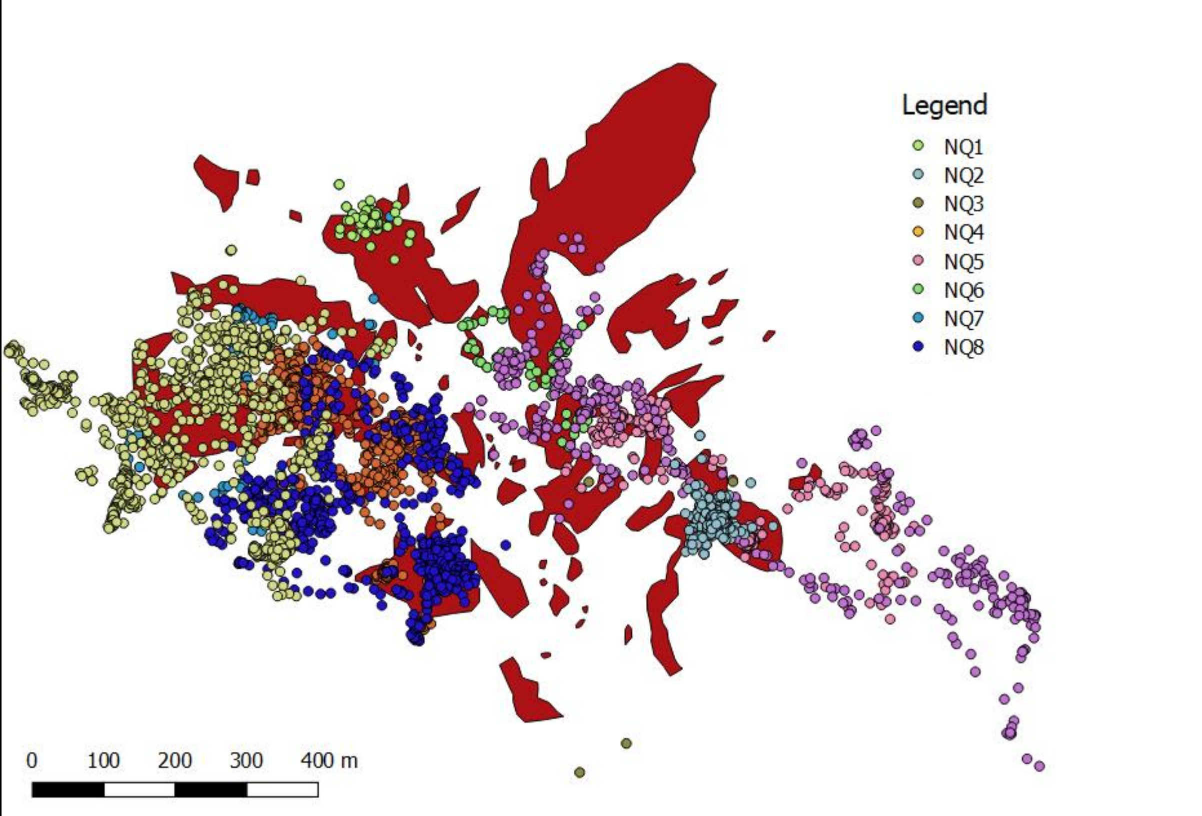



*Figure 13.* GPS data collected from eight northern quolls tracked on Indee station, in the Pilbara. Red areas denote rocky habitat.

## 4.2 Interactions between introduced predators

Cramer *et al.* (2016) identify predation by feral cats, foxes and dogs, altered fire regimes and over-grazing by introduced herbivores as three primary threats facing northern quolls in the Pilbara. Recent work by Hernandez-Santin *et al.* (2016) suggests that northern quolls avoid flat, open habitats frequented by feral cats. Northern quolls existing in the presence of predators may adjust their behaviour both spatially and temporally to avoid predators. Where "islands" of preferred habitat are further apart, the probability of predation may be too high and prevent northern quoll populations from persisting. Large, hot fires that remove protective habitat may further exacerbate predation risk.

We aim to examine the relationship between introduced predators, fire, and northern quoll occurrence. Landscapes will be chosen according to their fire history, to enable a model of the impact of fire history on northern quoll occupancy to be developed. Fire history will be quantified for the landscape surrounding rocky outcrops by measuring the frequency and average interval of fires over the past few decades (based on fine scale fire history maps). We hypothesize that frequent fires have diminished the use of savannah and grassland habitat by northern quolls, and interrupted their movement patterns, leading to range contraction. As we will be simultaneously monitoring other predators, including feral cats, foxes and dogs, we will be able to examine both the influence of fire history on these species that pose a threat to northern quolls, and the spatial and temporal relationships between these predators and northern quolls.

**Outcomes to date**

Since August 2017, motion detecting cameras have now been deployed at all 23 landscapes (184 sites), with over 48,000 traps nights achieved to date. Detections of quolls, feral cats and dogs are shown in Figure 14. So far, 1822 independent quoll detections have been recorded ($15^{th}$ Jan 2019), across 69.6% (16/23) of landscapes, and across four pastoral stations including Indee, Mallina, Pippingarra and Yandeyarra. We have also recorded 76 independent dog detections across 73.9% of landscapes (17/23), and 289 independent feral cat detections across 95.6% of landscapes (22/23). At the site scale, feral cats were present at 50.7% of sites where quolls were detected. Dogs were present at 17.8% of sites where quolls were detected.

Historical satellite imagery was used to map fire history within each of the study landscapes dating back to 1988. Future analyses will assess the interactions between other predators, fire and northern quolls which will allow us to examine the interactions between two high level threats (predation and fire) on northern quolls. The key outcome of this project is the development of causal statistical models that will enable exploration of the most effective management interventions, such as introduced predator control or different approaches to fire management.

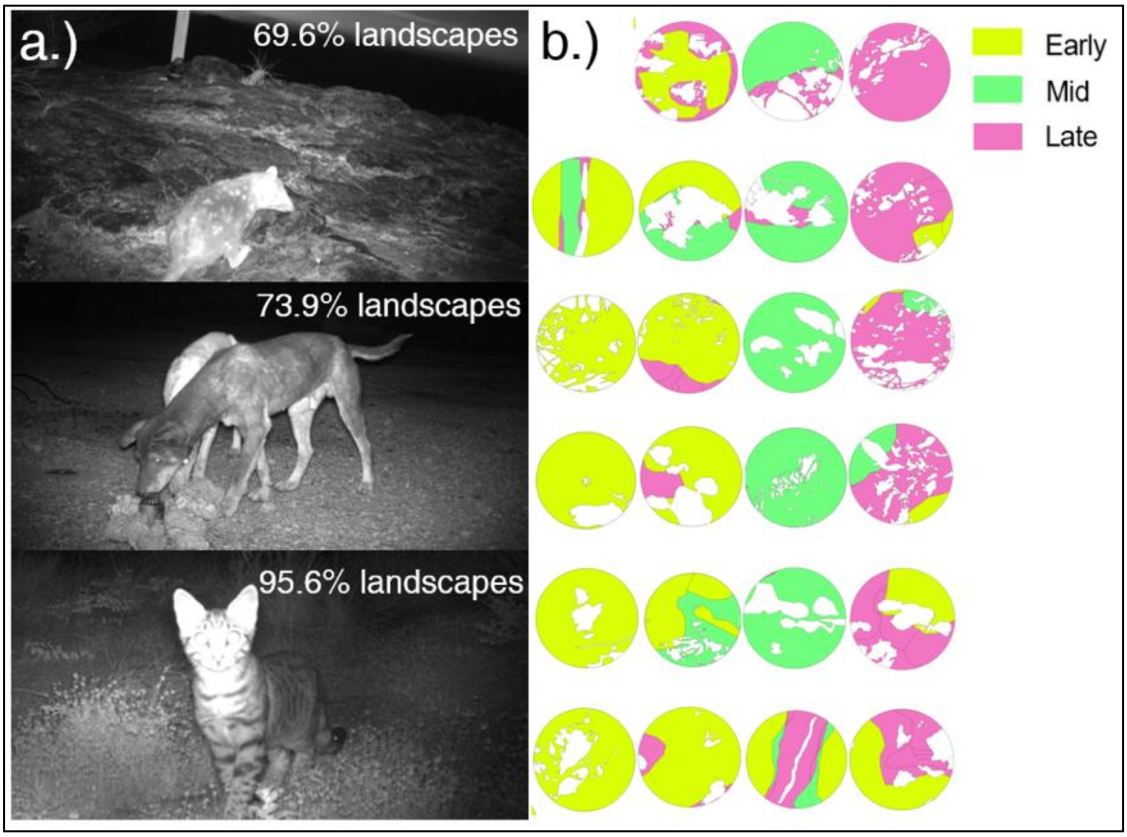



*Figure 14.* a.) Percentage occurrence of northern quolls, wild dogs/dingoes and feral cats captured on camera traps deployed across 23 landscapes as part of our project to determine intraguild interactions between northern quolls (top image), dogs (middle image) and feral cats (bottom image) b.) Fire successional age map across the 23 landscapes. Yellow represents early successional, green represents mid successional and pink represents late successional.

## 4.3 Recolonisation of restored or artificial habitat

### Background

An aspect of research identified to be important was to determine the ability of northern quolls to recolonise disturbed areas or colonise artificial habitat (Cramer *et al*., 2016). The mesas and ranges that make up the preferred habitat of Pilbara northern quolls are increasingly subject to destruction by mining development of iron-ore deposits, as well as granite outcrops, which are used in the construction of roads as well as railway beddings (Amir Abdul Nasir *et al*., 2018; Ramanaidou & Morris, 2010). In cases where known quoll habitat is disturbed due to mining development, the creation of artificial habitat has been proposed to mitigate direct impacts on resident quoll populations and to restore habitat (Atlas Iron, 2012). Recreating den sites, rock crevices located at mesas or rocky landforms in which female quolls raise their litters, is a particular challenge. These rocky landforms provide complex habitat, denning opportunities, protection from weather and predators as well as refuge from fire and extreme temperatures (Braithwaite and Griffiths, 1994; Oakwood, 2000; Cook, 2010). In summer, females use dens to secure dependent offspring when they are too large to be carried (Begg, 1981). Complex habitats may also support more dense and diverse prey populations (Pavey *et al.*, 2017).

Currently, some information exists on the ability of the northern quoll to colonise and use artificial infrastructure (Creese, 2012; Johnson and Oates, 2013; Dunlop *et al.*, 2015a; Henderson, 2015). However, to create artificial dens, rehabilitators must hold a genuine understanding of key characteristics associated with suitable natural denning sites (Maron *et al*., 2012). This information is currently limited within the literature. Breeding dens will likely be structured such that internal temperature and humidity are lower than the external ambient temperature, particularly given that: 1) the Pilbara experiences extreme temperatures during summer when average maxima exceed 40°C and temperatures regularly exceed 45°C and 2) quolls are prone to dehydration and hyperthermia at high temperatures (Cooper & Withers, 2010). Dens are also likely to have specific physical characteristics, such as an opening that is large enough for a quoll to enter but small enough to exclude potential predators (Hernandez-Santin *et al.,* 2016; O'Connell & Keppel, 2016),as well as specific food resources in close proximity (Cook, 2010).

Females have significantly smaller home ranges than males (Oakwood, 2002b), suggesting that they are more tied to core denning habitat and probably occupy prime denning sites. While there have been attempts to recreate northern quoll habitat, there remains very little information on how these artificial habitats compare to natural quoll dens. Understanding the characteristics of natural denning habitat (thermal properties, physical size, prey availability, predator abundance) will enable us to identify necessary conditions to be replicated as part of future artificial habitat creation

Specifically, we aim to:

- Determine the thermal and physical properties of natural dens used by females and compare these to natural (and non-denning) sites which were available but not selected by denning females, presumably because they do not possess required characteristics;
- Compare the thermal and physical properties of occupied dens to artificial habitat;
- Compare prey availability at occupied dens to non-denning sites and artificial sites;
- Compare visitation rates of predators (feral cats, dingoes) at denning sites, non-denning sites and artificial sites;
- Examine how female quolls use natural denning habitat and close surroundings; and
- Summarise information and data gathered to create guidelines for artificial den and habitat construction.

Female northern quolls were trapped at Indee Station near Port Hedland and tracked back to rocky dens using a combination of VHF tracking, fluorescent pigment tracking and line-and-spool tracking. Unoccupied natural dens were confirmed within 50 m of occupied dens using a combination of camera traps and quoll signs for verification. Potential artificial den sites were chosen using current artificial habitat constructions at Indee Station, Mount Dove and a Roy Hill bridge rock armoury. Remote camera traps were deployed at each den site to survey predator and prey activity. iButton temperature data loggers were deployed inside and outside dens to measure temperature differences between internal and external environments. Vegetation transects were undertaken to measure ground cover and active searches for native fig (*Ficus* spp.) were also undertaken. Physical features of dens (entrance size, aspect, depth) were also noted. Characteristics of each den type were compared to measure the success of artificial habitat at emulating natural denning habitat as well as differences between occupied and unoccupied natural dens.

**Outcomes to date**

We observed differences in the physical characteristics of artificial and natural den types. Occupied dens showed a greater percentage of embedded rock than that of unoccupied dens, while artificial dens showed little to no embedded rock at any site (Figure 15). This is likely due to artificial dens existing in highly disturbed areas. This is supported by the higher percentage of bare ground percentage at artificial den sites (Figure 15). This trend continues for percentage of rock less than 0.5 metres in size, with artificial dens showing a higher percentage of small rocks across sites when compared with occupied and unoccupied dens (Figure 15). *Triodia* percentage is very similar for both occupied dens and unoccupied crevices, however, occupied dens have the highest range between the ten sites (Figure 15). Analyses of den temperature as well as predator and prey abundance are ongoing.

The majority of den entrance heights for occupied dens, unoccupied dens and potential artificial dens are less than 600 mm (Figure 16). However, occupied dens show the largest range in entrance height as well as displaying the smallest range in den entrance width when compared with unoccupied crevices (Figure 16). Artificial dens show the lowest values across all sites in terms of entrance height and width, most likely due to the type of resources used in their creation (i.e. rock, concrete, gravel). The majority of occupied natural den sites are deeper than both unoccupied crevices and artificial dens (Figure 16). Unoccupied dens mostly contain one entrance, while occupied natural dens tend to have between one and six entrances (Figure 16).

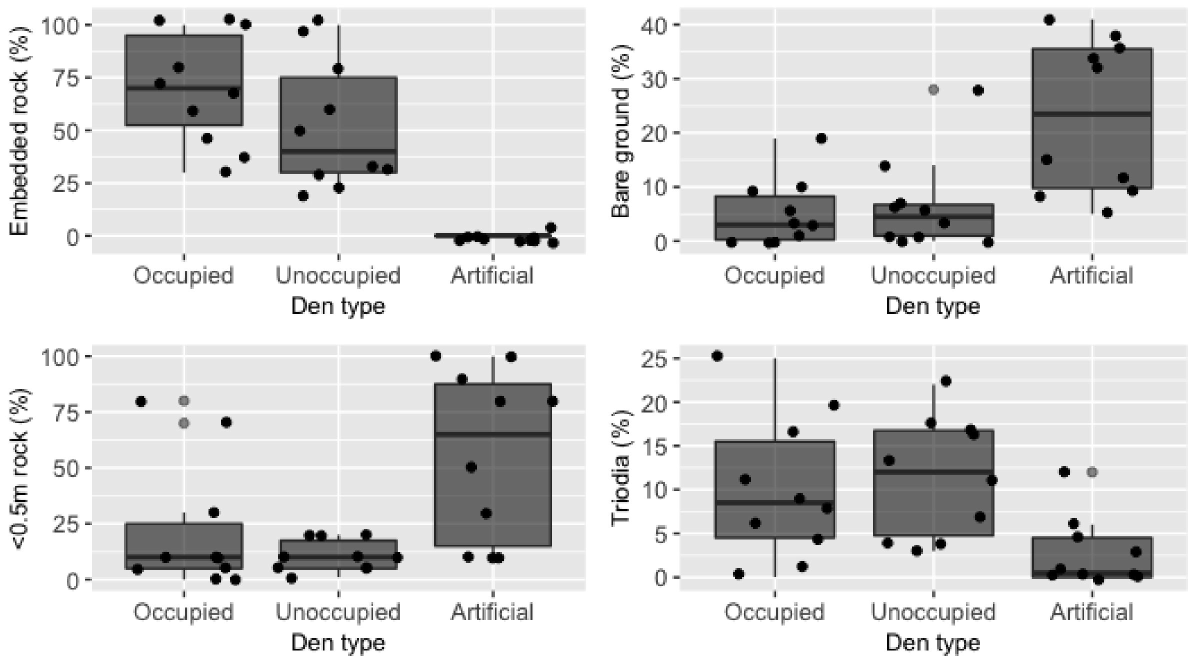



*Figure 15.* Occupied, unoccupied and artificial dens plotted against ground cover percentages; embedded rock, bare ground, >0.5m rock and Triodia (spinifex).

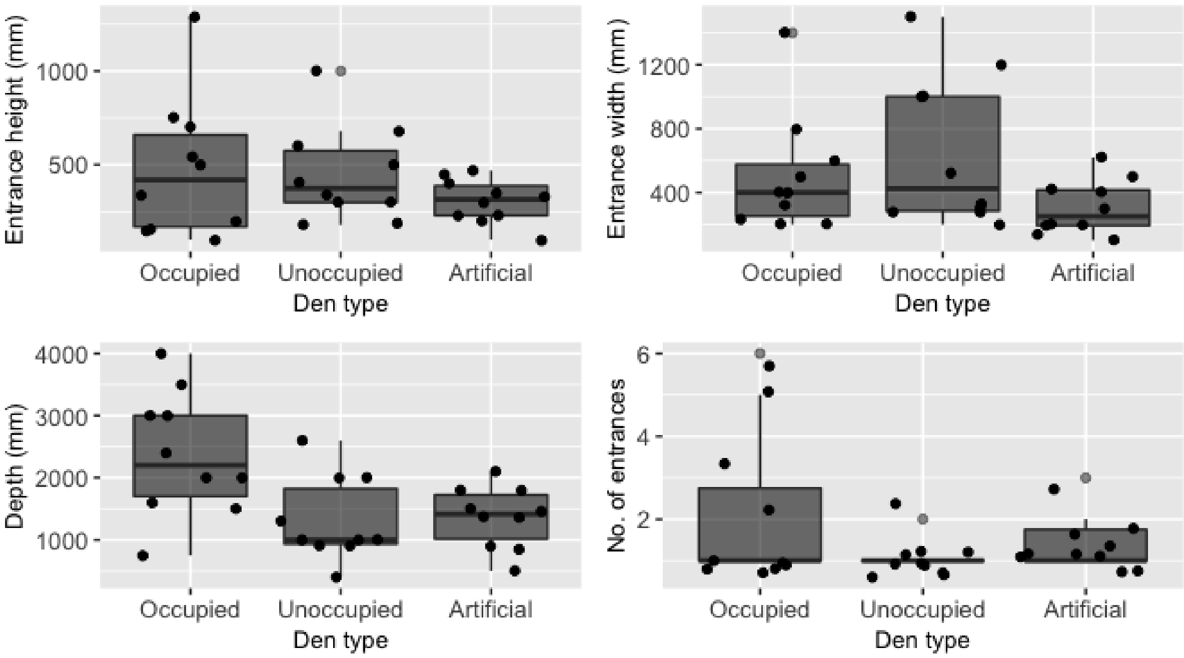



*Figure 16.* Occupied, unoccupied and artificial dens plotted against den characteristics; entrance height, entrance width, depth and number of entrances.

# 5 Efficacy of Felixer Grooming trap trial

**Background**

Control of feral cats is difficult due to their predisposition to hunting live prey rather than accepting baits, their cryptic and nocturnal behaviour, and their ability to persist in almost every habitat across the continent.

Ecological Horizons Pty Ltd are developing an automated Feral Cat Grooming Trap (the “Felixer”) as a potential new tool for feral cat management. The unit detects the presence of a feral cat and sprays a lethal dose of 1080 toxic gel onto the fur of the feral cat from up to four metres away. The feral cat instinctively grooms itself to remove the gel and in doing so ingests a lethal dose of the poison. The Felixer is capable of discharging 20 times (utilising 20 separate, measured dose cartridges) before the internal magazine needs to be reloaded with new cartridges. The unit takes a photograph every time the detection beams are crossed, allowing the efficacy of the trap in differentiating feral cats from non-target species to be assessed. Felixers can also be used as stand alone, solar powered camera traps. This new technology is being trialled Australia-wide, with more than 50 units deployed in different environments, initially with non-toxic cartridges. Northern quolls were identified as a potentially problematic non-target issue for using Felixers to control feral cats in Western Australia due to their cat-like shape, and vulnerability to doses of 1080. In collaboration with Roy Hill and Fortescue Metals Group, DBCA have been trialling three Felixer units in the Pilbara to determine their safety and efficacy.

If found to be efficient and effective, this automated unit provides a promising method for targeted feral cat control at specific localities. Examples where they may be useful include: high-value threatened species populations in limited areas (such as night parrot populations), locations that have a predator “sink” (such as on the outside of predator exclosures),  in locations where cats travel through restricted areas (such as peninsulas or islands), or where cats are required to traverse through enclosed areas (such as culverts under rail or roads). The units have low maintenance requirements, which is an advantage in remote regions. Data on the efficacy of these units will be important to the ongoing development of affordable and effective feral cat control in Australia.

Our key goals for the Pilbara trials follow a stepwise process:

1. Are the Felixers sufficiently target specific (i.e. not recognising other species, particularly northern quolls, as targets)?
2. Are they effective at reducing cat numbers?
3. Does this result in a positive effect on northern quolls?

**Outcomes to date**

Proper testing of this new technology is essential for validating the Felixer as an effective and low-risk feral cat management tool and eventually securing APVMA approvals for non-research deployments.

We used three Felixers in photo-only mode, paired with Reconyx cameras, for six months in high-density quoll habitat in order to address the first goal. In that time there were almost 200 independent instances of northern quolls crossing in front of the Felixers, of which none were identified as targets. There were also 19 other species (birds, mammals, reptiles) that were not targeted (*Figure 17*). The only species that were targeted were feral cats and one individual domestic dog, about the size of a Jack Russell. Surprisingly there were very few feral cat detections, with only two individuals recorded on the cameras on six occasions (*Figure 18*).

In order to answer the next questions, the Felixers will be trialled using toxic mode once approvals are secured. The criteria for a toxic trial site are for it to be not publicly accessible, away from towns and communities, away from other non-target issues (e.g. domestic dogs) and ideally with long-term data for cats and northern quolls. We will deploy the units for a further non-toxic trial period and later with 1080 toxin, subject to approvals. All units can be trialled together at this site for the trial duration (~6 months) in order to determine the effectiveness at reducing cat populations, and to determine if there is a subsequent response from quolls.

*Figure 17.* Photos from the WA Pilbara trial of Felixers operating in photo-only mode in the presence of northern quolls. Clockwise from top left: A feral cat correctly identified by the Felixer as a target, a northern quoll correctly identified by the Felixer as a non-target, northern quolls regularly spent time investigating the units.

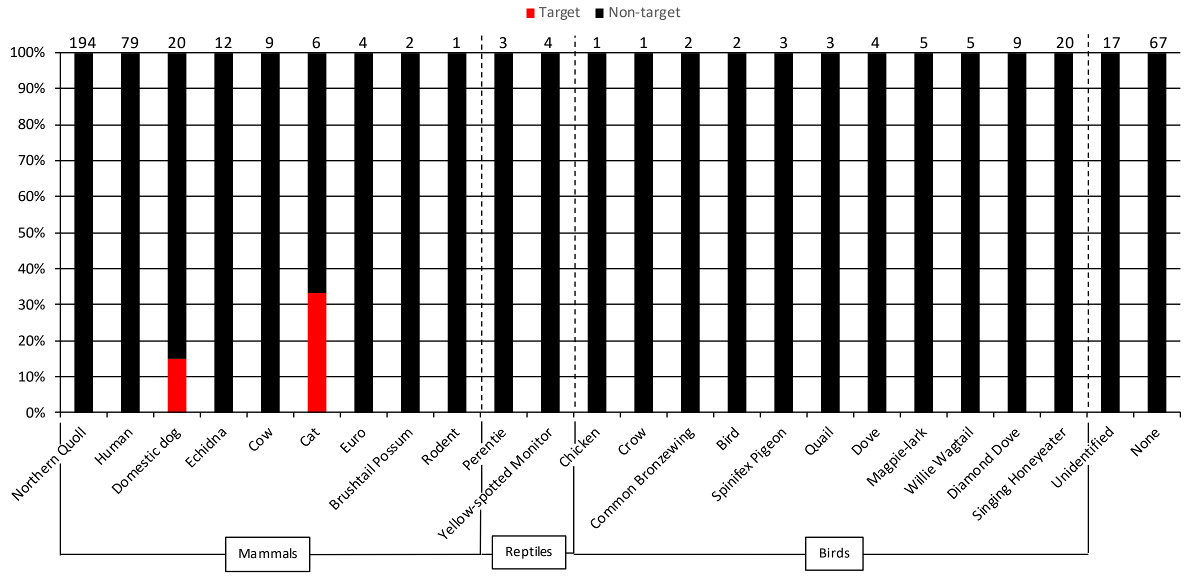



*Figure 18.* Summary of targeting results showing whether an animal was designated by Felixer units as a target (Red) or non-target (Black). Results shown the proportion of total detections of a species were determined to be targets, values on the top of the bars are total detections for each species.

# 6 Discussion

Monitoring of long-term sites, Quoll Knoll and CH182 granites show that quolls have a dynamic and intermittent presence in the landscape which is highly affected by predation and environment. Despite the small size of quoll knoll and presence of feral cats, it has again become a denning location for northern quolls and suitable habitat for quolls habit the area for extended periods of time. These promising detections of quolls even after a localised extinction in 2016 due to predation demonstrate the continuing need for feral predator control in the area. Felixer grooming traps are likely to be a useful tool to complement existing feral predator management. The photo-only trial of Felixer grooming traps show a very high degree of target specificity and results indicate that there should not be non-target issues with native Pilbara species (including northern quolls). Trials of the Felixer units will continue on FMG's North Star site with the view of progressing to toxic mode.

The introduction of top down camera setups demonstrates a cost-effective and accurate solution to surveying remote monitoring sites and whilst identifying quolls to the individual without the need for live-trapping and animal handling. Another benefit to this technique over live trapping is the length of deployment time allowing for a greater chance of quoll detections in more sparsely populated areas such as Wall Creek. Such areas of the southern Pilbara which appear to meet the habitat requirement of quolls but have low abundance of quolls or are found to be unoccupied highlight a need for more accurate predictors of quoll presence. Therefore, a more macro view of threatening and environmental processes through the landscape has been examined.

Our long-term targeted surveys within the region as well as the collaborative research projects that we have been engaged with indicate that one of the most important predictors of quoll presence is feral cat occupation within the landscape. Widespread monitoring in the Chichester Range and north to Port Hedland, show 95.6% of the landscapes monitored have a feral cat presence. This pervasive distribution of an introduced predator throughout the landscape illustrates how predation for critical weight range mammals in the Pilbara is an ever-present threat and can shape their distribution and abundance. The refuge provided by channel iron ore deposits and granite outcrops become increasingly more important for the survival of quoll populations as quolls have adjusted their behaviour to avoid predators in open and flat habitats. However, this predator avoidance behaviour can have a limiting effect on dispersal (and exacerbate range contraction) as the predation risk between "islands" becomes greater through distance to travel as well as large hot fires removing protective habitat.

Protective habitat degradation through mining and infrastructure development has been identified as a significant threatening process to the continued persistence of the Pilbara northern quoll. The viability of restored or artificial habitat for quolls to colonise and mitigate the direct impacts of this process is an important avenue of research. Better understanding of the necessary conditions which need replication for successful colonisation by breeding females is required. Northern quolls are exhibiting choices on the physical parameters of denning locations, relating to surrounding habitat characteristics, size of entrances and depth of the den. These characteristics are likely to be driven by temperature and humidity preferences, as well as protection from predators, and prey availability at sites. Comparison of natural and potential artificial denning sites, showed significant differences between occupied, unoccupied and artificial dens, with significant differences in all den characteristics (entrance height, entrance width, depth and number of entrances) suggesting if artificial habitat construction is to continue, a redesign of current methods will be required to best simulate natural denning sites.

# 7 Recommendations

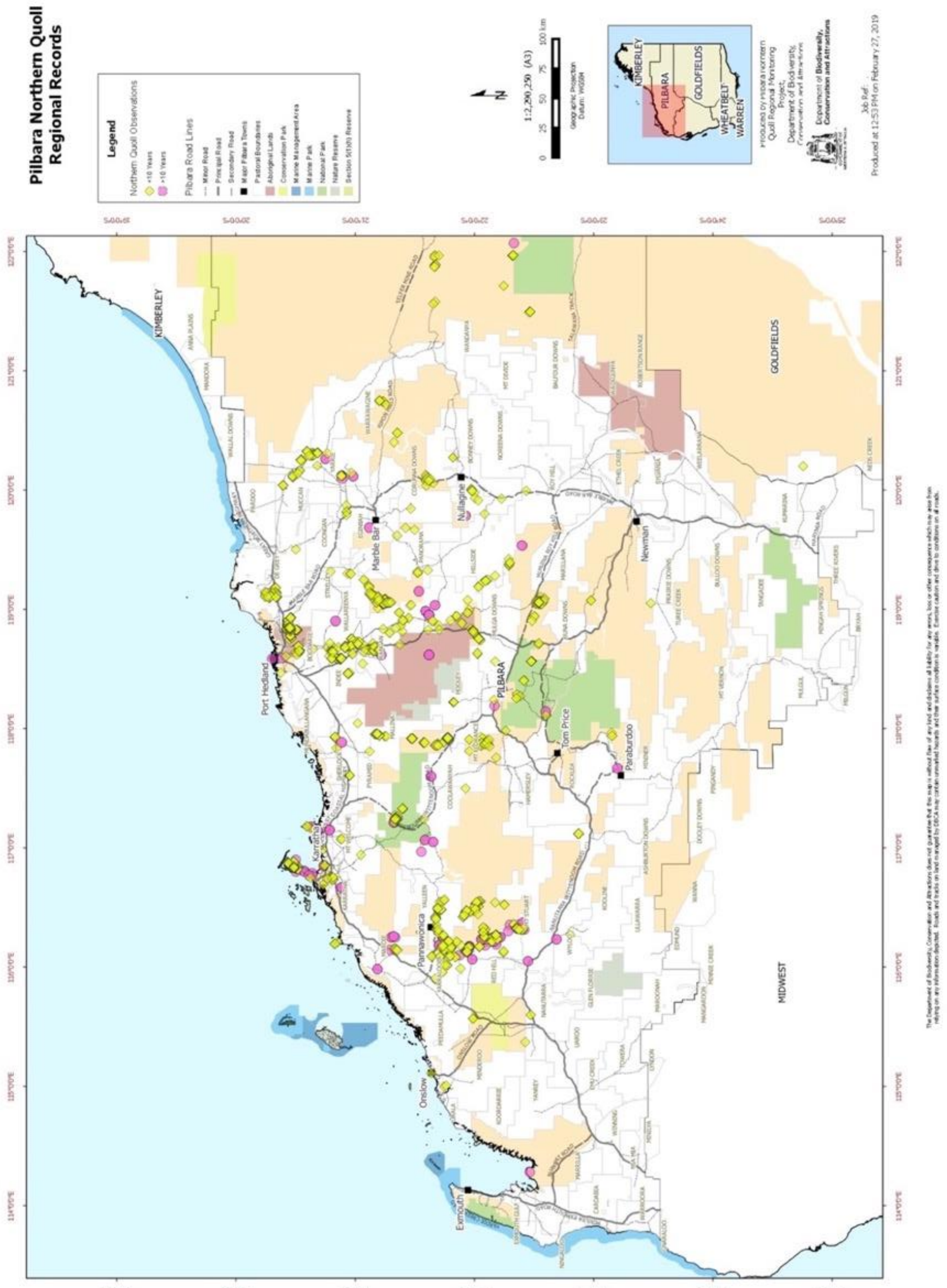
- Roy Hill to continue feral cat/fox control via trapping at Quoll Knoll and rail corridor area in order to maintain low predator numbers at the site. Cat control should be undertaken in February-March, June-July and September-October in order to target times of quoll dispersal, lowest prey availability for cats (i.e. cats are more likely to enter traps during these times) and denning of young (Table 3). Any quolls trapped to be microchipped, processed, photographed for individual identification and data provided to DBCA.
- Roy Hill to continue permanent passive camera trap work at Quoll Knoll complex, and West Shaw River Rail bridge (RHQMP05A) latrine site. We suggest use of at least two top-down cameras to be placed on the Quoll Knoll complex, to permit individual identification, allowing population estimates to be made. Additional forward-facing cameras to be deployed at known denning entrances to capture females carrying young and subadults. Annual review of images for northern quoll records, feral cat and fox records to be undertaken. These images and locations of capture to be provided to the Roy Hill feral pest contractor prior to each feral animal control event to enable a targeted control program.
- If the operational use of *Eradicat®* baiting in the Pilbara is approved by the APVMA and DBCA, Roy Hill could employ aerial baiting along their rail line in a buffer (e.g. 10km) around Quoll Knoll in conjunction with trapping efforts. *Eradicat®* would be used as per standard recommendations by Western Shield (maximum density of 50 baits per square km, avoiding public access roads, notifying other landholders, with appropriate 1080 permits, in coldest months of the year when young quolls are not present).
- RH and DBCA continue to collaboratively trial the Felixer feral cat grooming trap, subject to approvals, and as per the Felixer research agreement. Quoll Knoll is likely to be a suitable site for deployment of Felixer grooming traps once they are operational and approved for use by APVMA and other government agencies.
- RH and DBCA collaboratively to continue to monitor Wall Creek and Chainage 182 via camera traps for monitoring quoll and introduced predator densities at least for a 4-6-week period in 2019.
- Roy Hill to continue to support the trapping at two Chichester Ranges sites as a part of the DBCA regional monitoring program (Euro springs on Mt Florance Station (via cameras) and Python Pool (via cage traps), within the Millstream-Chichester National Park).

*Table 3.* Months of northern quoll and feral cat activity to inform management actions

| 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 | | | | | | | | | | | | |

# Appendices

## Appendix 1. Pilbara northern quoll records pre and post 2000



# Appendix 2. Tables of species detections from camera traps

*Table 4.* Occasions of species detected from camera traps set at Wall Creek and Euro Spring. An occasion was defined as a visit by a species to a camera in a 24h period; numbers in this table indicate the number of detection occasions for that species at each site. See (*Table 1*) for set durations and locations.

| Common Name | Scientific Name | Euro Springs | Wall Creek |
|---|---|---|---|
| *Common rock rat* | *Zyzomys argurus* | 27 | 134 |
| *Cow* | *Bos taurus* | | 6 |
| *Dog* | *Canis lupus dingo* | 3 | |
| *Euro* | *Osphranter robustus* | 2 | 77 |
| *Feral cat* | *Felis catus* | 1 | 5 |
| *Northern quoll* | *Dasyurus hallacatus* | 46 | 3 |
| *Rothschild's rock wallaby* | *Petrogale rothschildi* | 33 | 46 |
| *Macropod* | | | 1 |
| **Total Mammal Species** | | ***112*** | ***272*** |
| | | | |
| *Butcher bird* | *Cracticus nigrogularis* | 4 | 1 |
| *Crow* | *Corvus sp.* | | 55 |
| *Painted finch* | *Emblema pictum* | 1 | |
| *Singing honeyeater* | *Lichenostomus virescens* | | 1 |
| *Spinifex pigeon* | *Geophaps plumifera* | 1 | |
| *Western bowerbird* | *Ptilonorhyncus guttatus* | | 1 |
| *Willie wagtail* | *Rhipidura leucophrys* | | 2 |
| *Honeyeater* | | | 2 |
| *Bird* | | 1 | 3 |
| **Total Bird Species** | | ***7*** | ***65*** |
| | | | |
| *Black-headed monitor* | *Varanus tristis* | | 1 |
| *Mulga snake* | *Pseudechis australis* | 1 | |
| *Pilbara rock monitor* | *Varanus pilbarensis* | | 3 |
| *Spiny-tailed monitor* | *Varanus acanthurus* | | |
| *Egernia* | *Egernia sp.* | 2 | |
| *Varanid* | *Varanus sp.* | | 1 |
| **Total Reptile Species** | | ***3*** | ***5*** |

Table 5. Occasions of species detected from camera traps set at Chainage 182 and Quoll Knoll. An occasion was defined as a visit by a species to a camera in a 24h period; numbers in this table indicate the number of detection occasions for that species at each site. See (Table 1) for set durations and locations.

| ***Common Name*** | ***Scientific Name*** | ***CH182*** | ***Quoll Knoll*** |
|---|---|---|---|
| *Common rock rat* | *Zyzomys argurus* | 4 | 2 |
| *Euro* | *Osphranter robustus* | 3 | 21 |
| *Feral cat* | *Felis catus* | 2 | 8 |
| *Northern quoll* | *Dasyurus hallacatus* | 1 | 44 |
| *Short-beaked echidna* | *Tachyglossus aculeatus* | 1 | |
| **Total Mammal Species** | | ***11*** | ***75*** |
| | | | |
| *Australasian pipit* | *Anthus novaeseelandiae* | 3 | |
| *Butcher bird* | *Cracticus nigrogularis* | 1 | |
| *Grey-headed honeyeater* | *Ptilotula keartlandi* | | 16 |
| *Magpie-lark* | *Grallina cyanoleuca* | 13 | |
| *Spinifex pigeon* | *Geophaps plumifera* | 6 | 3 |
| *Pilbara grasswren* | *Amytornis whitei* | | 12 |
| *Variegated fairy-wren* | *Malurus lamberti* | | 12 |
| *Willie wagtail* | *Rhipidura leucophrys* | 1 | 4 |
| *Bird* | | | 4 |
| **Total Bird Species** | | ***24*** | ***51*** |
| | | | |
| *Perentie* | *Varanus giganteus* | | 29 |
| *Pilbara rock monitor* | *Varanus pilbarensis* | | 2 |
| *Spiny-tailed monitor* | *Varanus acanthurus* | 1 | 21 |
| *Varanid* | *Varanus sp.* | 1 | 1 |
| *Skink* | | | 1 |
| *Dragon* | | | 1 |
| **Total Reptile Species** | | ***2*** | ***55*** |

# Appendix 3. Camera trap images


L) Northern quoll from top-down camera, showing the ability to identify individuals by spot patterns. R) Dingo puppies at Mt Florance station


L) Rothschild rock wallaby with young at heel at Mt Florance station. R) Feral cat at Mt Florance station


L) Juvenile northern quoll at Quoll Knoll, 29 Jan 2019. R) Feral cat at Quoll Knoll.


L) Short-beaked echidna at Chainage 182, R) Northern quoll at Chainage 182

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