Biodiversity and Conservation Science

Targeted surveys for northern quolls in the Chichester Ranges 2019

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Report prepared for Roy Hill Pty Ltd

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Monitored northern quoll populations have fluctuated over time but were detected at five of the seven study sites subject to monitoring in 2019. Quoll abundance was similar at the five sites, with Quoll Knoll having the most individuals identified, despite having the highest detections of feral cats at sites where quolls were recorded. The site with the highest detections of feral cats (Bea Bea Creek; 14) had no quoll detections, and northern quolls returned to Mesa 228 this year after no detections since 2015.

Feral cats were active at all seven sites in 2019, and Aussie Feral Pests (AFP) captured and euthanised seven feral cats at Quoll Knoll during 2019—the most in a single year for the AFP program so far. Northern quolls were not recorded at Quoll Knoll after 8 August 2019, while seven feral cats were captured between July and November in 2019 by AFP. As there are small pockets of high-quality habitat located within low quality habitat (which can be dangerous to traverse for northern quolls), feral cat control of these high-quality habitats (i.e. Quoll Knoll) is likely to be critical in this landscape for the survival of northern quolls. Other invasive species control measures should also be investigated, including *Eradicat*® baiting and automated feral cat grooming traps (Felixers™).

Monitoring via top-down cameras appears to be an effective technique for identifying individuals and can be used for a much longer period than cage trapping. Camera traps also target a broader range of species (e.g. northern quolls, feral cats, common rock rats). Low and fluctuating numbers of quolls at sites in the Chichester Ranges limit their usefulness in monitoring changes in abundance quantitatively. Establishing monitoring sites elsewhere in the Pilbara that have been proved to have regular presence of northern quolls, may result in more meaningful findings and help to improve the knowledge bank of quoll biology in the Pilbara.

1. Introduction

This report summarises the northern quoll research undertaken by the Department of Biodiversity, Conservation and Attractions (DBCA) for Roy Hill in 2019. 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 2011/5866. The purpose of this 2019 survey was to provide further data to estimate the population, distribution, and survival of quolls within the Chichester Ranges, and was conducted based on DBCA recommendations from the results of the DBCA 2018 survey. The results of the 2019 survey is 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). 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 (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 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 more on complex rocky habitat like ridges and mesas (Molloy et al., 2017), compared to northern quolls in the Northern Territory or Queensland, where tree hollows and logs are common (Oakwood, 1997). When rearing young, female northern quolls in the Pilbara require sheltered crevices which are cooler and deeper than other available, but unutilised crevices (Cowan et al., 2020b). Complex rocky habitat also

provides 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).

These ridges and mesas of channel-iron deposits and banded iron formations in which northern quolls often 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 Agriculture, Water and Environment (DAWE) (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 semelparous reproduction, 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 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 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 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 potential 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 was 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. 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 zero unique records of northern quolls in the Pilbara on NatureMap, compared to 44 records from 2001 to 2019.

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) conducted by DBCA for Roy Hill. It is possible that predation pressure is limiting the dispersal of northern quolls into these suitable habitats. DBCA established two long-term monitoring sites at more westerly Chichester Range sites, Euro Springs, and Python Pool in 2014, in an area where quoll populations appear to increase in number and distribution (Coffey Environments, 2012, Birch et al., 2019). However, 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) during construction of the railway line. This population has been monitored opportunistically since and is the focus of ongoing feral cat control actions. An individual quoll was also identified at the nearby Mesa 228 in 2015, with no further detections since, while feral cats have been identified intermittently at Mesa 228. 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. 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 (Molloy et al., 2017). Regular surveys for threatened species have been undertaken at nearby sites relevant to the Fortescue Metals Group (Spectrum Ecology, 2018), so data for those sites are used for comparison with data from Quoll Knoll.

2. Methods

Since 2014, several new locations of intermittent occupancy have been identified in the Chichester Ranges. 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. In 2019 we revisited many sites originally identified in 2014, to gain a more thorough understanding of quoll distribution in these areas. The areas that have been surveyed by DBCA in 2019 are shown in Figure 1.

2.1 Cage trapping

Live trapping was conducted by DBCA at Quoll Knoll (10 traps; Figure 2) and West Shaw Bridge (5 traps; Figure 3) in July 2019. Live trapping employed 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 three consecutive nights for a total of 150 trap nights, baited with peanut butter, oats and sardines. Traps were set up in transects ~50m apart and opened for four nights for a total of 60 trap nights between the sites. Each individual quoll was microchipped, weighed and measured, body condition was assessed, and tissue samples were taken for genetic analysis. DBCA also trialled enclosures, made of PVC pipe, for common rock rats (*Zyzomys argurus*) inside cage traps at Quoll Knoll, in order to protect trapped rock rats from quolls and feral cats outside the trap reaching in and killing them.

Targeted feral cat trapping occurred along the Roy Hill SRL near Quoll Knoll, in April, July, and November 2019. 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 consecutive nights (Aussie Feral Pests, 2019) for each trapping event. Traps were repositioned as new cat tracks were discovered. Any northern quolls incidentally captured in cat traps were scanned for a microchip, tissue taken, measured, and released, with data provided to DBCA.

Figure 1: Map of the 2019 Roy Hill northern quoll camera and cage trapping sites (Chainage 182, Wall Creek, Euro Springs, Mesa 228, Cockeraga Creek, Bea Bea Creek, Quoll Knoll) in the context of the Pilbara, showing Roy Hill Railway and other relevant quoll DBCA monitoring sites.

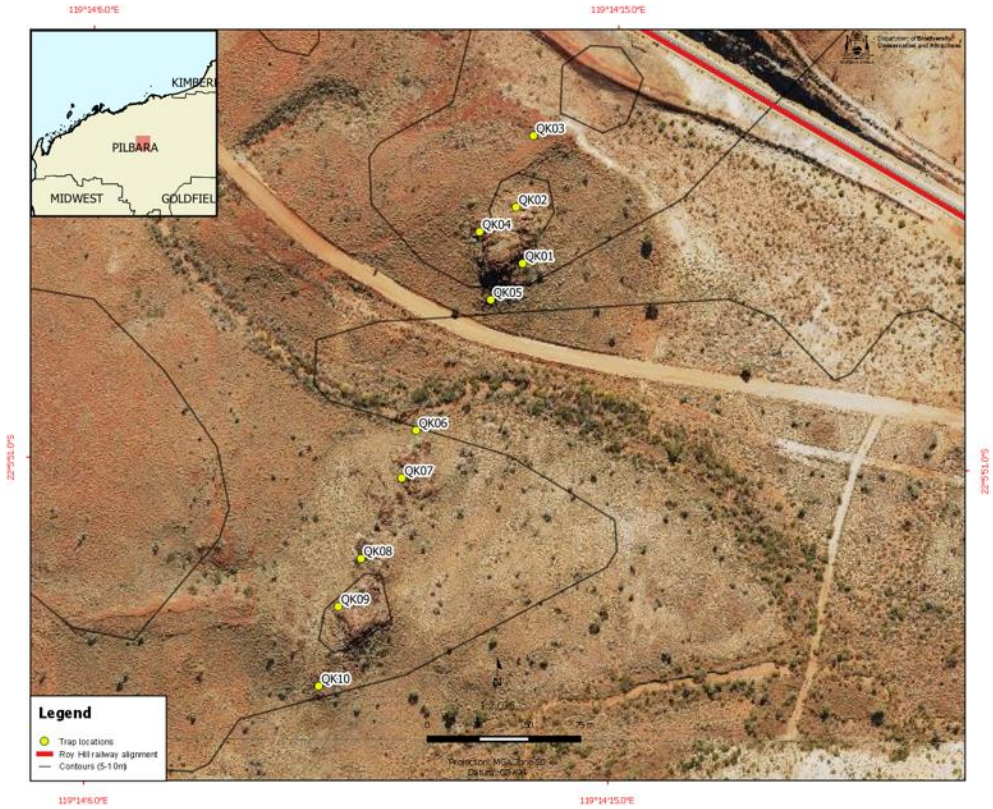


Figure 2: Cage trap locations at Quoll Knoll for 2019

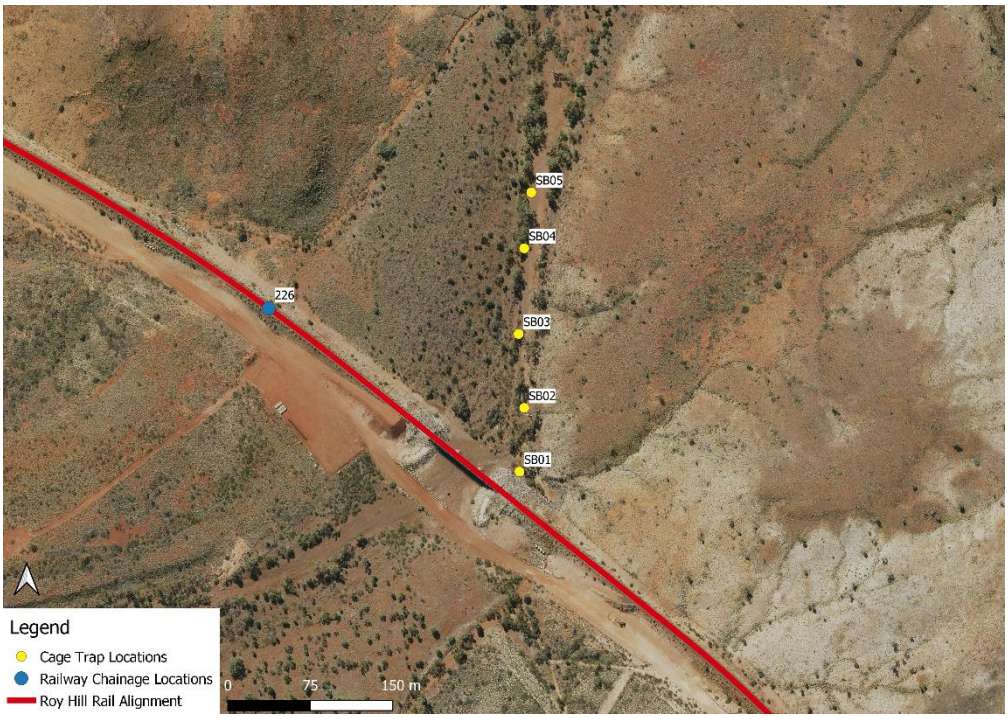


Figure 3: Cage trap locations at West Shaw Bridge for 2019.

2.2 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 Figure 4), and set up in most of the sites subject to monitoring in 2019. 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 top-down setup.

Five outward-facing cameras were placed on their own at Mesa 228 (16th July – 26th September; 360 camera trap nights), while two were placed at Cockeraga Creek (19th July – 26th September; 138 camera trap nights), and Bea Bea Creek (19th July – 26th September; 138 camera trap nights) respectively. Five top-down cameras were placed at Chainage 182 (17th July – 25th September; 350 camera trap nights), Wall Creek (19th July – 26th September; 345 camera trap nights), and Euro Springs (20th July – 27th September; 345 camera trap nights) respectively (Table 1; Appendix 1). The four outward-facing and two top-down permanent cameras at Quoll Knoll were also analysed (16th February – 31st December; 1405 camera trap nights). Quolls were only identified to the individual level on images from top-down cameras due to spot placement on their backs and not from outward-facing cameras due to difficulty identifying individuals.

Analysis of all photographs was done through importing photos into Colorado Parks and Wildlife 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., 2016). For all other species, detection events were separated by at least 60-minutes. 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).

Figure 4: Top-down camera setup at Chainage 182.

Table 1: Site locations and survey effort for the 2019 monitoring season.

Site	Latitude	Longitude	Camera trap nights	Trap nights	Start date	End date
Euro Springs	-21.77	117.91	345	-	20/07/2019	27/09/2019
Wall Creek	-22.03	118.63	345	-	19/07/2019	26/09/2019
Chainage 182	-21.85	118.96	350	-	17/07/2019	25/09/2019
Quoll Knoll	-22.10	119.24	1405	40	16/02/2019	31/12/2019
West Shaw Bridge	-22.10	119.25	-	20	17/07/2019	20/07/2019
Mesa 228	-22.11	119.25	360	-	16/07/2019	26/09/2019
Cockeraga Creek	-22.04	118.75	138	-	19/07/2019	26/09/2019
Bea Bea Creek	-21.99	118.82	138	-	19/07/2019	26/09/2019

3. Chichester Ranges monitoring

In 2019, DBCA and Roy Hill monitored several sites throughout the Chichester Range (Table 2). The density of northern quolls (*Dasyurus hallucatus*), common rock rats (*Zyzomys argurus*), and feral cats (*Felis catus*) varied between sites. Each site is discussed in detail below.

Table 2: Species detection history for the seven sites. Captures during 2019 included northern quolls (*Dasyurus hallucatus*), common rock rats (*Zyzomys argurus*) and feral cats (*Felis catus*). Northern quoll totals are for individual species (except for Mesa 228 due to cameras being outward-facing), while totals for all other species are the total detections separated by 60 minutes or more.

Site	Species	Captures
Euro Springs	Quoll	2
	Rock rat	24
	Cat	2
	Camera Trap Nights	*345*
Wall Creek	Quoll	2
	Rock rat	12
	Cat	2
	Camera Trap Nights	*345*
Mesa 228	Quoll	106 detections
	Rock rat	29
	Cat	2
	Camera Trap Nights	*360*
Quoll Knoll	Quoll	4
	Rock rat	65
	Cat	4
	Camera Trap Nights	*1405*
Chainage 182	Quoll	2
	Rock rat	0
	Cat	3
	Camera Trap Nights	*350*
Bea Bea Creek	Quoll	0
	Rock rat	3
	Cat	14
	Camera Trap Nights	*138*
Cockeraga Creek	Quoll	0
	Rock rat	0
	Cat	2
	Camera Trap Nights	*138*

3.1 Quoll Knoll and West Shaw Bridge

The rocky knoll dubbed “Quoll Knoll” is near Chainage 225, situated between the Roy Hill rail line and a light vehicular access track, with a minor extension of the ridge found to the west of the light vehicular access track (Figure 5). The main part of 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 (Figure 5). 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. West Shaw Bridge is a Roy Hill railway overpass with two granite rock armouries less than 500 metres south of Quoll Knoll (Figure 5). 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). Cameras have been set up across the Quoll Knoll complex on both sides of the vehicular track and at the latrine site under the West Shaw Bridge (Figure 6).

Figure 5: Landscape shots of a) the small rock outcrop referred to as Quoll Knoll, and b) the West Shaw Bridge.

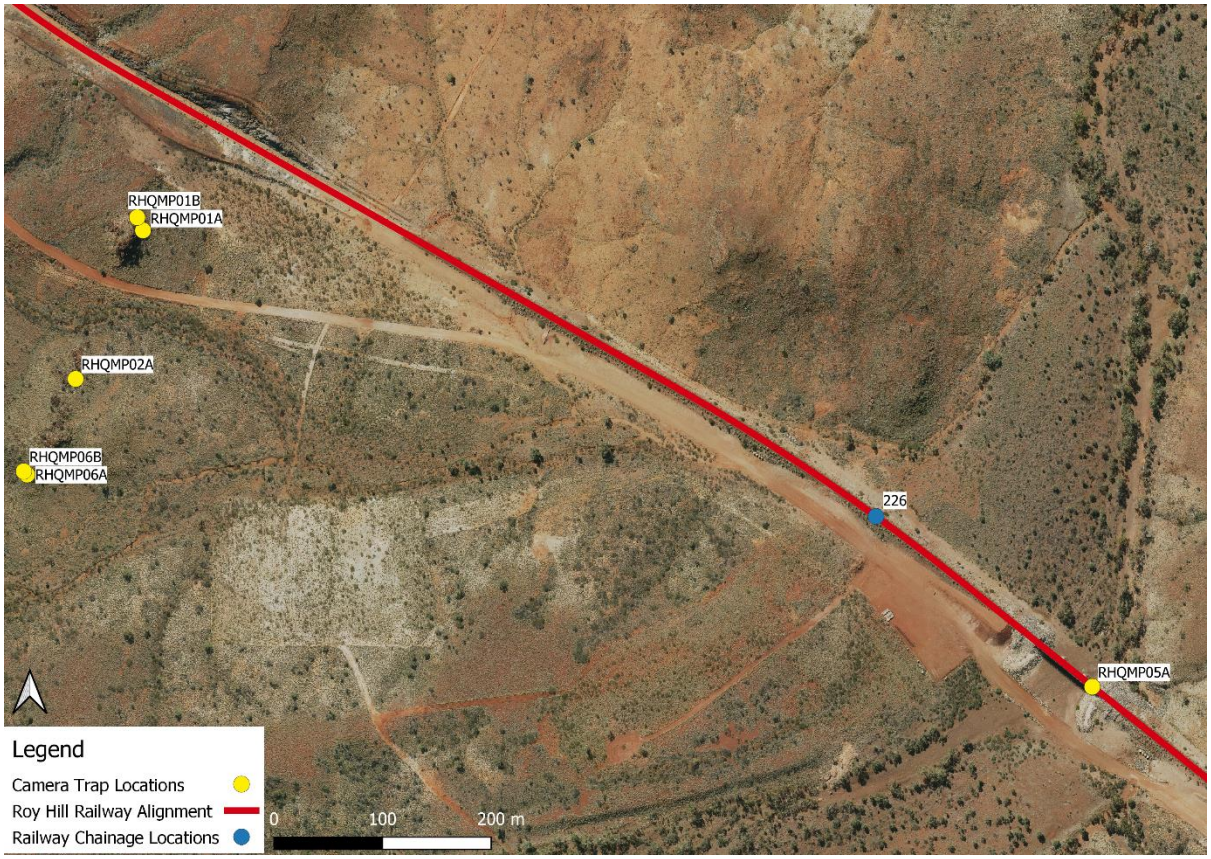


Figure 6: The permanent camera traps located at Quoll Knoll and the West Shaw Bridge.

Cage trap captures included one adult male northern quoll (*Dasyurus hallucatus*) at West Shaw Bridge, two common rock rats (*Zyzomys argurus*), and one pseudantechinus (*Pseudantechinus* sp.). No northern quolls were captured from cage traps set at Quoll Knoll by DBCA in July 2019, however AFP captured the same male quoll from West Shaw Bridge at Quoll Knoll in April, and a different male at Quoll Knoll in July 2019. No female northern quolls were captured at Quoll Knoll or West Shaw Bridge in 2019.

The first test of rock rat enclosures inside traps took place at Quoll Knoll in 2019, with evidence of their use by a captured rock rat (Figure 7). This PVC enclosure helped to decrease the chance of a rock rat being killed by a predator (i.e. quoll, feral cat) located outside of the cage trap, reaching into the cage.

Figure 7: A common rock rat using a rock rat enclosure (PVC pipe) inside a cage trap set to target northern quolls.

From camera trap images analysed for the full year of 2019, quoll detections at Quoll Knoll dropped significantly after June, while activity increased in March (Figure 8). Northern quolls were not detected after the 9th of August 2019 (Figure 8). Feral cats were only detected in May, June and early August and no feral cat detections after the 8th of August. There were examples of similarities in the activity of quolls and cats at Quoll Knoll, with a northern quoll and a feral cat active at the same camera just over two hours apart (Figure 9). Quolls were present without feral cats until May 2019, then were present with cats at Quoll Knoll from May to August in 2019, with feral cats present again in November (Figure 10). AFP found evidence of mammals in the stomach contents of captured feral cats—although it is uncertain if these mammals were northern quolls. There were four individual northern quolls detected from top-down cameras at Quoll Knoll in 2019, while there were 65 detections of rock rats (Table 2). One quoll that was detected on a camera trap seemed to have a clipped ear (Figure 9), and therefore may have been trapped by AFP in April. There were four feral cat detections from camera traps in 2019—likely from two individuals based on colour and markings—however AFP trapped and killed seven feral cats at Quoll Knoll over the year—perhaps including the feral cats caught on camera traps (Aussie Feral Pests, 2019). There were nine perentie detections and 72 euro detections at Quoll Knoll also (Appendix 2).

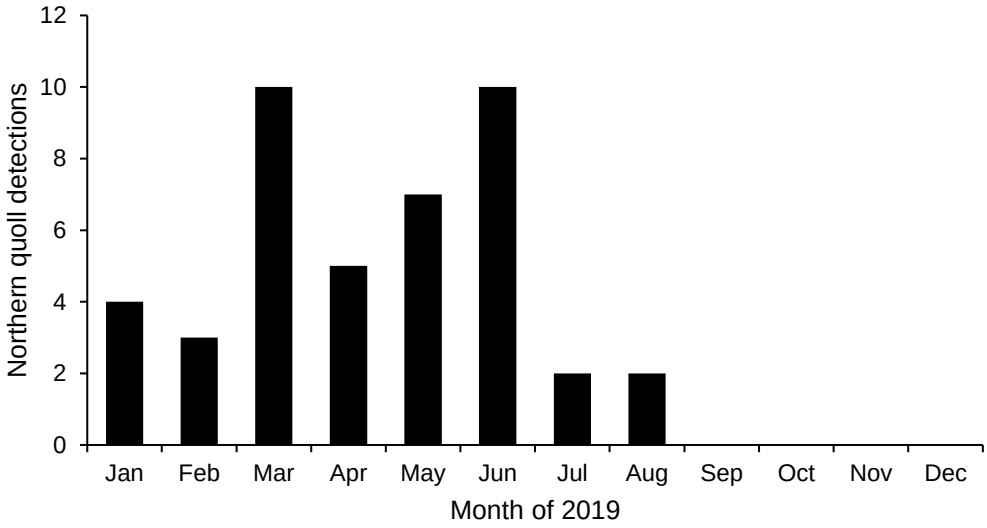


Figure 8: Individuals detected from camera traps at Quoll Knoll throughout 2019, identified by spot patterns.

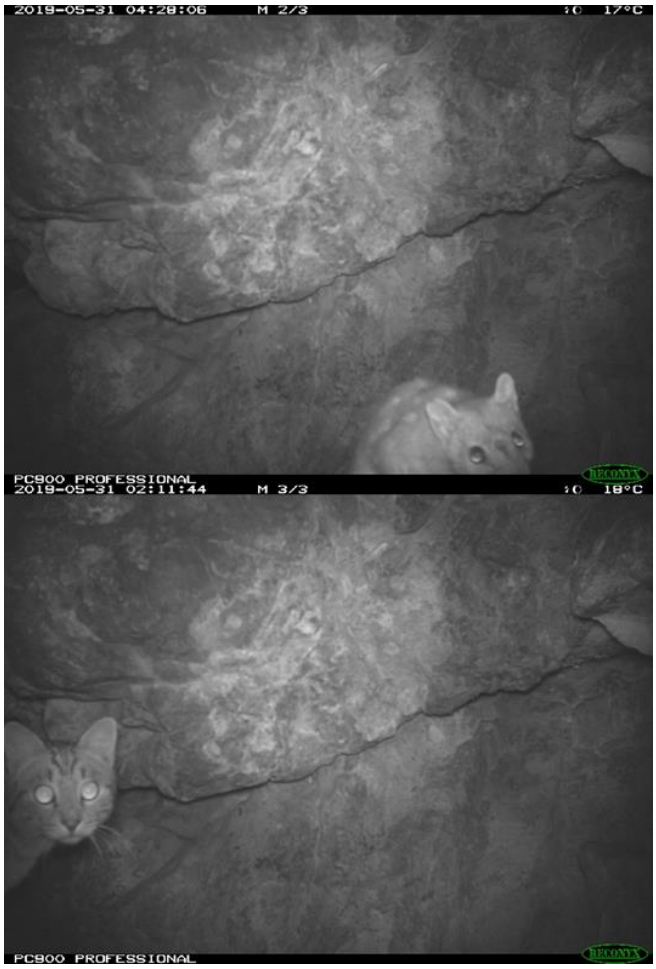


Figure 9: A northern quoll and a feral cat active at the same Quoll Knoll camera only two hours and 17 minutes apart.

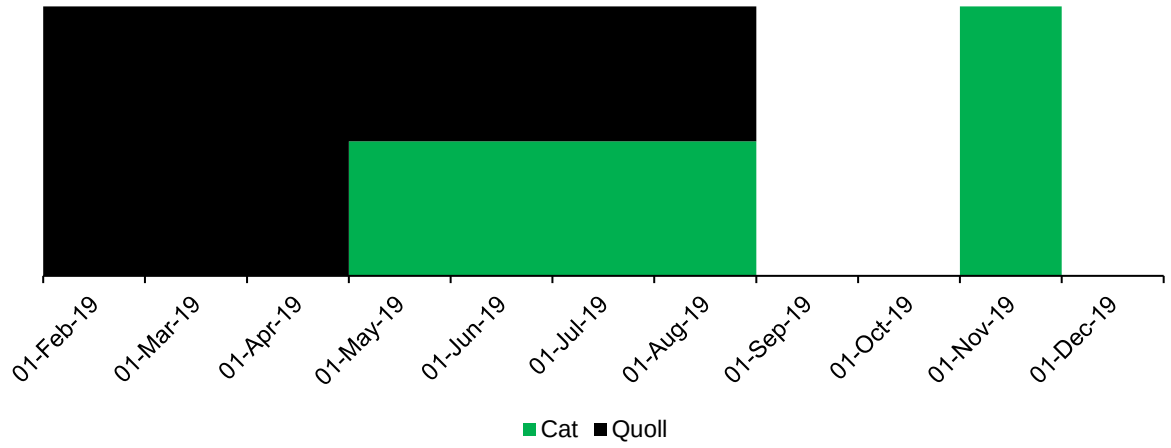


Figure 10: The presence and absence of northern quolls and feral cats at Quoll Knoll in 2019. Shaded areas indicate a presence (a capture on a camera trap or in a cage trap). Height of shaded areas do not indicate significance but allow comparison between quolls and feral cats.

3.2 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. 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* sp. grassland. Two individual quolls were identified at Euro Springs from 26 detections, and there were two detections of feral cats (Table 2). There were 24 detections of common rock rat, no perentie detections and 11 euro detections (Appendix 2).

3.3 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. 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).

Two individual quolls, two detections of feral cats, and 12 detections of rock rats were observed on camera traps at Wall Creek (Table 2). Evidence of quolls has been recorded previously at other nearby sites including Bea Bea Creek and Cockeraga Creek, located at 19

km and 12.4km from Wall Creek respectively (Appendix 1; Appendix 2). However, in 2019 there were no detections of northern quolls at Bea Bea Creek or Cockeraga Creek. Feral cats were detected at both of these sites however, and were particularly prominent at Bea Bea creek with 14 detections in total from what appears to be—based on colours and markings—three or four individuals (Appendix 2).

3.4 Mesa 228

Mesa 228 (approximately 1.5km south from Quoll Knoll) was chosen to be included as a survey site in 2015 due to its proximity to the Quoll Knoll population, size of suitable habitat and complexity of breakaway habitat. This site was excluded from the long-term monitoring program in 2018 due to a lack of quoll detections, with no quolls present in 2016 and 2017. However, monitoring returned to this site in 2019 to gain further understanding of the fluctuations of northern quolls at locations that supported small and intermittent presence. There were 106 detections of northern quolls (not individually identified due to cameras being outward-facing), and an abundance of northern quoll scat found. Northern quolls were detected at Mesa 228 monthly from July 2019 until the final camera data was collected on the 26th of September 2019. There were 28 detections of rock rats two detections of feral cats, five detections of perenties, and 58 detections of euros (Table 2; Appendix 2).

3.5 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. Previous surveys had identified this area as a potential monitoring site for quolls along the Roy Hill rail alignment, but access was restricted during the construction phase of the railway. 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 in 2018, with a single detection of one individual quoll from 408 camera nights. In 2019, there were two individual northern quolls detected at Chainage 182 and 3 detections of feral cats, with no rock rat detections and 10 euro detections (Table 2).

4. Discussion

Quolls were detected at five of the seven study sites during 2019. They were recorded at Quoll Knoll up until August, but no quolls were detected from August to the end of December 2019 . Aussie Feral Pests removed seven feral cats from Quoll Knoll in 2019, all duringJuly or after. Mesa 228 had fewer feral cat detections than Quoll Knoll and northern quolls were present for the first time since 2015 at Mesa 228. Northern quolls were present at Mesa 228 up until camera data was collected on the 26 September. It is unknown why Mesa 228 has been re-populated by quolls in 2019, and there is not enough evidence to attribute it to predator or prey factors alone.

The Chichester Ranges contain small, disjunct quoll populations, separated by several kilometres of unsuitable denning habitat and it has been shown that quolls have a dynamic and intermittent presence in this landscape, highly affected by predation and environment (Hernandez-Santin et al., 2016, Birch et al., 2019). Feral cats have been linked to the extinction of 63 species worldwide (Doherty et al., 2016), and the avoidance of feral cats by quolls has resulted in the restriction of the distribution of northern quolls to rocky areas across northern Australia (Hernandez-Santin et al., 2016). However, some habitat overlap occurs, and feral cats have been observed to predate on Pilbara northern quolls, with a study finding six of 41 collared northern quolls being killed by cats in a six-month period (Morris et al., 2015), and evidence of cats eating northern quolls at Quoll Knoll in the past (Aussie Feral Pests, 2016). Widespread monitoring in the Chichester Range and north to Port Hedland show that 96% of the landscapes monitored have a feral cat presence. This pervasive distribution of feral cats throughout the landscape illustrates how their predation on mammals in the Pilbara is an ever-present threat and can shape their distribution and abundance (Murphy and Davies, 2014). This is shown at Bea Bea Creek, where there were 14 detections of feral cats, coinciding with no northern quoll detections. Feral cat eradication around Quoll Knoll and Mesa 228 has also potentially allowed the prey of northern quolls (i.e. common rock rats) to remain stable, creating further positive effects for quolls outside of a lower predation risk. This highlights the continued need for feral predator control in the area. Northern quoll survival has been shown to be high during *Eradicat*® baiting (Cowan et al., 2020a), and may assist with reducing mortality of northern quolls by feral cat predation (Moro et al., 2019). Felixer™ grooming traps may also be a useful tool to complement existing feral predator management.

The use of top-down camera setups instead of the more labour-intensive cage trap arrays is a cost-effective monitoring method. Quolls can also be identified 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 and Mesa 228. Top-down cameras should be paired with outwards-facing cameras in order to best capture the presence of northern quolls and their predators (i.e. feral cats) in the future (Moore et al., 2020) particularly given the fluctuating occupancy pattern of the monitoring sites by quolls within the Chichester Ranges.

Suitable refuge habitat for northern quolls in the eastern Chichester Ranges appears to be small and widely dispersed throughout the landscape, making northern quolls vulnerable to predation when moving between habitats, or dispersing following recruitment. Pilbara populations of adult female northern quolls have pouch young present from August – October

(variable according to rainfall), den young between November and February, and young emerge and disperse from February – April. Predation upon juveniles has the most impact on northern quoll populations (Moro et al., 2019), and their naivety potentially makes them more vulnerable to predation. Therefore, targeted cat trapping should occur at times of northern quoll denning, mating and dispersal (Appendix 3), and Eradicat™ baiting should occur during winter, when live prey availability is low for feral cats, and juvenile northern quolls are not present to take baits.

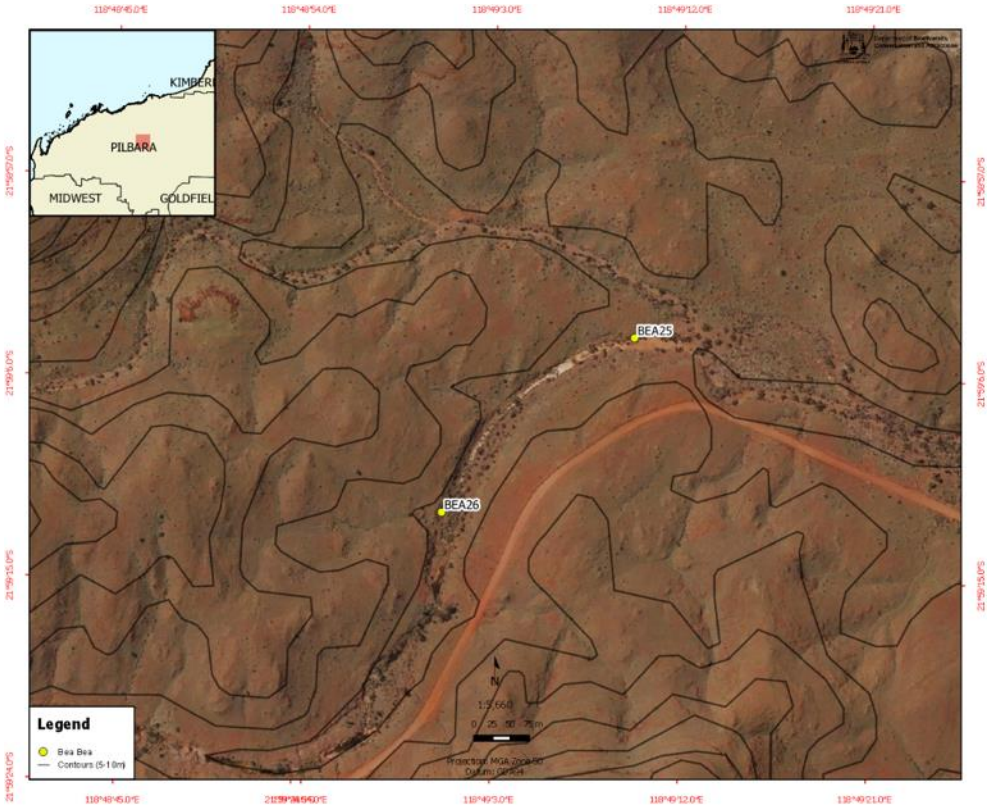
5. Recommendations

- Continue to monitor northern quolls during 2020 at the Quoll Knoll complex for the full year, via the current permanent passive camera array, and include analysis of images in the annual report. Camera set up to have at least two top-down cameras on the Quoll Knoll complex. Camera data to support feral animal control activities.
- Due to practicality and improved monitoring methods, annual quoll monitoring at both Quoll Knoll and Mesa 228 is to transition to cameras only for extended time periods. This will be to trial a new camera arrangement based on Harry Moore's findings to not only detect quolls but assess predators. The aim is to test and develop a robust method that can be used across the Pilbara for comparative purposes. 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 this camera monitoring.
- Mesa 228 is no longer to be part of the long-term cage trapping program.
- Other Chichester Range locations monitored in 2019 (Chainage 182, Wall Creek, Bea Bea Creek, Cockeraga Creek) are not to be long-term monitoring sites given the intermittent presence of quolls, and no longer need to be subject to monitoring.
- Monitored quoll and cat populations have varied over time and there were seven feral cats captured by AFP in 2019—the most of any year. Harry Moore's PhD project shows that feral cat presence is the most important indicator of northern quoll occupancy. Hence, continue to undertake feral cat control via cat trapping at Quoll Knoll in 2020, in order to make this area available for individuals to recolonise and breed. Control to be undertaken three times per year during February/March, June/August, and October/November.
- Any northern quolls trapped during a feral cat control program to be microchipped, processed, tissue taken, photographed, and data provided to DBCA. Images of quolls and feral predators taken from the passive camera array at Quoll Knoll to be provided to the feral pest contractor prior to each feral animal control event, to enable a targeted program.
- Fox control to be implemented in 2020 at the sites where foxes and fox evidence has been sighted previously, and active searches for foxes around Quoll Knoll are to be undertaken with traps set accordingly.
- Investigate the opportunity to undertake baiting along the rail line within a buffer area (e.g. 20,000 ha) around the Quoll Knoll complex in conjunction with feral predator trapping events and adjoining tenure holders. Eradicat® baits to be used once their operational use is approved by APVMA and DBCA. Approval may not be granted until late 2020/early 2021.

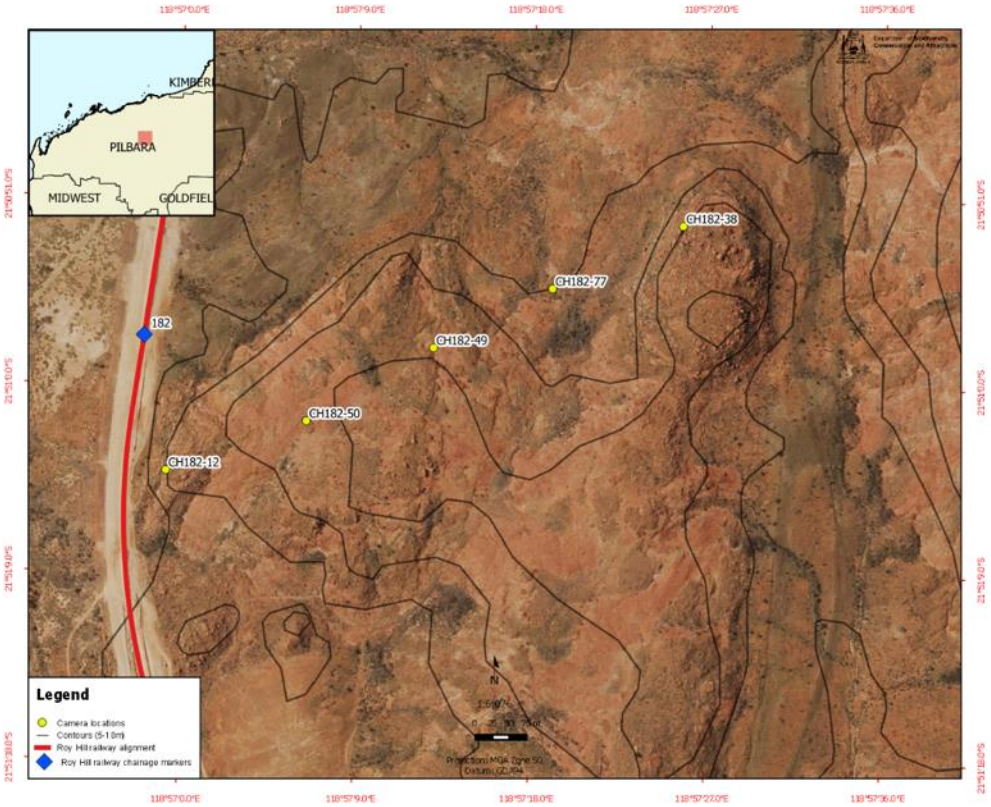
- DBCA, Roy Hill, and FMG to continue the trials in 2020 of the Felixer feral cat grooming trap, subject to APVMA and other approvals, with the future intent of a trap being located at Quoll Knoll.
- Data from the two Chichester Range sites (Python Pool and Euro Springs) that is part of the DBCA regional monitoring program and is supported by Roy Hill, has shown that only one of these sites is considered useful as a long-term trapping site. DBCA recommends that Python Pool be monitored in 2020 and seek support from Roy Hill to set up an alternate monitoring site located outside the Chichester Ranges, but within the Pilbara (e.g. Dolphin Island), that is proven to be a viable long-term monitoring site.
- The current DBCA Pilbara regional monitoring program has achieved many goals outlined in the current approved Roy Hill northern quoll research plan, as well as refining techniques based on knowledge gained. Given that the current Roy Hill northern quoll research plan has not resulted in two viable long-term monitoring sites to provide reliable data for the DBCA Pilbara regional monitoring program, DBCA recommend investigating a review of the current approved Roy Hill northern quoll research plan to enable research effort to be directed towards more meaningful outcomes that benefit the conservation of northern quolls.

6. Appendices

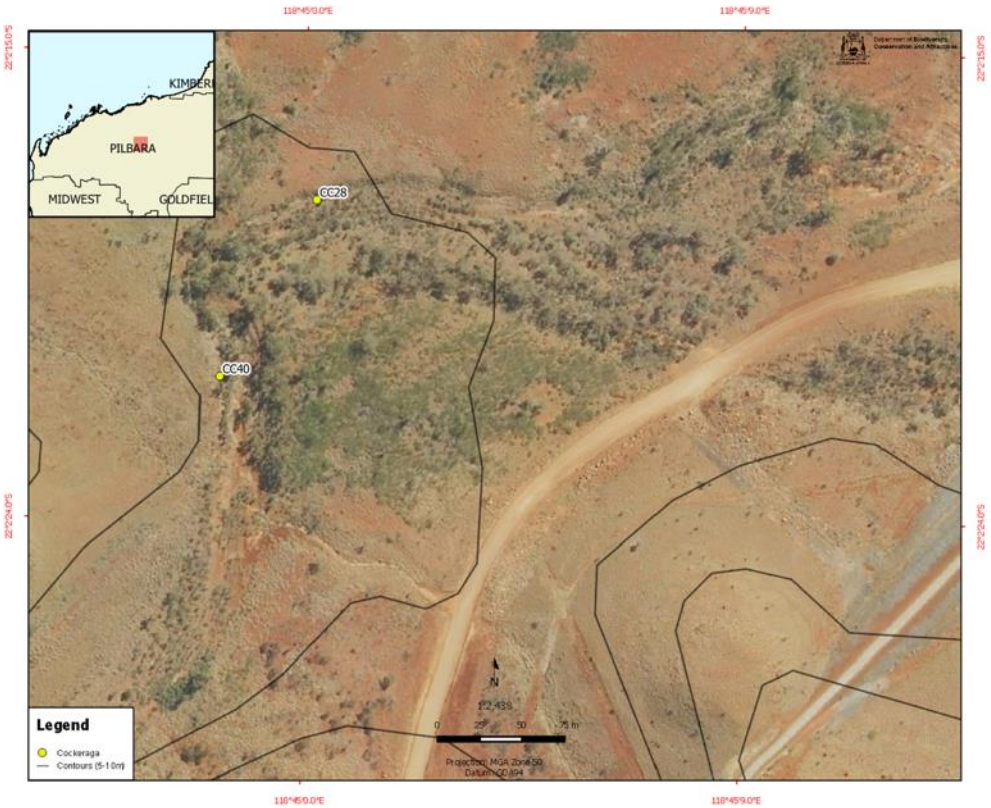
6.1 Appendix 1: Camera trap arrays at each site monitored in 2019.



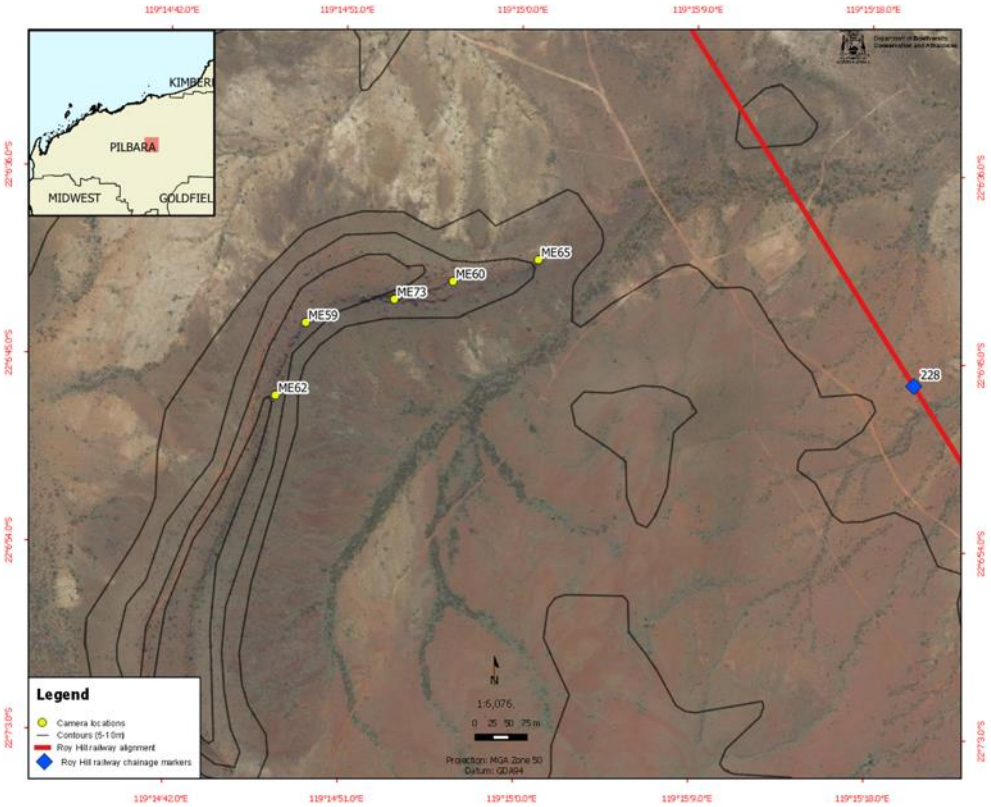
Appendix 1.1: Camera trap array at Bea Bea Creek.



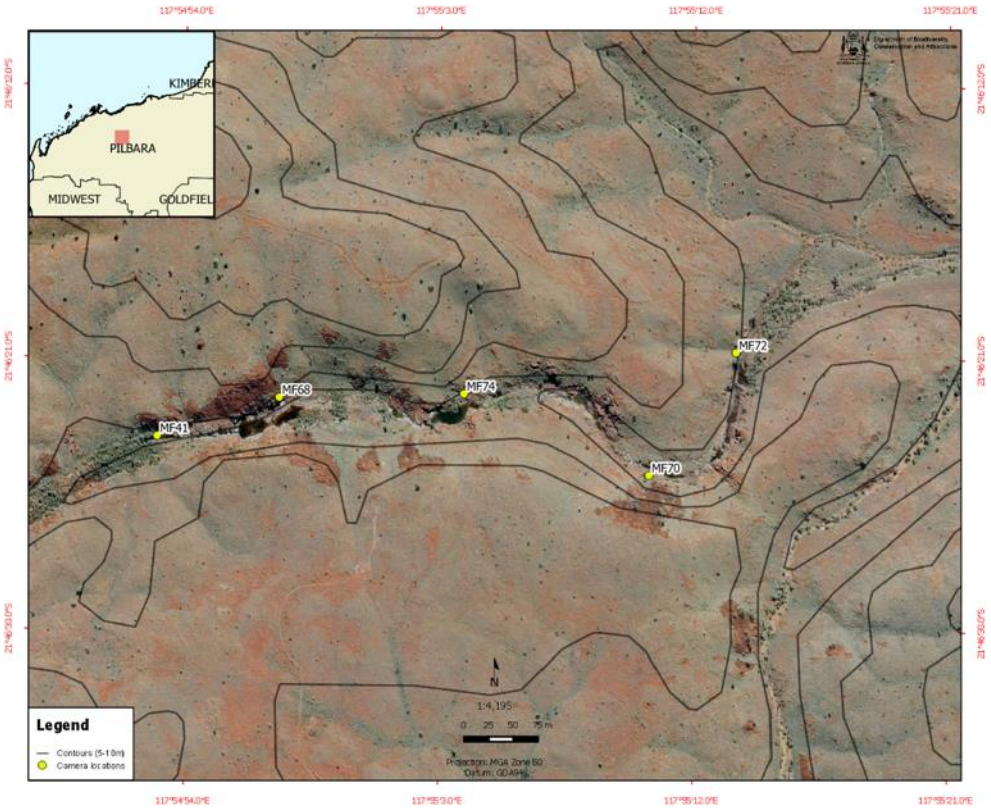
Appendix 1.2: Camera trap array at Chainage 182.



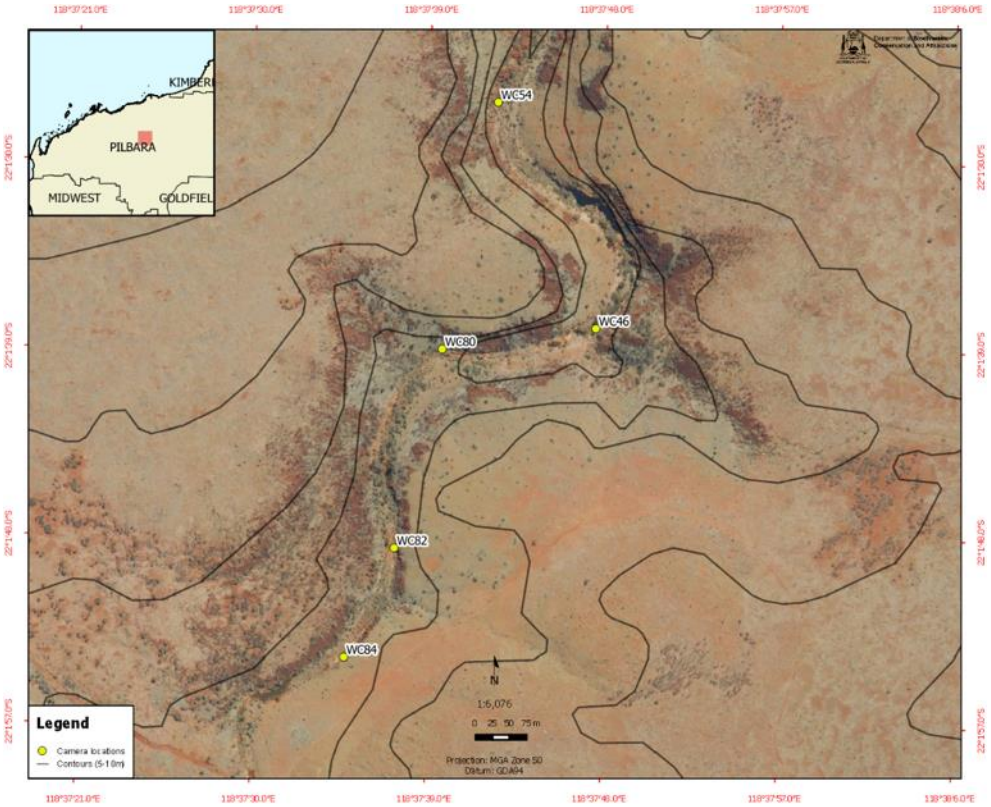
Appendix 1.3: Camera trap array at Cockeraga Creek.



Appendix 1.4: Camera trap array at Mesa 228.



Appendix 1.5: Camera trap array at Euro Springs.



Appendix 1.6: Camera trap array at Wall Creek.

6.2 Appendix 2: Detection summaries from camera traps at the 2019 monitoring sites

Species	Bea Bea Creek	Chainage 182	Cockeraga Creek	Euro Springs	Mesa 228	Quoll Knoll	Wall Creek
Feral Cat	14	3	2	2	2	4	2
Common Rock Rat	3			24	29	65	12
Common Wallaroo	5	10	16	11	58	72	31
Cow	2						
Dasyurid						1	
Dog					1	2	
Echidna					4	3	
Macropod				1		1	4
Northern Quoll		4		26	106	39	9
Pseudantechinus					4	13	
Rodent							2
Rothschild's Rock Wallaby		2		15			20
Total mammals	**24**	**19**	**18**	**79**	**204**	**200**	**80**
Australasian Pipit						1	
Black-faced Woodswallow						6	
Butcher Bird					1	3	
Crow	17		20		3	6	20
Diamond Dove						5	
Grey Shrike-thrush	1		2			1	
Grey-crowned Babbler						4	
Grey-headed Honeyeater						2	
Magpie-lark						4	
Painted Finch						7	
Spinifex Pigeon				6		1	
Striated Grasswren						4	
Torresian Crow							13
Unknown bird	2	1	1			7	1
Variegated Fairy-wren			1			1	
Western Bowerbird		1		1			
Willie Wagtail	1			1		4	
Yellow-throated Miner					1		
Total birds	**21**	**2**	**24**	**8**	**5**	**56**	**34**
Ctenotus sp.						5	
Egernia				7		4	
Perentie	1				5	9	
Pilbara Rock Monitor				7		20	1
Reptile						7	1
Snake				1			
Spiny-tailed Monitor	2			1		1	
Varanid				2	1	1	
Total reptiles	**3**	**0**	**0**	**18**	**6**	**47**	**2**
Invertebrate						3	

6.3 Appendix 3: Northern quoll and feral cat activity outlined to inform management activities

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												

References

aussie Feral Pests 2016. Report for-ROYOPS-ENV-049 Feral Animal Control August 2016. Perth: Unpublished report prepared for Roy Hill Pty Ltd: Aussie Feral Pests.

Aussie Feral Pests 2019. Report for-OP-SOW-00686 Feral Animal Control November 2019. Perth: Unpublished report prepared for Roy Hill Pty Ltd: Aussie Feral Pests.

Begg, R. J. 1981. The Small Mammals of Little Nourlangie Rock, N.T III. Ecology of Dasyurus hallucatus, the Northern Quoll (Marsupialia : Dasyuridae). *Wildlife Research,* 8**,** 73-85.

Biota Environmental Sciences 2005. Fauna Habitats and Fauna Assemblage of the Proposed FMG Stage B Rail Corridor and Mindy Mindy, Christmas Creek, Mt Lewin and Mt Nicholas Mine Areas. Perth: Report prepared for Fortescue Metals Group: Biota Environmental Sciences Pty Ltd.

Birch, N., Dunlop, J. A., Moore, H. & Cowan, M. 2019. Targeted surveys for northern quolls in the Chichester Ranges. Perth: Report prepared for Roy Hill Pty Ltd. Department of Biodiversity, Conservation and Attractions.

Bolger, D. T., Morrison, T. A., Vance, B., Lee, D. & Farid, H. 2012. A computer-assisted system for photographic mark–recapture analysis. *Methods in Ecology and Evolution,* 3**,** 813-822.

Braithwaite, R. W. & Griffiths, A. D. 1994. Demographic variation and range contraction in the northern quoll, Dasyurus hallucatus (Marsupialia : Dasyuridae). *Wildlife Research,* 21**,** 203-217.

Burrows, N. D., Ward, B. & Robinson, A. 2009. Fuel dynamics and fire spread in spinifex grasslands of the Western Desert. *Proceedings of the Royal Society of Queensland, The,* 115**,** 69.

Coffey Environments 2012. Significant species management plan - Abydos DSO Project. Perth: Report prepared for Atlas Iron Ltd: Coffey Environments Australia Pty Ltd.

Cook, A. 2010. *Habitat use and home-range of the northern quoll, Dasyurus hallucatus: effects of fire.* Master's, The University of Western Australia.

Cook, A. & Morris, K. D. 2013. Northern Quoll survey and monitoring project - Pilbara Region of Western Australia. Perth, Western Australia: Department of Environment and Conservation.

Cowan, M., Moro, D., Anderson, H., Angus, J., Garretson, S. & Morris, K. 2020a. Aerial baiting for feral cats is unlikely to affect survivorship of northern quolls in the Pilbara region of Western Australia. *Wildlife Research*.

Cowan, M. A., Dunlop, J. A., Turner, J. M., Moore, H. A. & Nimmo, D. G. 2020b. Artificial refuges to combat habitat loss for an endangered marsupial predator: How do they measure up? *Conservation Science and Practice,* 2**,** e204.

Cramer, V. A., Dunlop, J., Davis, R. A., Ellis, R., Barnett, B., Cook, A., Morris, K. & Van Leeuwen, S. 2016. Research priorities for the northern quoll (Dasyurus hallucatus) in the Pilbara region of Western Australia. *Australian Mammalogy,* 38**,** 135-148.

Davis, R. A., Wilcox, J. A., Metcalf, B. M. & Bamford, M. J. 2005. Fauna survey of proposed Iron Ore mine, Cloud Break. Perth: Report prepared for Fortescue Metals Group: Bamford Consulting Ecologists.

Department Of Sustainability, E., Water, Population And Communities, 2011. Environment Protection and Biodiversity Conservation Act 1999 referral guidelines for the endangered northern quoll, *Dasyurus hallucatus*. Canberra.: DSEWPAC Australia.

Department Of The Environment 2016. EPBC Act referral guideline for the endangered northern quoll *Dasyurus hallucatus*. Canberra: EPBC Act Policy Statement: Commonwealth of Australia.

Diete, R. L., Meek, P. D., Dixon, K. M., Dickman, C. R. & Leung, L. K. P. 2016. Best bait for your buck: bait preference for camera trapping north Australian mammals. *Australian Journal of Zoology,* 63**,** 376-382.

Doherty, T. S., Glen, A. S., Nimmo, D. G., Ritchie, E. G. & Dickman, C. R. 2016. Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences of the United States of America,* 113.

Dunlop, J., Birch, N. & Moore, H. 2018. Pilbara northern quoll research program. Annual report, 2017. Perth: Department of Biodiversity, Conservation and Attractions.

Dunlop, J., Cook, A. & Morris, K. 2014. Pilbara northern quoll project: surveying and monitoring *Dasyurus hallucatus* in the Pilbara, Western Australia. 14.

Dunlop, J., Rayner, K. & Doherty, T. S. 2017. Dietary flexibility in small carnivores: a case study on the endangered northern quoll, Dasyurus hallucatus. *Journal of Mammalogy,* 98**,** 858.

Dunlop, J. A. & Johnson, B. 2016. Northern Quoll targeted surveys at Wall Creek and Mesa 228. Perth: Report prepared for Roy Hill Pty Ltd: Department of Parks and Wildlife.

Ecologia Environment 2008. RGP5 Level 2 Fauna Survey - Chichester Deviation. Perth: Report to BHP Billiton Iron Ore Pty Ltd: Ecologia Environment.

Fisher, D. O., Dickman, C. R., JONES, M. E. & BLOMBERG, S. P. 2013. Sperm competition drives the evolution of suicidal reproduction in mammals. *Proceedings of the National Academy of Sciences,* 110**,** 17910.

Fortescue Metals Group 2010. Solomon Project - Public Environmental Review. Perth: Fortescue Metals Group Ltd.

Henneron, L., Sarthou, C., De Massary, J.-C. & Ponge, J.-F. 2019. Habitat diversity associated to island size and environmental filtering control the species richness of rock-savanna plants in neotropical inselbergs. *Ecography*.

Hernandez-Santin, L., Goldizen, A. W. & Fisher, D. O. 2016. Introduced predators and habitat structure influence range contraction of an endangered native predator, the northern quoll. *Biological Conservation,* 203**,** 160-167.

How, R. A., Spencer, P. B. S. & Schmitt, L. H. 2009. Island populations have high conservation value for northern Australia's top marsupial predator ahead of a threatening process. *Journal of Zoology,* 278**,** 206-217.

Johnson, B. & Anderson, H. 2014. Northern quoll (Dasyurus hallucatus) remote camera and trapping survey in the central and eastern Chichester Ranges, Pilbara region of Western Australia. Woodvale, WA: Department of PArks and Wildlife.

Johnson, C. N. & Isaac, J. L. 2009. Body mass and extinction risk in Australian marsupials: The 'Critical Weight Range' revisited. *Austral Ecology,* 34**,** 35-40.

Molloy, S. W., Davis, R. A., Dunlop, J. A. & Van Etten, E. J. B. 2017. Applying surrogate species presences to correct sample bias in species distribution models: a case study using the Pilbara population of the Northern Quoll. *Nature Conservation,* 18**,** 27-46.

Moore, H. A., Dunlop, J. A., Valentine, L. E., Woinarski, J. C. Z., Ritchie, E. G., Watson, D. M. & Nimmo, D. G. 2019. Topographic ruggedness and rainfall mediate geographic range contraction of a threatened marsupial predator. *Diversity and Distributions,* 25**,** 1818-1831.

Moore, H. A., Valentine, L. E., Dunlop, J. A. & Nimmo, D. G. 2020. The effect of camera orientation on the detectability of wildlife: a case study from north-western Australia. *Remote Sensing in Ecology and Conservation*.

Moro, D., Dunlop, J. & Williams, M. R. 2019. Northern quoll persistence is most sensitive to survivorship of juveniles. *Wildlife Research,* 46**,** 165-175.

Morris, K. D., Cowan, M., Angus, G. J., Anderson, H., Garretson, S., Algar, D., Moro, D. & Williams, M. R. 2015. The northern quoll cat bait uptake and survivorship study, Yarraloola Land Management Area, Pilbara Region, WA. Perth: Department of Parks and Wildlife.

Murphy, B. P. & Davies, H. F. 2014. There is a critical weight range for Australia's declining tropical mammals. *Global Ecology and Biogeography,* 23**,** 1058-1061.

Oakwood, M. 1997. *The ecology of the northern quoll, Dasyurus hallucatus.* Doctor of Philosophy, Australian National University.

Oakwood, M. 2000. Reproduction and demography of the northern quoll, *Dasyurus hallucatus*, in the lowland savanna of northern Australia. *Australian Journal of Zoology,* 48**,** 519-539.

Oakwood, M. 2002. Spatial and social organization of a carnivorous marsupial Dasyurus hallucatus. *Journal of Zoology,* 257**,** 237-248.

Oakwood, M., Bradley, A. J. & Cockburn, A. 2001. Semelparity in a Large Marsupial. *Proceedings: Biological Sciences,* 268**,** 407-411.

Oakwood, M., Woinarski, J. C. Z. & Burnett, S. 2016. *Dasyurus hallucatus. The IUCN Red List of Threatened Species 2016* [Online]. Available: http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T6295A21947321 [Accessed 14 May 2019].

Ramanaidou, E. R. & Morris, R. C. 2010. A synopsis of the channel iron deposits of the Hamersley Province, Western Australia. *Applied Earth Science,* 119**,** 56-59.

Roy Hill Holdings Pty Ltd. 2014. Northern quoll research plan. Perth, western Australia: Roy Hill Holdings Pty Ltd.

Schmitt, L. H., Bradley, A. J., Kemper, C. M., Kitchener, D. J., Humphreys, W. F. & How, R. A. 1989. Ecology and physiology of the northern quoll, Dasyurus hallucatus (Marsupialia, Dasyuridae), at Mitchell Plateau, Kimberley, Western Australia. *Journal of Zoology,* 217**,** 539-558.

Spectrum Ecology 2018. Operational Areas, Nullagine and North Star: Conservation significant fauna monitoring 2018. Perth: Prepared for: Fortescue Metals Group: Spectrum Ecology.

Woinarski, J. C. Z., Burbidge, A. & Harrison, P. 2014. *The action plan for Australian mammals 2012*, CSIRO publishing.