Northern Quoll targeted surveys at Wall Creek and Mesa 228

Report prepared for Roy Hill Pty Ltd

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Contents

Figures

Tables

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Abbreviations

EPBC Act - Environmental Protection and Biodiversity Conservation Act 1999

GPS – Global Positioning System

NQRP – (Roy Hill's) Northern Quoll Research Plan

PIT – Passive Implant Transponder

RC4 – Rail Camp 4

SRL - Special Rail Lease

Summary

Roy Hill Pty Ltd seek to better understand the northern quoll populations and in the vicinity of their now operational Roy Hill to Port Hedland iron ore railway. For this purpose, two monitoring sites were added to the Department of Parks & Wildlife Pilbara northern quoll Regional Monitoring Program in 2015, with 2016 being the second year of survey. The sites, Mesa 228 (including nearby small rocky habitat named 'Quoll Knoll'), and Wall Creek, are both in the eastern Chichester Range. These sites were surveyed in August 2016 via trapping, remote cameras and scat searches according to the methods used in the regional program.

Northern quoll presence was detected at Wall Creek via a single photo on a remote camera prior to the trapping survey and a single scat. Several northern quoll scats were collected in the vicinity of the Mesa 228 and Quoll Knoll sites. No animals were captured during either 200 trap-night survey of Wall Creek or Mesa 228. Despite previously consistent records of one or two resident females at Quoll Knoll, none were captured in the 40 trap night survey at this location. Permanent remote camera stations at Quoll Knoll indicated that at least one northern quoll has been regularly present at the rocky complex; with an individual animal last recorded on 8 July 2016. A female was observed with one offspring in January 2016, but the young animal was not subsequently photographed and may have dispersed from the habitat.

During the monitoring survey, a large adult male feral cat was trapped at Quoll Knoll and euthanized (as part of a Roy Hill feral animal program run concurrently with the Northern Quoll monitoring program). Hair in the gut of this feral cat consisted entirely of northern quoll, suggesting that it may have predated upon the resident northern quoll at Quoll Knoll. This is the likely explanation of a lack of captures via trapping.

Immediate recommended actions include:

- Maintain the presence of permanent cameras at Quoll Knoll
- Follow up on the permanent cameras at Quoll Knoll to see whether any northern quolls persist following this predation event;
- Set additional lured cameras at locations where evidence of northern quolls were found (Rail culvert, West Shaw River Rail bridge rock armour, Quoll Knoll complex) to determine if any northern quolls are still present; and
- Continue feral control targeting feral cats.

Previous actions recommended to Roy Hill have included monitoring the Quoll Knoll site via remote cameras, and impact mitigation measures (slow speed limit, road signs for awareness, cat trapping at sensitive times of the year) in light of the road and rail infrastructure in this area. These recommendations were implemented by Roy Hill in 2015 and continued during 2016. Risks to animals using the rail service track has significantly reduced from that experienced in mid 2015 as the nearby rail camp is unoccupied and vehicle usage is greatly reduced, however the rail is now operational with trains running 4-5 times per day. Modifications to future monitoring protocols are recommended.

1 Introduction

This report details the research undertaken by the Department of Parks and Wildlife (Parks & Wildlife) in 2016 on northern quoll populations and distribution within the Chichester Ranges. The research is part of Roy Hill's Northern Quoll Research Plan (NQRP) (100RH-3000-EN-REP-2033) as part of the requirements of Condition 3 of *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) approval 2011/5867. This work conducted in 2016 is a continuation of previous survey efforts throughout the area (Johnson and Anderson, 2014; Dunlop *et al.,* 2015). The results of this and previous surveys are summarised and discussed.

1.1 Northern quoll *Dasyurus hallucatus*

The northern quoll is a medium-sized predatory 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.*, 2008; 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.*, 2008). 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 *et. al.* 1994; Hill and Ward, 2010; Woinarski et al., 2014).

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 Parks and Wildlife 2013; DSEWPaC 2011). In the Pilbara, northern quolls appear to depend primarily on more complex rocky habitat 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 within the EPBC (1999), 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 (Oakwood, 2002a; Radford, 2012). 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 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, Environment, Water, Population and Communities 2012) for the northern quoll in the Pilbara, a proportion of offset funds for this species has been directed towards scientific research. Parks and Wildlife has also implemented a Pilbara-wide quoll research program (Dunlop *et al.*, 2014) to provide a regional context for more targeted population research.

1.2 Roy Hill EPBC requirements

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 comprises 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 incorporates 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. Construction has recently finished, operations have started and camps are in the process of being demobilized.

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 Parks & Wildlife Pilbara northern quoll regional research program (Dunlop *et al.*, 2014). The specific objectives of the NQRP include:

- To improve the understanding of the 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 taxonomic and conservation status of the Chichester Ranges northern quoll population.

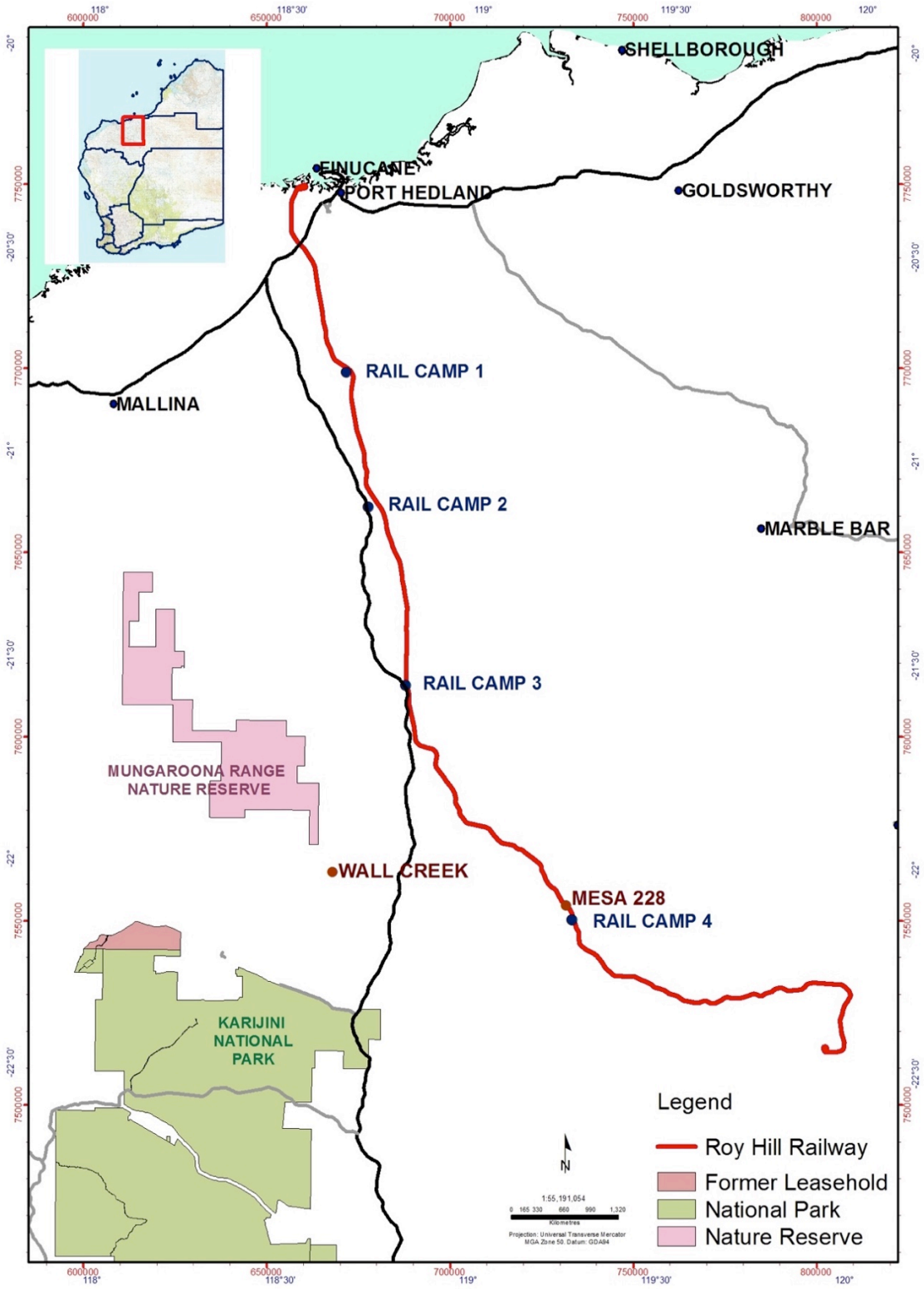

Figure 1. Map of the 2016 Roy Hill northern quoll trapping sites (Wall Creek and Mesa 228) in the context of the Pilbara, showing Roy Hill Railway and the currently unoccupied Rail Camps 1-4.

1.3 Previous Surveys

Previous surveys indicate that populations of northern quolls in the eastern area of the Chichester Ranges appear to be highly fragmented with small breeding colonies occupying relatively isolated islands of suitable refuge and foraging habitat. Some sites appearing to meet the requirements for suitable quoll habitat, failed to produce evidence of quoll presence during those previous survey efforts.

Significant effort has been in recent years to determine the presence and extent of northern quolls within the Chichester Ranges (Biota Environmental Sciences, 2005; Davis *et al.*, 2005; Ecologia Environment, 2008). Quoll populations appear to increase further north and west of this study area (Coffey Environments, 2012; Rapallo, 2012). Parks and Wildlife have established two long-term monitoring sites at more westerly Chichester Range sites, Mt Florance and Python Pool.

Three individual quolls (one male and two females) were captured in 2014 and 2015 from the rock outcrop complex, known as Quoll Knoll, within the Roy Hill Special Rail Lease (SRL) (Dunlop *et al.,* 2015). This colony is one of few in the area, and in the context of the broader low abundance of quolls in the south-eastern Pilbara, is at or near the south-east limit of Pilbara quoll distribution. It should be considered significant because of the low density and sparse spread of quoll populations, and large gaps between suitable habitat in this area. The nearby Mesa 228 (approximately 1.5km from Quoll Knoll) was chosen to be included as a survey site due to its proximity to the Quoll Knoll population, size and complexity of breakaway habitat. One individual male northern quoll was captured at Mesa 228 in 2015. The gorge at Wall Creek (Hooley Station) was also chosen as a monitoring option due to the presence of good northern quoll habitat parameters including permanent water, rugose gorge walls, minimal disturbance, generally healthy vegetation. However, no individuals were captured in 2015 (Dunlop *et al.,* 2015).

2 Methods

2.1 Sites and site conditions

Mesa 228 (Figure 2) is a long lateritic ridge mesa, approximately 900m long with numerous caves and crevices along the upper breakaway ridge. Vegetation includes *Triodia* sp., *Eucalyptus* sp., and other shrubs surrounding and on top of ridge. The rocky knoll dubbed "Quoll Knoll" is approximately 1.5km to the north of Mesa 228, next to and between the Roy Hill rail line and a light vehicular access track (Figure 3). Quoll Knoll is a small (200m) lateritic outcrop of very large boulders, including two smaller sections on the south side of the vehicular track. 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.

Wall Creek on Hooley Station (Figure 4) is a 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 base of the slope, mixed vegetation complex with *Triodia* sp., *Eucalyptus* sp., *Acacia* sp., *Melaleuca* sp., and other shrub species. The upper slopes of the gorge consist of an open woodland of *Triodia* sp. and mulga (*Acacia aneura* and related *Acacia* species).

Climatic data were collated from the nearest weather station, Wittenoom, located 38km from Wall Creek and 95km from Mesa 228. The monthly averages of rainfall and temperature from 1951 to 2015 are shown in Figure 5. The Pilbara experiences the majority of its rainfall during monsoonal rainfall events over summer, with cool and dry winters. No large monsoons occurred during the 2015/2016 summer, so the region received less summer rainfall than usual, but had an unusually high amount of rainfall in June 2016.

Figure 2. Rocky breakaway habitat on the ridge that forms Mesa 228.

Figure 3. The small rocky outcrop referred to as Quoll Knoll. The outcrop lies directly between the Roy Hill rail line and the light vehicle service track.

Figure 4. Tumbledown breakaways and cliffs at Wall Creek trapping site. The rocky gorge extends approximately 2.5 kilometers north-south, and feeds into the Yule River.

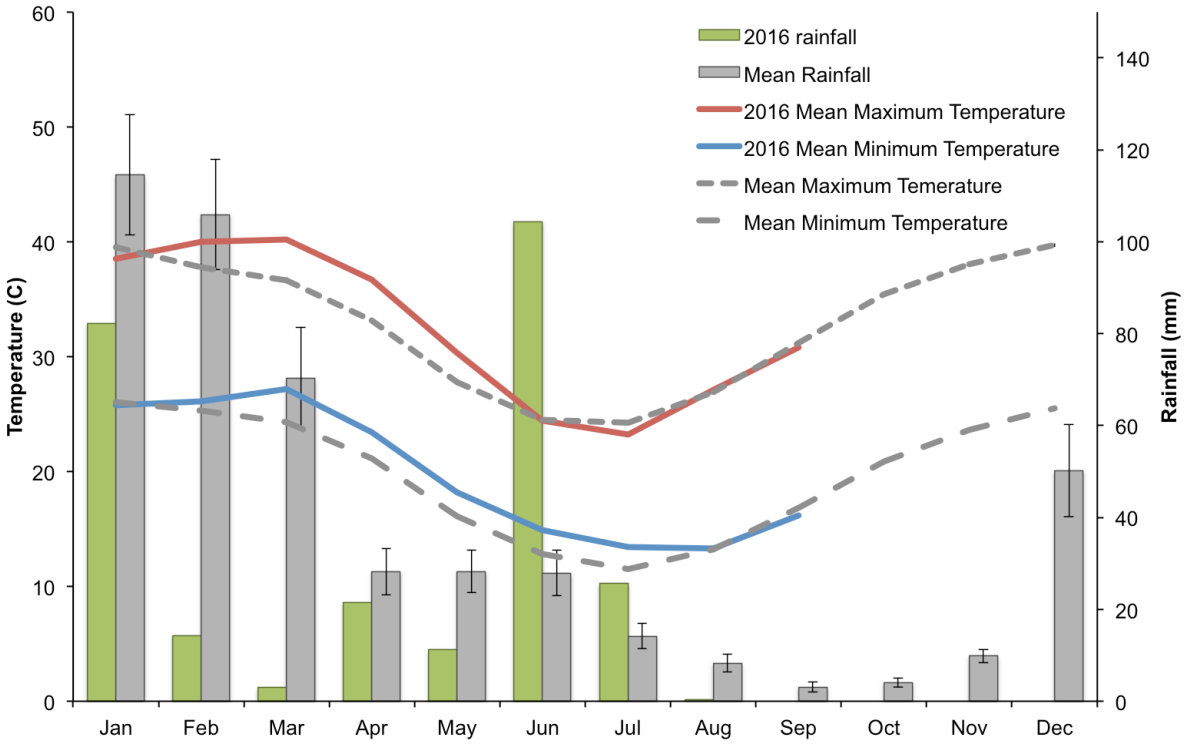

Figure 5. Climate data from the nearest WA Bureau of Meteorology weather station (Wittenoom station 005026). Mean data from 1951 to 2015 (mean maximum and minimum monthly temperatures, mean monthly rainfall) are shown in grey. Data from 2016 (mean minimum and maximum temperatures, and monthly rainfall) are shown in colour.

2.2 Field effort

Parks and Wildlife undertook 200 trap nights at both Wall Creek (30 August – 2 September 2016) and Mesa 228 (24-27 August 2016) plus an additional 40 trap nights at Quoll Knoll (24-27 August 2016). Approximately 10 person-hours of scat searches were completed at Wall Creek, Coonarrie Creek, Cockeraga Creek, Mesa 228, Quoll Knoll complex and at the West Shaw River rail overpass south-east of Quoll Knoll.

At Wall Creek, 18 remote cameras with scent lures were set along the 2.2km length of the gorge for just over 6 weeks prior to the trapping survey (15 July – 30 August). Other cameras were set opportunistically; Coonarrie Creek (10 cameras for 3 nights), Mesa 228 (4 cameras for 3 nights), and West Shaw River rail overpass (2 cameras for 1 night following the discovery of scats nearby).

In addition to this, Roy Hill have four permanent, unbaited remote cameras set at Quoll Knoll and on the two smaller knolls to the west of the LV track (Knoll 2 and Knoll 3) (since April 2014), at Roy Hill railway chainage 225 to monitor the presence of northern quolls. Two other cameras have been placed by Roy Hill on the eastern side of the rail on small rocky Quoll Knoll ridge extensions that have been dissected by the rail alignment. These were in place from 28 July to 23 August 2016.

2.3 Trapping

Trapping was undertaken at both Mesa 228 and Wall Creek, as per the standard regional monitoring protocol set out in Dunlop *et al.* (2014). An additional ten traps were set at the small area of Quoll Knoll and the surrounding rocky outcrops. Animals were trapped using wire cage traps (45 cm x 17 cm x 17 cm, Sheffield Wire co, Welshpool WA) covered with hessian for shade and protection, baited with peanut butter, oats and sardines. Fifty traps were set at Mesa 228 and Wall Creek, spaced 50 m apart in two lines of 25 traps, with approximately 50 m between each transect. At Quoll Knoll, ten traps were spaced evenly encircling the rocky outcrops north and south of the light vehicle track. Traps were opened for four consecutive nights at each site. Traps were checked and closed within three hours of sunrise each morning, rebaited and opened in the late afternoon. Details of the locations and durations of each cage trap set can be found inTable 8.

All captured quolls are implanted with a subcutaneous microchip (PIT) for individual identification. Standard measurements collected from any captured quolls and other species would include: body weight, short pes length, head length, age class, sex, body and reproductive condition. Animals are only measured on their first capture. Weights were sometimes re-measured on subsequent captures to ensure that animals were not losing body mass due to stress/lack of foraging during the trapping process. A small amount of ear tissue is collected from each individual of all species at initial capture and stored in 100% ethanol for genetic analysis. Animals are examined for ectoparasites, especially around the ears, neck and genitals.

Targeted feral cat trapping also occurred along the Roy Hill SRL in the vicinity of Quoll Knoll, undertaken at the time of the northern quoll survey. This feral animal control program was conducted by Aussie Feral Pests. 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 quoll captured in cat traps are provided to Parks and Wildlife for processing. Feral animal scats or stomach contents of euthanised feral cats were provided to Parks and Wildlife for dietary analysis.

2.4 Remote cameras

Motion sensing cameras (Reconyx PC900) were used as an additional method to trapping and scat survey in order to detect quoll presence. Cameras were set to record activity at all times of day and night with five consecutive photographs per trigger. The cameras were fixed to a stable object such as a tripod, tree or rock, in front of a scent lure consisting of peanut butter, oats, sardines and fish oil in an inaccessible ventilated pod. Cameras were set approximately 100m apart in order to spread detections across as many home ranges (usually delineated by females) as possible. For analysis purposes, an occasion was defined as a visit by a species on one camera in a 24-hour period. If multiple individuals were able to be identified (e.g. multiple animals in an image, or differently patterned individuals), this was recorded.

Roy Hill have up to four permanent, unbaited remote cameras set up at Quoll Knoll and on the two smaller knolls to the west of the light vehicle track, at Roy Hill railway chainage 225 to monitor the presence of northern quolls as per previous recommendations (Johnson and Anderson, 2014). The four cameras at Quoll Knoll have been in place since April 2014, with an additional two cameras located to the east of the rail line from 28 July 2016. Other cameras were set opportunistically during the time of the survey; at Mesa 228 (four cameras for three nights), at West Shaw River rail bridge (two cameras for one night following the discovery of a northern quoll latrine site), and at Coonarrie Creek (ten cameras for three nights). Details of the locations and durations of set for each camera can be found in Table 7.

2.5 Dietary analysis

Quoll and feral predator scat searches were undertaken at the trapping sites and several other areas on an opportunistic basis. Searches are undertaken with personnel spending several hours walking through likely habitat (breakaways, creek systems, mesas and ridges) examining rocky crevices and caves. Scats are collected and stored in a paper envelope with associated data (GPS location, date, species, collector). Once dry, scats were kept frozen until sent for analysis to a specialist (G. Story, Scats About, NSW) where food types were recorded for each scat and a percent volume of each food item within the scat was visually estimated using a grid system.

Scats and gut contents were oven-dried at 100°C for 12 hours to kill parasite eggs. Samples were then placed in individual fine weave nylon bags, washed in a washing machine and air-dried. Food items were identified via microscopy from the undigested parts of plants and animals, including hair, teeth, claws, scales, feathers, bones and exoskeletal remains. Food items were recorded for each scat and a percent volume of each food item within the scat was visually estimated using a grid system. Food items were identified to the lowest possible taxonomic class through comparison of remains with reference material or the literature (Brunner and Triggs, 2002). Hair was identified to species from characteristics of the hair scales, patterning and shape when cross-sectioned as per Brunner and Coman (1974).

Scat searches were undertaken at all trapping sites (Wall Creek, Mesa 228, Quoll Knoll) as well as nearby likely habitat (West Shaw River rail bridge, Cockeraga Creek, Coonarrie Creek). Working in tandem with the Parks and Wildlife northern quoll survey team was Daniel Reed from Aussie Feral Pests (AFP), who was undertaking feral animal control in/around Quoll Knoll. Feral cat scat and gut contents samples collected by AFP were provided to Parks and Wildlife and sent for dietary analysis.

3 Results

3.1 Trapping

In total, 440 trap nights were undertaken at the Wall Creek and Mesa 228 & Quoll Knoll sites, with no captures of northern quolls. One large male feral cat was captured at the time of the quoll trapping survey Aussie Feral Pests in the creekline adjacent to Quoll Knoll and then euthanised.

No quolls were captured at any of the three sites, from a total of 440 trap nights (Table 1). At Wall Creek, three common rock rats (*Zyzomys argurus*) were captured. At Mesa 228, a total of 25 individual common rock rats were captured, and one was captured at Quoll Knoll. All individuals were measured, weighed and had DNA samples taken. Genetic samples will be passed on with data to L. Schmitt at University of Western Australia as part of his research into the *Zyzomys* species complexes.

As part of the feral species control program, feral cat trapping occurred from 24-28 August. One large adult male tabby cat was captured and euthanised at Quoll Knoll on 25 August 2016.

Table 1. Capture results from cage trapping at each of the sites. Mesa 228 and Quoll Knoll are approximately 1.5km apart. Trapping occurred from 23-27 Aug 2016 at Mesa 228 and Quoll Knoll, and 28 Aug – 1 Sep 2016 at Wall Creek.

	Lat	Lon	Trap nights	Captures
Wall Creek	-22.02791	118.6282	200	3 *Zyzomys argurus*
Mesa 228	-22.11425	119.2458	200	25 *Zyzomys argurus*
Quoll Knoll	-22.09658	119.2368	40	1 *Zyzomys argurus*

3.2 Remote cameras

Remote cameras revealed quoll presence at Wall Creek, from one image from 828 camera nights (18 cameras set for 46 days). Opportunistic cameras set in additional locations did not reveal quoll presence.

A total of 20 species were detected on remote camera, from 33 cameras set across four sites. Cameras were set at Wall Creek for an extended period of time (18 cameras x 46 days = 828 camera nights) and therefore generated the majority of species detections (Table 3).

Despite this extended camera set period, only one northern quoll instance was detected at Wall Creek, on 27 July 2016. The instance of a northern quoll on remote camera was present in a location that was subsequently part of the trap line (-22.0278, 118.6272). Northern quolls were not detected from 30 camera nights at Coonarrie Creek, 12 camera nights at Mesa 228 or two camera nights at the West Shaw River rail bridge.

Other species detected included Rothschild's rock wallabies, euros, dingoes, cattle, nine identifiable species of bird and three species of reptile (Table 3). Feral cats (at least three

individuals) were detected on several occasions on different cameras at Wall Creek, and on one occasion at Coonarrie Creek.

Between December 2015 and early July 2016, at least two northern quoll individuals have been captured on remote sensor cameras on both sides of the LV track (Table 2) on Roy Hill cameras. Two quolls were captured in the same image in January 2016 (Figure 6); one of which appears to be a juvenile. The most recent detection of northern quolls in this area was made on the 8th July 2016.

Table 2. Detections of northern quolls, feral cats and canids at the four Roy Hill permanent, unbaited remote cameras located around Quoll Knoll from December 2015 - July 2016. Numbers indicate the number of days each month that a single individual was detected on camera. An asterisk (*) indicates two individuals in one image. GPS locations for each camera are shown at the bottom of the table.

	Quoll Knoll A			**Quoll Knoll B**			**Knoll 2**			**Knoll 2-3**		
	Quoll	Cat	Canid	Quoll	Cat	Canid	Quoll	Cat	Canid	Quoll	Cat	Canid
Dec-15	0	0	0	0	0	0	1	0	0	1	0	0
Jan-16	1*	0	0	0	0	0	0	2	0	2	0	0
Feb-16	0	1	1	0	0	0	1	0	0	2	0	0
Mar-16	1	0	0	1	0	0	0	0	0	1	0	0
Apr-16	0	0	0	1	0	0	1	0	0	2	0	0
May-16	0	0	0	0	0	0	0	0	0	2	1	0
Jun-16	0	0	0	0	0	0	0	0	0	2	0	0
Jul-16	0	0	0	0	0	0	0	0	0	2	0	0
GPS Coordinates	-22.0877, 119.2369			-22.0878, 119.2367			-22.0889, 119.2363			-22.0888, 119.2362		

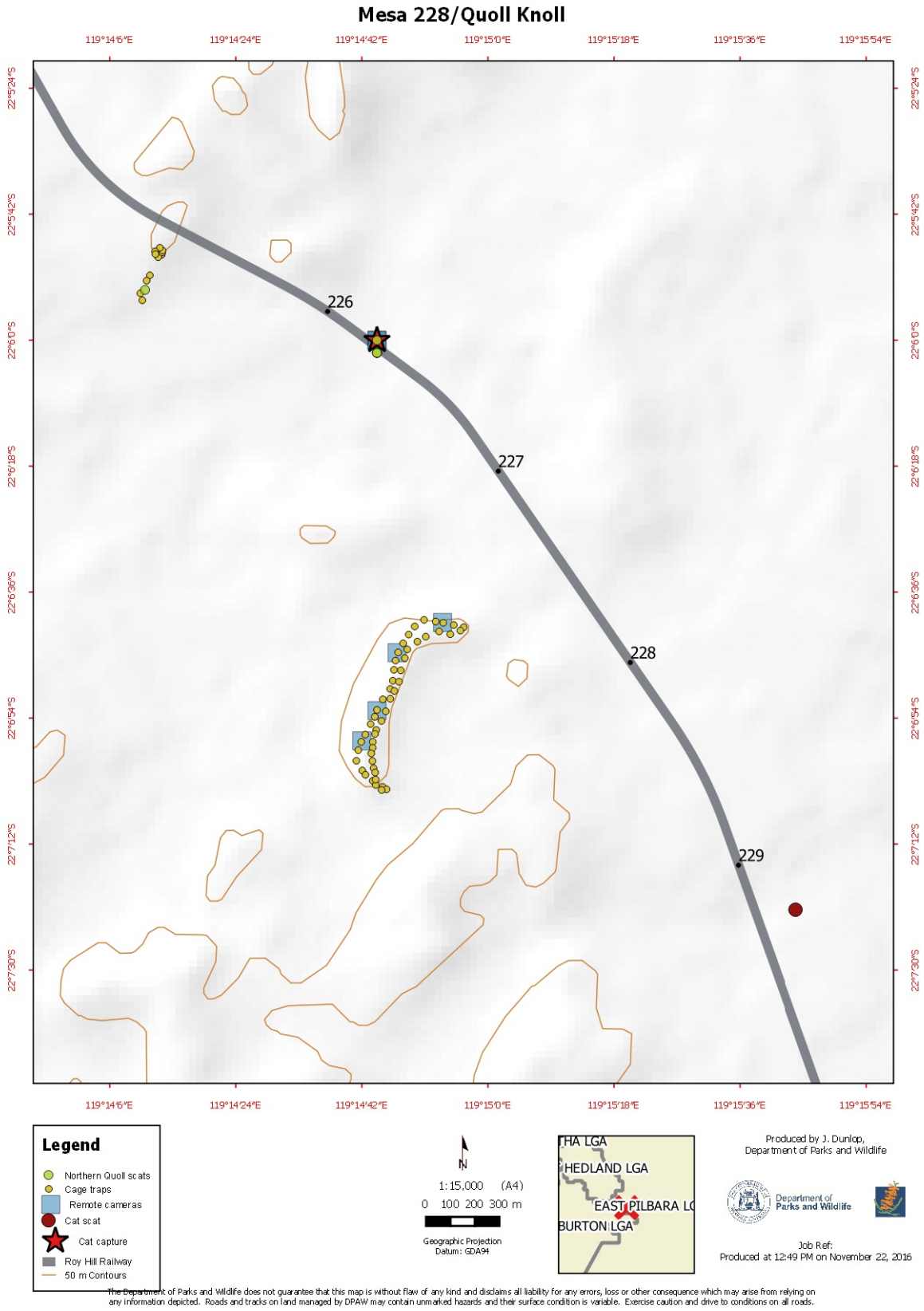

Figure 6. Map depicting remote cameras and cage traps set in the vicinity of Mesa 228 and Quoll Knoll, as well as the northern quoll scat, feral cat scat, and feral cat capture.

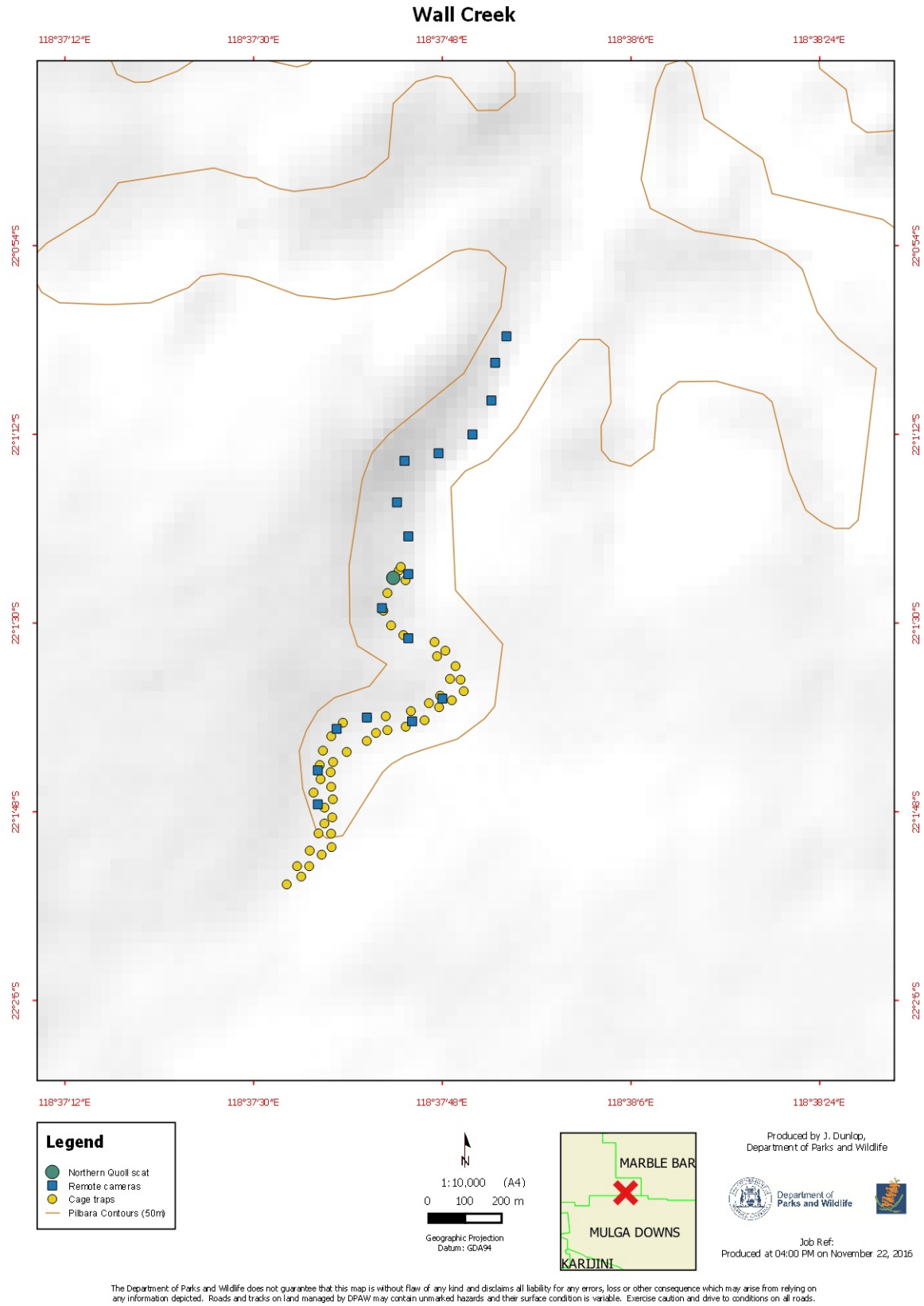

Figure 7. Map depicting remote cameras and cage traps set at Wall Creek, as well as the northern quoll scat found within the gorge.

Figure 8. Two northern quolls captured on Roy Hill remote sensor cameras on Quoll Knoll, 10 January 2016 (image provided by Roy Hill).

Table 3. Species detected from remote cameras set at Wall Creek (WC), Coonarrie Creek (CC), Mesa 228 (ME) and West Shaw River (WSR). Camera locations and set dates can be found in *Table 7*. Numbers indicate the individual days that the species occurred on each camera.

Common name	Feral cat	Dingo	Common rock rat	Cattle	Euro	Rothschild's rock wallaby	Northern quoll	Western bower bird	Pacific Black Duck	White-faced Heron	Painted finch	Pelican	Torresian crow	Australian Magpie	Magpie-lark	Willy wagtail	Other bird	Pilbara skink	Sand Goanna	Mulga snake
Latin name	***Felis catus***	***Canis dingo***	***Zyzomys argurus***	***Bos taurus***	***Macropus robustus***	***Petrogale rothschildi***	***Dasyurus hallucatus***	***Ptilonorhyncus guttatus***	***Anas superciliosa***	***Egretta novaehollandiae***	***Emblema pictum***	***Pelicanus conspicillatus***	***Corvus orru***	***Cracticus tibicen***	***Grallina cyanoleuca***	***Rhipidura leucophrys***	**-**	***Egernia pilbarensis***	***Varanus gouldii***	***Pseudechis australis***
WC43	0	0	**1**	0	**5**	**5**	0	0	0	0	0	0	**3**	**1**	0	**1**	0	0	0	0
WC44	0	0	0	0	0	**3**	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0
WC45	**1**	0	0	0	0	**4**	0	0	0	0	0	0	**3**	0	0	0	0	**2**	0	0
WC46	0	0	0	0	0	**1**	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0
WC47	0	0	**4**	0	**1**	**2**	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0
WC48	0	0	**1**	0	0	**3**	0	**3**	0	0	0	0	**4**	0	0	0	0	0	0	0
WC49	**1**	0	0	0	0	**0**	0	0	0	0	0	0	**4**	0	0	0	0	0	0	**1**
WC50	0	**1**	0	0	0	**2**	0	0	0	0	0	0	**5**	0	0	0	0	0	0	0
WC51	0	0	0	0	**3**	**4**	0	0	0	0	0	0	**5**	0	0	**1**	0	0	0	0
WC52	0	0	0	0	0	**4**	0	0	0	0	0	0	**7**	0	0	0	0	0	0	0
WC53	**1**	**2**	**2**	0	0	**3**	0	0	0	0	0	0	**5**	0	0	0	0	0	0	0
WC54	0	0	0	0	**1**	0	0	0	0	0	0	0	**5**	0	**1**	0	0	0	0	0
WC55	0	0	0	**1**	0	0	0	0	**1**	**1**	0	0	**4**	0	**3**	0	0	0	0	0
WC56	0	0	**4**	**0**	**2**	0	0	0	0	0	0	0	**2**	0	**0**	0	0	0	0	0
WC57	0	**2**	**1**	0	**3**	**3**	0	0	0	0	**1**	0	**8**	0	0	0	0	0	0	0
WC58	**3**	0	0	0	**5**	**1**	**1**	0	0	0	0	0	**3**	0	0	0	0	0	0	0
WC59	0	0	0	**3**	0	0	0	0	0	0	0	0	**1**	0	**1**	0	0	0	0	0
WC60	**2**	0	**2**	0	**2**	0	0	0	0	0	0	0	**4**	0	0	0	**1**	0	0	0
CC10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CC21	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0
CC24	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	**1**	0
CC25	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0
CC26	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0
CC27	**1**	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	**1**	0	0	0
CC29	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0
CC30	0	0	0	0	**1**	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0
CC35	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0
ME03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ME09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ME15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ME19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSR01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSR01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.3 Dietary analysis

Northern quoll scats were collected from Mesa 228, Quoll Knoll and surrounding rocky areas, the West Shaw River rail bridge, and Wall Creek (Table 4). No scats were found at Coonarrie Creek or Cockeraga Creek. Dietary analysis of northern quoll scats revealed consumption of eight species of mammal, as well as bird, reptile and invertebrates. The gut of the feral cat captured near Quoll Knoll contained entirely northern quoll hair, indicating likely predation of at least one of the resident quolls at this location.

Although scats were collected from Mesa 228, Quoll Knoll and the West Shaw River rail bridge, none were thought to be recent. A latrine site was found at the nearby West Shaw River railway bridge, amongst the new rock armour on a steel gilder. Scats at this latrine were not fresh. A northern quoll track was seen on 28 July in the dried mud in and outside the rail culvert next to the same rail bridge (*Figure 9*). One relatively fresh scat was collected at Wall Creek. No scats were found at Coonarrie Creek or Cockeraga Creek.

One feral cat scat was collected from a rail culvert east of Quoll Knoll (-22.1225556, 119.2621667). No cat scats were found at Wall Creek or at other sites searched. Sample hair collected from the gut of the captured feral cat was determined to be 100% northern quoll hair. Analysis of the cat scat revealed consumption of the native rodent *Leggadina lakedownensis*, a bird and invertebrates (Table 5).

From the eight scat samples collected and analysed, northern quolls were observed to consume at least 11 different food items (Table 4). These included three species of rodent (*Zyzomys argurus, Pseudomys hermannsbergensis* and the introduced *Mus musculus*), and the small marsupial *Dasykaluta rosamondae.* Other vertebrate species included birds, skinks and what is presumed to be scavenged carrion of *Macropus robustus* and *M. rufus*. Invertebrates consumed included beetles, grasshoppers and ants. Northern quoll grooming hairs were present in two of eight scats but were not included in the table as they made up negligible volume.

Figure 9. Northern quoll track observed in dried mud at the entrance to a culvert at southern side of the rail bridge at Chainage 226, taken on 28 July 2016 (image provided by Roy Hill)

Table 4. Frequency of occurrence (%FO) and percentage volume (%VO) of food items contained in eight scats of Pilbara northern quolls *Dasyurus hallucatus.*

Date	Site	Lat	Lon	*Zyzomys argurus*	*Pseudomys hermannsbergensis*	*Mus musculus*	*Dasykaluta rosamondae*	*Macropus robustus*	*Macropus rufus*	Bird	Skink	Beetle	Grasshopper	Ant
24/08/16	Mesa 228	-22.1162	118.2454	40					50			10		
25/08/16	Quoll knoll	-22.1005	119.2456			95						5		
25/08/16	Quoll knoll	-22.1005	119.2456	80						9	9		1	1
25/08/16	Quoll knoll	-22.1005	119.2456	50			5					20		25
25/08/16	Quoll knoll	-22.1005	119.2456	1							70	9		20
24/08/16	Quoll knoll	-22.0980	119.2364						40		40	15		5
25/08/16	RH Rail	-22.1000	119.2456	70				25				4		1
28/08/16	Wall Creek	-22.0238	118.6287	20	4					75				1
	% Volume of Occurrence			**43.5**	**4**	**95**	**5**	**25**	**45**	**42**	**39.7**	**10.5**	**1**	**8.8**
	% Frequency of Occurrence			**75**	**12.5**	**12.5**	**12.5**	**12.5**	**25**	**25**	**37.5**	**75**	**12.5**	**75**

Table 5. Food items contained in two feral cat dietary samples collected at the Mesa 228/Quoll Knoll site. Feral cat gut contents came from a euthanized adult male feral cat that was trapped as part of the feral control program.

Sample	Date	Site	Lat	Lon	*Leggadina lakedownensis*	*Dasyurus hallucatus*	Bird	Grasshopper	Ant	Centipede
Gut contents	25/08/16	Quoll Knoll	-22.1000	119.2456	0	100	0	0	0	0
Scat	25/08/16	Roy Hill Rail	-22.1226	119.2622	60	0	20	9	1	10

4 Discussion

4.1 Mesa 228 / Quoll Knoll

Northern quolls have persisted in low numbers at Quoll Knoll since their discovery at this location during rail corridor surveys in 2014, following identification of potential habitat in 2011 (Phoenix Environmental Sciences, 2011). The lack of fresh scats, no captures at this location, and presence of quoll in the gut of a large male feral cat may indicate the local extinction of this population. The last live record of a northern quoll at Quoll Knoll were the trap capture of one adult female between rocky knolls 2 and 3 on 19 March 2016 (during a feral cat control trapping program), and a remote camera image on 8 July 2016. The feral cat with quoll hair in its gut contents was captured on 25 August 2016.

The average passage rate of food particles through a cat's digestive tract is 13-35 hours (Warner, 1981; Peachey *et al.*, 2000), indicating that the northern quoll was consumed very recently. It is possible that the northern quoll was killed a few days before the 25 August, and the cat had come back to feed on the carcass. There is a small possibility that the northern quoll had died incidentally and been opportunistically scavenged by the feral cat. However it was noted that the remains found in the cat stomach contents were not decayed material indicating that it was a recent quoll death, and predation is most likely.

There appears to be some degree of utilisation of Mesa 228 by northern quolls, based on one individual captured in this location in 2015, and scats collected in 2014 and 2015. Small areas of suitable habitat such as this and Quoll Knoll may provide important "stepping stones" of refugia in the landscape for animals traversing the landscape during dispersal or the mating season. This indicates the importance of maintaining these small areas of suitable habitat with minimal threats to prevent localised extinctions or further range contraction.

The resident population of northern quolls at the Quoll Knoll habitat was identified to be at risk due to its small size, isolation and nearby disturbances (Johnson and Anderson, 2014; Dunlop *et.al* 2015). Potential threats identified include; vehicle strike, loss of access to foraging habitat due to the linear obstruction of the rail cutting, and the potential for increased predation (particularly by feral cats) due to clearing and presence of the road, which provides a pathway for feral animal movement. Mitigation measures recommended in Johnson and Anderson (2014), and their current relevant implementations are shown in Table 9 for the construction and operational phases of the rail development. These mitigation measures, plus monitoring and review of the population, may assist in the conservation of this population in a highly disturbed zone.

4.2 Wall Creek

Wall Creek does not appear to support a viable population of quolls based on lack of images, scats and captures from surveys in the last two years. Despite apparently suitable complex rocky habitat, we speculate that presence of many feral cats and dingoes indicates that this location is not currently viable for persistence of quoll populations. Remote cameras

set in this location recorded at least three individual feral cats using this area, and five occasions of dingo activity over a six-week period.

Ongoing fauna monitoring by Ecoscape Environmental Consultants for the Fortescue Metals Group (2012-2015) indicated an increasing trend of quoll captures at the Solomon mine (Hamersley range) and along the Rail infrastructure (Chichester range), and a stable population trend at the North Star mine. Northern Quolls have been recorded via scat collection, motion camera and cage trapping at other nearby sites included Coonarrie Creek, Bea Bea Creek and Cockeraga creek, located at 36.5 km, 19 km and 12.4km from Wall Creek respectively. Continued monitoring program being undertaken by Ecoscape for Fortescue Metals Group at the nearby Cockeraga Creek, has recorded ongoing presence of Northern Quoll in this section of the Chichester Range, although with only a small population density in this area (D. Cancilla *pers com Sept 2016*).

Remote cameras set for a prolonged period at Wall Creek recorded 18 species inhabiting the gorge area, including seven mammals, at least 10 bird species and two reptiles. The most commonly recorded species were Rothschild's rock wallabies and torresian crows. Of particular importance were the eight occasions of feral cats and five of dingoes recorded on remote cameras. Other mammals recorded on remote cameras included a single photograph of a northern quoll, several rock rats, cattle, euros and Rothschild's rock wallabies.

Predation by feral cats is recognised to be a primary threatening process to northern quolls, along with poisoning by invasive cane toads and inappropriate fire regimes (Woinarski *et al.*, 2014). Feral cats have been identified to feed on 400 vertebrate species in Australia, including 28 species identified as threatened under IUCN listing (Doherty *et al.*, 2015). Feral cats have been linked to the extinction of 63 species worldwide (Doherty *et al.*, 2016). Recent examinations of the interaction between feral cats and northern quolls in the Pilbara demonstrate that feral cats most frequently used flat, open habitats, and that northern quolls avoided areas used by cats (Hernandez-Santin *et al.*, 2016). Feral cats have been observed to predate upon Pilbara northern quolls, with six of 41 collared northern quolls being killed by cats in a six-month period (Morris *et al.*, 2015). It is likely that introduced predators such as feral cats prevent northern quolls from the successful use of some areas of the landscape, at a local and large scale. Predator avoidance has been suggested to explain the contraction of the distribution of northern quolls to rocky areas across northern Australia.

Suitable 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 moving following recruitment. Pilbara populations of northern quolls have pouch young present from Aug – Oct (variable according to rainfall), den young between November and February, and young emerge and disperse Feb-April (Table 6). Predation upon juveniles has the most impact on northern quoll populations, and their naivety probably makes them more vulnerable to predation. Therefore, targeted cat control should occur at times of northern quoll denning, mating and dispersal.

Table 6. Recorded times of breeding activity for female Pilbara northern quolls from the Pilbara (green), and the Northern Territory (orange). Northern Territory data sourced from Begg (1981; 1997).

	Apr	May	Jun	Jul	Aug	Sep	Oct
No development							
Pouch developed							
Pouch young present							
Teats regressed							
No development							
Pouch developed							
Pouch young present							
Teats regressed							

Dietary analysis of the eight northern quoll scats collected in this study revealed them to be opportunistic predators feeding on a variety of mammal, bird, reptile and invertebrate species. Items found to be consumed by northern quolls in this study align with previous findings, in which their diet is opportunistic and omnivorous. Unlike previous northern quoll dietary studies (Oakwood, 1997; Pollock, 1999; Radford, 2012), none of the eight samples collected here contained vegetative material, however this may be attributable to seasonality or small sample size. Vegetation is presumed to be a less preferred food item due to lower energy reward, and is likely to be opportunistic according to seasonal fruiting and flowering (Oakwood, 1997). Northern quolls have a broad dietary niche, with an opportunistic and omnivorous feeding habit including many small vertebrates and invertebrate prey items, as well as carrion (Dunlop *et al.*, Accepted).

5 Recommendations

Following the predation event at Quoll Knoll as evidence from the feral cat stomach contents, Parks and Wildlife recommend the following actions:

- Place lured cameras at locations where evidence of northern quolls were found (Rail culvert, West Shaw River Rail bridge rock armour, Quoll Knoll complex) to determine if any northern quolls are still present.
- Continue permanent passive remote camera work at Quoll Knoll complex and collect images every three months. Review images for northern quoll records and cat records.
- Continue feral cat control via cat trapping at Quoll Knoll and rail corridor area in order to make this habitat available for individuals to recolonise. Cat control should be undertaken in February-March, June-July and September-October in order to target times of quoll dispersal, lowest prey availability and denning of young (respectively).
- Investigate potential for other cat control options, such as the Felixer feral cat grooming trap
- Monitoring of quolls at Quoll Knoll to be undertaken by quoll trapping at the same time as mid-year cat trapping. Any quolls trapped to be microchipped and photographed for individual identification.

Major headway has been achieved for several aspects of the Parks and Wildlife regional program, including better description of the distribution, population genetics, regional diet variation and collection of morphological/life history data in the last three years (Dunlop *et al.*, 2016). Future priorities that have been recognised include a better understanding of introduced predator interactions with northern quolls, fine-scale habitat use, and large-scale population dynamics and structure (Department of Parks and Wildlife, 2016). For future monitoring of Chichester Range sites as per the NQRP and the Pilbara regional research program, Parks and Wildlife recommend:

- Modify the monitoring program to use remote cameras for monitoring quoll and introduced predator densities at Wall Creek and Mesa 228/ Quoll Knoll for a 4-6 week period (cameras at 100m intervals). No trapping to be undertaken at these locations in 2017.
- Roy Hill support the trapping of the other two Chichester trapping sites currently incorporated in the Parks & Wildlife regional monitoring program (Euro springs on Mt Florance Station and Python Pool, within the Millstream-Chichester National Park) rather than continued trapping at Wall Creek and Mesa 228/Quoll Knoll.

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7 Appendices

Table 7. Locations and dates of all remote cameras set for northern quoll and feral species detections.

Location	Camera	Lat	Lon	Start date	End date	Set days
Wall Creek	WC43	-22.0174	118.6317	15/07/16	29/08/16	46
Wall Creek	WC44	-22.0181	118.6314	15/07/16	29/08/16	46
Wall Creek	WC45	-22.0191	118.6313	15/07/16	29/08/16	46
Wall Creek	WC46	-22.0200	118.6308	15/07/16	29/08/16	46
Wall Creek	WC47	-22.0205	118.6299	15/07/16	29/08/16	46
Wall Creek	WC48	-22.0207	118.6290	15/07/16	29/08/16	46
Wall Creek	WC49	-22.0218	118.6288	15/07/16	29/08/16	46
Wall Creek	WC50	-22.0227	118.6291	15/07/16	29/08/16	46
Wall Creek	WC51	-22.0237	118.6291	15/07/16	29/08/16	46
Wall Creek	WC52	-22.0246	118.6284	15/07/16	29/08/16	46
Wall Creek	WC53	-22.0254	118.6291	15/07/16	29/08/16	46
Wall Creek	WC54	-22.0260	118.6301	15/07/16	29/08/16	46
Wall Creek	WC55	-22.0270	118.6300	15/07/16	29/08/16	46
Wall Creek	WC56	-22.0276	118.6292	15/07/16	29/08/16	46
Wall Creek	WC57	-22.0275	118.6280	15/07/16	29/08/16	46
Wall Creek	WC58	-22.0278	118.6272	15/07/16	29/08/16	46
Wall Creek	WC59	-22.0289	118.6267	15/07/16	29/08/16	46
Wall Creek	WC60	-22.0298	118.6267	15/07/16	29/08/16	46
Coonarrie Creek	CC10	-21.9433	118.9674	24/08/16	27/08/16	4
Coonarrie Creek	CC21	-21.9432	118.9688	24/08/16	27/08/16	4
Coonarrie Creek	CC24	-21.9425	118.9695	24/08/16	27/08/16	4
Coonarrie Creek	CC25	-21.9427	118.9688	24/08/16	27/08/16	4
Coonarrie Creek	CC26	-21.9425	118.9698	24/08/16	27/08/16	4
Coonarrie Creek	CC27	-21.9421	118.9671	24/08/16	27/08/16	4
Coonarrie Creek	CC29	-21.9431	118.9667	24/08/16	27/08/16	4
Coonarrie Creek	CC30	-21.9427	118.9660	24/08/16	27/08/16	4
Coonarrie Creek	CC35	-21.9427	118.9663	24/08/16	27/08/16	4
Mesa 228	ME03	-22.1112	119.2482	24/08/16	27/08/16	4
Mesa 228	ME09	-22.1124	119.2464	24/08/16	27/08/16	4
Mesa 228	ME15	-22.1147	119.2456	24/08/16	27/08/16	4
Mesa 228	ME19	-22.1159	119.2450	24/08/16	27/08/16	4
West Shaw Bridge	WSR1	-22.1000	119.2456	26/08/16	27/08/16	1
West Shaw Bridge	WSR2	-22.1000	119.2456	26/08/16	27/08/16	1

Table 8. Locations of individual trap sites in this targeted northern quoll trapping survey at Wall creek and Mesa 228/Quoll Knoll. WC: Wall Creek, RH: Mesa 228, QK: Quoll Knoll. Locations are given in decimal degrees.

Name	Latitude	Longitude	Elevation (m)	Start Date	End Date
WC01E	-22.03192201	118.625877		28/08/16	1/09/16
WC02E	-22.03171497	118.626262	450.847656	28/08/16	1/09/16
WC03E	-22.03143996	118.626473	448.290833	28/08/16	1/09/16
WC04E	-22.03113503	118.626803	449.245728	28/08/16	1/09/16
WC05E	-22.03093403	118.627065	450.712494	28/08/16	1/09/16
WC06E	-22.03057604	118.627052	448.402466	28/08/16	1/09/16
WC07E	-22.03014596	118.627084	447.34549	28/08/16	1/09/16
WC08E	-22.02966702	118.6271	448.685547	28/08/16	1/09/16
WC09E	-22.02933602	118.627055	445.801178	28/08/16	1/09/16
WC10E	-22.02894903	118.627041	447.112976	28/08/16	1/09/16
WC11E	-22.02867896	118.627105	444.851379	28/08/16	1/09/16
WC12E	-22.02841301	118.627466	447.140411	28/08/16	1/09/16
WC13E	-22.02812098	118.627998	446.611176	28/08/16	1/09/16
WC14E	-22.027909	118.628243	443.642822	28/08/16	1/09/16
WC15E	-22.02783499	118.628545	440.84671	28/08/16	1/09/16
WC16E	-22.02774396	118.62903	440.763397	28/08/16	1/09/16
WC17E	-22.02757197	118.629529	441.861084	28/08/16	1/09/16
WC18E	-22.02722797	118.629915	437.464386	28/08/16	1/09/16
WC19E	-22.02704298	118.630252	447.582306	28/08/16	1/09/16
WC20E	-22.026802	118.630568	447.087921	28/08/16	1/09/16
WC21E	-22.02649799	118.630484	438.890656	28/08/16	1/09/16
WC22E	-22.02613799	118.630351	434.902252	28/08/16	1/09/16
WC23E	-22.02572904	118.63008	439.316864	28/08/16	1/09/16
WC24E	-22.02549803	118.629794	440.610168	28/08/16	1/09/16
WC25E	-22.02386297	118.629026	429.897828	28/08/16	1/09/16
WC01W	-22.03143904	118.626152		28/08/16	1/09/16
WC02W	-22.03102799	118.626487	451.296387	28/08/16	1/09/16
WC03W	-22.030569	118.626719	452.021301	28/08/16	1/09/16
WC04W	-22.03030799	118.626876	449.993896	28/08/16	1/09/16
WC05W	-22.02988797	118.626877	450.271027	28/08/16	1/09/16
WC06W	-22.02948899	118.626587	453.316986	28/08/16	1/09/16
WC07W	-22.02913301	118.626774	449.724731	28/08/16	1/09/16
WC08W	-22.02876002	118.626753	449.084808	28/08/16	1/09/16
WC09W	-22.02837797	118.626836	449.409943	28/08/16	1/09/16
WC10W	-22.027995	118.627057	450	28/08/16	1/09/16
WC11W	-22.02763801	118.627366	448.317657	28/08/16	1/09/16
WC12W	-22.02749996	118.628004	448.150543	28/08/16	1/09/16
WC13W	-22.02746602	118.628502	448.912415	28/08/16	1/09/16
WC14W	-22.02733099	118.629168	444.144287	28/08/16	1/09/16
WC15W	-22.02712001	118.629645	442.050659	28/08/16	1/09/16
WC16W	-22.02692203	118.629942	441.924774	28/08/16	1/09/16
WC17W	-22.02647603	118.630205	440.667725	28/08/16	1/09/16
WC18W	-22.02587597	118.629861	441.016602	28/08/16	1/09/16
WC19W	-22.02531698	118.628969	439.738281	28/08/16	1/09/16
WC20W	-22.02505999	118.628643	439.524597	28/08/16	1/09/16
WC21W	-22.02466898	118.628439	439.642761	28/08/16	1/09/16
WC22W	-22.02420202	118.628545	438.978882	28/08/16	1/09/16
WC23W	-22.02381302	118.628743	435.538605	28/08/16	1/09/16
WC24W	-22.02360498	118.628848	435.253998	28/08/16	1/09/16
WC25W	-22.02350901	118.628899	438.595612	28/08/16	1/09/16
RH01W	-22.11138899	119.249039	417.933044	23/08/16	27/08/16
RH02W	-22.11130198	119.248646	413.011536	23/08/16	27/08/16
RH03W	-22.11121397	119.248229	412.652954	23/08/16	27/08/16
RH04W	-22.111161	119.24793	414.718506	23/08/16	27/08/16
RH05W	-22.11109696	119.247467	411.926361	23/08/16	27/08/16

Name	Latitude	Longitude	Elevation (m)	Start Date	End Date
RH06W	-22.11135697	119.247098	410.479401	23/08/16	27/08/16
RH07W	-22.11168	119.24686	410.518799	23/08/16	27/08/16
RH08W	-22.11202802	119.246638	411.57901	23/08/16	27/08/16
RH09W	-22.11238702	119.246442	414.828217	23/08/16	27/08/16
RH10W	-22.11271198	119.246336	418.362732	23/08/16	27/08/16
RH11W	-22.11308003	119.246273	420.054626	23/08/16	27/08/16
RH12W	-22.11351103	119.246229	422.197296	23/08/16	27/08/16
RH13W	-22.11383902	119.246124	423.339783	23/08/16	27/08/16
RH14W	-22.11424897	119.245833	424.436462	23/08/16	27/08/16
RH15W	-22.11467201	119.245602	426.266022	23/08/16	27/08/16
RH16W	-22.114943	119.245512	426.420044	23/08/16	27/08/16
RH17W	-22.11523402	119.245347	427.143707	23/08/16	27/08/16
RH18W	-22.11565303	119.245138	427.46402	23/08/16	27/08/16
RH19W	-22.11594304	119.244976	427.447205	23/08/16	27/08/16
RH20W	-22.11626801	119.244858	428.20697	23/08/16	27/08/16
RH21W	-22.11669104	119.244783	429.332947	23/08/16	27/08/16
RH22W	-22.11707502	119.245017	430.133545	23/08/16	27/08/16
RH23W	-22.11724601	119.245142	431.118988	23/08/16	27/08/16
RH24W	-22.11748498	119.245433	431.993439	23/08/16	27/08/16
RH25W	-22.117648	119.245555	429.203979	23/08/16	27/08/16
RH01E	-22.11152301	119.248906	411.200958	23/08/16	27/08/16
RH02E	-22.11166701	119.248507	411.356964	23/08/16	27/08/16
RH03E	-22.11155604	119.248064	351.100861	23/08/16	27/08/16
RH04E	-22.11176399	119.247535	413.493011	23/08/16	27/08/16
RH05E	-22.11195996	119.247202	412.327362	23/08/16	27/08/16
RH06E	-22.112268	119.246799	412.938721	23/08/16	27/08/16
RH07E	-22.11261299	119.246705	410.349365	23/08/16	27/08/16
RH08E	-22.11310199	119.246545	408.095642	23/08/16	27/08/16
RH08E	-22.113548	119.246472	411.695496	23/08/16	27/08/16
RH09E	-22.11391797	119.246289	414.975311	23/08/16	27/08/16
RH10E	-22.11422701	119.246127	417.239258	23/08/16	27/08/16
RH11E	-22.11472599	119.24595	416.13031	23/08/16	27/08/16
RH12E	-22.11510904	119.245779	416.92334	23/08/16	27/08/16
RH13E	-22.11546703	119.245571	418.277435	23/08/16	27/08/16
RH14E	-22.11562302	119.245523	418.150574	23/08/16	27/08/16
RH15E	-22.11594002	119.245434	420.293976	23/08/16	27/08/16
RH16E	-22.11617304	119.24543	422.042664	23/08/16	27/08/16
RH17E	-22.11639801	119.245374	422.899811	23/08/16	27/08/16
RH18E	-22.11670001	119.245421	420.167816	23/08/16	27/08/16
RH19E	-22.11698298	119.245465	421.761902	23/08/16	27/08/16
RH20E	-22.11715599	119.245526	421.445312	23/08/16	27/08/16
RH21E	-22.11743401	119.245547	423.394806	23/08/16	27/08/16
RH22E	-22.11772604	119.245824	421.708252	23/08/16	27/08/16
RH23E	-22.11782201	119.245978	415.993713	23/08/16	27/08/16
RH24E	-22.117849	119.245783	423.421417	23/08/16	27/08/16
RH25E	-22.096607	119.237058	393.208862	23/08/16	27/08/16
QK01	-22.09670104	119.236924	384.955536	23/08/16	27/08/16
QK02	-22.09651203	119.237083	392.914093	23/08/16	27/08/16
QK03	-22.09643399	119.237094	395.814392	23/08/16	27/08/16
QK04	-22.09632704	119.236988	396.306549	23/08/16	27/08/16
QK05	-22.09646903	119.236799	393.62323	23/08/16	27/08/16
QK06	-22.096579	119.236813	395.815369	23/08/16	27/08/16
QK07	-22.09742096	119.236592	381.17337	23/08/16	27/08/16
QK08	-22.09763403	119.236463	385.381256	23/08/16	27/08/16
QK09	-22.09813602	119.236214	389.582275	23/08/16	27/08/16
QK10	-22.09841204	119.236292	388.0867	23/08/16	27/08/16

Table 9. Prior recommendations and their implementation to 2015, and current implemenetation to reduce impacts of Roy Hill rail construction, operation and associated activities on northern quolls in the area

CONSTRUCTION PHASE		
Mitigation	**Implementation to 2015**	**Current Implementation**
Apply strategic signage around the Quoll Knoll area including the light vehicle track warning drivers of quolls in the area	Signage erected at call-up points.	Permanent warning road signs installed at call-up points.
Educate workers (especially night shift) at camps to raise awareness of quolls and other fauna	Camp and Site notices regularly advise of fauna interaction, particularly with northern quolls. All Rail Camps closed end of 2015 and unoccupied during 2016. Rail Camp 4 to be removed by end March 2017.	All Rail Camps closed end of 2015 and unoccupied during 2016. Rail camp 4 to be removed by end of March 2017
Enforce a 40k/h speed limit on tracks in vicinity of quoll knoll	Permanent signs to be erected. Temporary signs installed. Permanent road signs installed.	Permanent road signs installed
Limit further vegetation clearance around quoll sites	Ground disturbance permit process in place to limit vegetation clearance and Environmental team approval requirements. Same status	Same status
Limit night works to reduce potential vehicle	No night works.	Same status

OPERATIONAL PHASE		
Mitigation	**Implementation to 2015**	**Current Implementation**
Rehabilitate the LV track and borrow pits when appropriate, and create artificial refuges using rock debris waste from construction phase	LV track will not be rehabilitated. Rehabilitation of borrow pits completed.	Same status
Monitor Quoll Knoll with remote cameras, supplemented with annual trapping, to ensure quolls are still utilising the area	Underway and ongoing.	Same status
Creation of artificial refuge from rail sleepers in areas designated by Roy Hill environmental team	TBA once operation begins.	Same status
Fauna road kill reporting procedures to be implemented	Ongoing. Part of fauna procedures.	Ongoing
Pest animal management procedures to align with Parks and Wildlife standard operating procedures for trapping	Ongoing.	Ongoing
Location and timing of strategic pest animal baiting and trapping should follow Parks and Wildlife recommendations. These may include: • **Any trapping in the vicinity of known quoll habitat should be undertaken simultaneously with annual Parks and Wildlife monitoring where possible;** • **The revision of annual pest-**	Underway.	Underway

management programs and target pest species should be considered following closure of the rail camps in the vicinity of the Quoll Knoll site.		
Review images from cameras permanently located on Quoll Knoll. If feral animals identified, implement control program shortly thereafter. Target feral animal control program in November and April.	Underway and ongoing.	Underway and ongoing

Table 10. Raw trapping data from 200 trap nights at Mesa 228 and Wall Creek, and 40 trap nights at Quoll Knoll in August and September 2016.

Date	Site	Trap number	Species	Sex	N/R/RT	Weight (g)	Age (A/S)	Head (mm)	Pes (mm)	Tissue
24-Aug-16	Mesa 228	8	*Zyzomys argurus*		N					
24-Aug-16	Mesa 228	25	*Zyzomys argurus*		N					
24-Aug-16	Mesa 228	37	*Zyzomys argurus*	F	N					
25-Aug-16	Mesa 228	25	*Zyzomys argurus*	M	N	40	A	37.1	18.3	Y
25-Aug-16	Quoll knoll	6	*Zyzomys argurus*	M	N	35	A	33.4	17.9	Y
25-Aug-16	Mesa 228	28	*Zyzomys argurus*	M	N	40	A	36.3	16.4	Y
25-Aug-16	Mesa 228	35	*Zyzomys argurus*	F	N	28	S	32.2	17.2	Y
25-Aug-16	Mesa 228	37	*Zyzomys argurus*	F	N	45	A	35	17.5	Y
26-Aug-16	Mesa 228	3	*Zyzomys argurus*	F	N	55	A	17.1	34.3	Y
26-Aug-16	Mesa 228	4	*Zyzomys argurus*		RT					
26-Aug-16	Mesa 228	8	*Zyzomys argurus*	M	N	40	A	35.2	17.7	Y
26-Aug-16	Mesa 228	25	*Zyzomys argurus*	M	N	45	A	35.9	18.3	Y
26-Aug-16	Mesa 228	28	*Zyzomys argurus*	M	N	40	A	37	17.7	Y
26-Aug-16	Mesa 228	31	*Zyzomys argurus*	F	N	45	A	36.8	18.1	Y
26-Aug-16	Mesa 228	34	*Zyzomys argurus*	F	N	30	A	33.9	17.3	Y
26-Aug-16	Mesa 228	36	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	27	*Zyzomys argurus*	M	N	20	S	30	15.6	Y
27-Aug-16	Mesa 228	28	*Zyzomys argurus*	F	N	50	A	36.5	18.4	Y
27-Aug-16	Mesa 228	37	*Zyzomys argurus*	F	RT	45	A	36.2	18.1	Y
27-Aug-16	Mesa 228	18	*Zyzomys argurus*	F	N	45	A	34	17.4	Y
27-Aug-16	Mesa 228	13	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	14	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	10	*Zyzomys argurus*	F	N	45	A	35.1	18	Y
27-Aug-16	Mesa 228	4	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	1	*Zyzomys argurus*	M	N	45	A	35.2	18.4	Y
30-Aug-16	Wall creek	22E	*Zyzomys argurus*	F	N	55	A	36.5	17.5	Y

Table 9. Prior recommendations and their implementation to 2015, and current implemenetation to reduce impacts of Roy Hill rail construction, operation and associated activities on northern quolls in the area

CONSTRUCTION PHASE		
Mitigation	**Implementation to 2015**	**Current Implementation**
Apply strategic signage around the Quoll Knoll area including the light vehicle track warning drivers of quolls in the area	Signage erected at call-up points.	Permanent warning road signs installed at call-up points.
Educate workers (especially night shift) at camps to raise awareness of quolls and other fauna	Camp and Site notices regularly advise of fauna interaction, particularly with northern quolls. All Rail Camps closed end of 2015 and unoccupied during 2016. Rail Camp 4 to be removed by end March 2017.	All Rail Camps closed end of 2015 and unoccupied during 2016. Rail camp 4 to be removed by end of March 2017
Enforce a 40k/h speed limit on tracks in vicinity of quoll knoll	Permanent signs to be erected. Temporary signs installed. Permanent road signs installed.	Permanent road signs installed
Limit further vegetation clearance around quoll sites	Ground disturbance permit process in place to limit vegetation clearance and Environmental team approval requirements. Same status	Same status
Limit night works to reduce potential vehicle	No night works.	Same status

OPERATIONAL PHASE		
Mitigation	**Implementation to 2015**	**Current Implementation**
Rehabilitate the LV track and borrow pits when appropriate, and create artificial refuges using rock debris waste from construction phase	LV track will not be rehabilitated. Rehabilitation of borrow pits completed.	Same status
Monitor Quoll Knoll with remote cameras, supplemented with annual trapping, to ensure quolls are still utilising the area	Underway and ongoing.	Same status
Creation of artificial refuge from rail sleepers in areas designated by Roy Hill environmental team	TBA once operation begins.	Same status
Fauna road kill reporting procedures to be implemented	Ongoing. Part of fauna procedures.	Ongoing
Pest animal management procedures to align with Parks and Wildlife standard operating procedures for trapping	Ongoing.	Ongoing
Location and timing of strategic pest animal baiting and trapping should follow Parks and Wildlife recommendations. These may include: • **Any trapping in the vicinity of known quoll habitat should be undertaken simultaneously with annual Parks and Wildlife monitoring where possible;** • **The revision of annual pest-**	Underway.	Underway

management programs and target pest species should be considered following closure of the rail camps in the vicinity of the Quoll Knoll site.		
Review images from cameras permanently located on Quoll Knoll. If feral animals identified, implement control program shortly thereafter. Target feral animal control program in November and April.	Underway and ongoing.	Underway and ongoing

Table 10. Raw trapping data from 200 trap nights at Mesa 228 and Wall Creek, and 40 trap nights at Quoll Knoll in August and September 2016.

Date	Site	Trap number	Species	Sex	N/R/RT	Weight (g)	Age (A/S)	Head (mm)	Pes (mm)	Tissue
24-Aug-16	Mesa 228	8	*Zyzomys argurus*		N					
24-Aug-16	Mesa 228	25	*Zyzomys argurus*		N					
24-Aug-16	Mesa 228	37	*Zyzomys argurus*	F	N					
25-Aug-16	Mesa 228	25	*Zyzomys argurus*	M	N	40	A	37.1	18.3	Y
25-Aug-16	Quoll knoll	6	*Zyzomys argurus*	M	N	35	A	33.4	17.9	Y
25-Aug-16	Mesa 228	28	*Zyzomys argurus*	M	N	40	A	36.3	16.4	Y
25-Aug-16	Mesa 228	35	*Zyzomys argurus*	F	N	28	S	32.2	17.2	Y
25-Aug-16	Mesa 228	37	*Zyzomys argurus*	F	N	45	A	35	17.5	Y
26-Aug-16	Mesa 228	3	*Zyzomys argurus*	F	N	55	A	17.1	34.3	Y
26-Aug-16	Mesa 228	4	*Zyzomys argurus*		RT					
26-Aug-16	Mesa 228	8	*Zyzomys argurus*	M	N	40	A	35.2	17.7	Y
26-Aug-16	Mesa 228	25	*Zyzomys argurus*	M	N	45	A	35.9	18.3	Y
26-Aug-16	Mesa 228	28	*Zyzomys argurus*	M	N	40	A	37	17.7	Y
26-Aug-16	Mesa 228	31	*Zyzomys argurus*	F	N	45	A	36.8	18.1	Y
26-Aug-16	Mesa 228	34	*Zyzomys argurus*	F	N	30	A	33.9	17.3	Y
26-Aug-16	Mesa 228	36	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	27	*Zyzomys argurus*	M	N	20	S	30	15.6	Y
27-Aug-16	Mesa 228	28	*Zyzomys argurus*	F	N	50	A	36.5	18.4	Y
27-Aug-16	Mesa 228	37	*Zyzomys argurus*	F	RT	45	A	36.2	18.1	Y
27-Aug-16	Mesa 228	18	*Zyzomys argurus*	F	N	45	A	34	17.4	Y
27-Aug-16	Mesa 228	13	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	14	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	10	*Zyzomys argurus*	F	N	45	A	35.1	18	Y
27-Aug-16	Mesa 228	4	*Zyzomys argurus*		RT					
27-Aug-16	Mesa 228	1	*Zyzomys argurus*	M	N	45	A	35.2	18.4	Y
30-Aug-16	Wall creek	22E	*Zyzomys argurus*	F	N	55	A	36.5	17.5	Y