The Effects of Mining Infrastructure on Northern quoll Movement and Habitat.

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EDITH COWAN UNIVERSITY

Use of Thesis

Abstract

The Northern quoll (*Dasyurus hallucatus*) provides an example of a nationally threatened and declining mammal species. Declines have been catastrophic, extensive and rapid due to predation on the introduced cane toad (*Rhinella marina*) by the Northern quoll. In recent decades declines have been linked to numerous threatening processes including; habitat removal, predation by feral and domestic animals, inappropriate fire regimes, and the degradation and fragmentation associated with pastoralism.

A new threat is emerging within the Pilbara from the impacts of mining activities which are contributing significantly to Northern quoll habitat loss. The region is undergoing an unprecedented rate of development in rail infrastructure corridors to transport minerals and connect mine sites to ports. Infrastructure corridors can create barriers to wildlife movement due to the presence of a hostile environment and the subsequent avoidance of these structures. This study will investigate interactions with mining infrastructure barriers by fitting custom made GPS pinpoint 50 collars (Sirtrack) to Northern quoll which will collect spatial locational data. This will be undertaken in the Pilbara Region, on land tenanted by Roy Hill Holdings Pty Ltd, 143km northwest of Newman.

This project has used GPS collars to collect nocturnal foraging data which, has not achieved by any other studies of this species. The aims of this study were to expand the limited ecological knowledge of the Northern quoll, the effects of mining infrastructure on quoll movements, the use of underpasses to move between areas of prime habitat, and to investigate the use of foraging habitat and den sites. This study has provided home range estimates using this new technology, a maximum distance moved during nocturnal foraging, good information on the relationship of geology to habitat preference and no evidence of Northern quoll crossing rail infrastructure.

Declaration

I certify that this proposal does not, to the best of my knowledge and belief:

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(ii) contain any material previously published or written by another person except where due reference is made in the text; or

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1 General Introduction

1.1 Mammal Decline

The human footprint on the earth is expanding with increasing population growth and the use and modification of the world's natural resources (Woinarski, Burbidge, & Harrison, 2015). A mammal extinction crisis is currently occurring and is being driven by this unsustainable use of resources (Ameca y Juárez, Mace, Cowlishaw, & Pettorelli, 2014). On a global scale mammals are exhibiting a high rate of biodiversity decline due to habitat destruction, human exploitation, and the effects of invasive species (Ameca y Juárez *et al.*, 2014; Loehle & Eschenbach, 2012). Additionally, the impacts of climate change are expected to further increase mammal extinction rates in the future (Ameca y Juárez *et al.*, 2014; Loehle & Eschenbach, 2012).

Over the last 500 years, extinctions within Australia have made up approximately one-third of all mammal extinctions worldwide (Woinarski *et al.*, 2011). Since 1788, 28 of Australia's endemic land mammals have gone extinct (Burbidge *et al.*, 2008; Woinarski *et al.*, 2015). This is a greater rate of decline than found on any other continent, and declines are set to continue (McKenzie *et al.*, 2007). Many species with formerly wide distributions have disappeared from mainland Australia since European settlement (Burbidge *et al.*, 2008; Woinarski, 2015). 10 species that once occurred on the mainland now persist only on islands and a further 43 terrestrial mammal species are currently threatened with extinction (McKenzie *et al.*, 2007).

The reason for mammal decline in Australia has been difficult to identify, and are highly contested, due to multiple contributing factors (Fisher *et al.*, 2014; McKenzie *et al.*, 2007). These include environmental changes; the introduction of feral species, grazing by feral herbivores, land clearing, altered fire regimes and exotic disease (Fisher et al., 2014; McKenzie *et al.*, 2007; Turpin & Bamford, 2014). Australian mammals also exhibit environmental and species attributes such; as requirements for shelter and foraging habitat, regional productivity, fecundity, diet, phylogeny and longevity which are believed to increase their susceptibility to extinction (McKenzie *et al.*, 2007). Body weight is often used as a surrogate to determine life history traits for Australian mammals (Burbidge *et al.*, 2008; McKenzie *et al.*, 2007). Most recent mammal reductions and extinctions fall within a mean adult body weight range and has been termed the ‘critical weight range’ for Australian mammal species (McKenzie *et al*., 2007).

Species within the critical weight range of 35 g to 5500 g are more likely to decline or become extinct, especially those that dwell or forage on the ground (Burbidge *et al*., 2008; McKenzie *et al*., 2007). There is a growing body of evidence which concludes that declines of these species is due to predation by the introduced red fox (*Vulpes vulpe*) and the feral cat (*Felis catus*) (Johnson & Isaac, 2009; Woinarski, 2015) Species within this weight range are a good meal size and therefore accessible to predation by cats and foxes (Woinarski, 2015).

Rodent and marsupial species have experienced the greatest declines, especially within arid and semi-arid regions (Fisher *et al*., 2014; McKenzie *et al*., 2007; Woinarski *et* al., 2015). These species are often cryptic, nocturnal, live in remote areas, and perform important ecological roles within their immediate environment (Woinarski *et al.*, 2015). In addition, extinctions are expected to be high in landscapes with low connectivity, fast declining or degraded natural vegetation cover, and with intensive land use in modified areas (Dennis, Dapporto, Dover, & Shreeve, 2013). Future extinctions within Australia are expected to greatly impact medium size species occurring in arid and semi-arid regions when not in association with refuge areas (Woinarski *et al*., 2011).

1.2 Fragmented Landscapes

The destruction and fragmentation of habitat is considered the most important cause of current mammal extinction crisis, worldwide (Fahrig, 1997). Fragmentation is literally the breaking apart of habitat (Fahrig, 1997) which is often subdivided by linear corridor clearings such as roads, power lines or railways (Rico, Kindlmann, & Frantisek, 2007). Creating linear clearings within the landscape causes habitat loss and increases habitat fragmentation (Rico *et al*., 2007; Taylor & Goldingay, 2010). It can also lead to reduced habitat quality, landscape connectivity, and can further encourage the spread of invasive species (Taylor & Goldingay, 2010). Linear clearings also form barriers within the landscape acting to reduce animal movements (Dennis *et al*., 2013).

Landscape barriers can effect populations by; dividing them into isolated sub-populations, restrict animal movements, create edge effects, subdividing habitat and restricting the movement of animals (McGregor, 2004; Rico *et al*., 2007). A decrease in the quality and size of habitat can cause populations to decline through impaired population dynamics (Rico *et al.*, 2007). This may include; reduced reproduction events, altered social structure and altered patterns of gene flow within the population resulting in genetic drift and inbreeding due to genetic isolation (Taylor & Goldingay, 2010). If populations become fully isolated the effects of random demographic and genetic changes combined with environmental variations, can be enough to drive local extinctions (Laurence, 2009). For sensitive species the presence of hostile terrain may be enough to impede dispersal and depress species richness (Laurence, 2009).

Barriers for wildlife are often created by avoidance of structures due to the presence of a hostile environment. This may include the road surface, individual vehicles, noise or fumes deterring them from the area (McGregor, 2004). Previous studies indicate that the width of the barrier, independent of the surface structure (sealed or dirt), and the intensity of the traffic within the area is important to the movements of small mammals (Rico *et al.*, 2007). Linear clearings, such as roads, may not create barriers for all species but can still contribute to the mortality of populations through possible vehicle collision (Rico *et al.*, 2007).

Landscape connectivity can be achieved using habitat corridors and underpasses (Dennis *et al.*, 2013). To apply efficient long term conservation measures the identification of habitat connectivity barriers and pathways to maintain genetic diversity and dispersal is required (Braaker *et al.*, 2014). Wildlife overpasses and underpasses are often incorporated into the construction of major highways in order to mitigate the effects of creating barriers within the landscape (Jones, 2014), especially when barriers are created between two areas containing required resources (McGregor, 2004). These may be beneficial as just a small number of migrants entering a population will be sufficient to prevent populations from undergoing genetic drift (Laurence, 2009). Conservation measures such as underpasses, are used to link isolated and vacant population units, to restore local extinctions, to reduce the probability of regional extinction and to facilitate range adjustments in line with climate change (Dennis *et al.*, 2013).

Factors that contribute to the decline of wildlife are unique from species to species and for individual populations (Cardoso *et al.*, 2009). The use of habitat by an individual is a behavioural choice made when selecting resources (Chetkiewicz, St. Clair, & M.S., 2006).

This alters the density and distribution of individuals across different habitats according to the spread of resources across the landscape (Chetkiewicz *et al*., 2006; Dennis *et al*., 2013). In order to protect and manage good quality habitat for conservation it is important to understand the broad and fine scale requirements of each species, especially within core areas of habitat (Haby, Conran, & Carthew, 2013). It will therefore be important for management actions to vary accordingly (Burbidge *et al*., 2008). Natural habitats are likely to come under further pressure in the coming decades and understanding the biology of species will be critical in conserving areas most sensitive for the preservation of each species (Cardoso *et al*., 2009)

1.3 GPS Monitoring and Spatial Analysis

Many studies of wild animals have previously used radio tracking data to identify habitat use of species (Johnson, 1980). Traditionally radiotelemetry has been used as a tool to determine wildlife movements through space and time by sampling an individual's trajectory at discrete intervals (Aebischer, P.A., & R.E., 1993). Radio tracking using Very High Frequency (VHF) technology requires the receiver to within range of the animal to triangulate a position (Calenge & Dufour, 2006). These methods rely on the researcher being in the field which can potentially effect an animal's behaviour (Calenge & Dufour, 2006). First developed to study the ecology of large mammals, biotelemetry technology is still evolving, with technology growing ever smaller (Calenge & Dufour, 2006). Smaller devices have been developed for use on ground dwelling animals weighing less than 70g, yet few studies have been published having employed these devices on terrestrial animals under 10g (Dennis *et al*., 2010).

The major advantage of using Global Positioning System (GPS) technology over traditional techniques, such as radio tracking, is the ability to collect a high number of remote locations automatically and more precisely than VHF methods (Matthews *et al*., 2013). New technology such as GPS telemetry allow for precise and accurate temporal and spatial locational data collection which is unbiased, frequent, and can be collected at night (Hebblewhite & Haydon, 2010). It has also made possible the ability to collect locational data automatically at regular, short intervals (Dray, Royer-Carenzi, & Calenge, 2010) and can be especially useful for highly cryptic species (Cagnacci, Boitani, Powell, & Boyce, 2010). The use of GSP technology means that data can be collected simultaneously from several animals at once, including nocturnal foraging data rather than day time denning (important for animals within inaccessible locations at night) and is less likely to interfere with the normal behaviour of the animal. GPS technology can also reduce the associated costs of obtaining manual locations, although, the additional cost of the unit can be substantial (Hebblewhite & Haydon, 2010).

The development of Geographical Information systems (GIS) has made the study of habitat selection much easier by incorporating GPS locations, taking into account the spatial dimension of data (Calenge & Dufour, 2006). This has resulted in the development of numerous methods across a range of possible analysis (Calenge & Dufour, 2006). Advanced modelling techniques and statistical tools allow ecologists to combine these records with precise land cover maps to identify the connectivity pathways of animals (Braaker *et al.*, 2014).

1.4 The Northern quoll

1.4.1 Ecology

The Northern quoll (*Dasyurus hallucatus*) is a medium sized carnivorous marsupial, the smallest of Australia's four *Dasyurid* species (Oakwood, 2000). These include the Spotted-tailed quoll (*D.maculatus*) the Eastern quoll (*D.viverrinus*) and the Western quoll (*D. geoffroii*) (Jones, 2014). It is a solitary, nocturnal species with a broad and flexible diet consisting primarily of invertebrates, small mammals, birds, vertebrates and fleshy fruits when seasonally abundant (Oakwood, 2000).

The range of the Northern quoll once extended across the north of Australia from near Brisbane in Queensland, to the Pilbara region of Western Australia, covering near 5000km (How, Spencer, & Schmitt, 2009). In recent years the Northern quoll has undergone a sharp reduction in the central and eastern parts of its former range and has now disappeared from most of Northern Queensland and the Northern Territory (How *et al.*, 2009). It now occurs in only six disjunct populations (Cardoso *et al.*, 2009) in the Pilbara and Kimberly regions of Western Australia, including island populations off the coast (Spencer, 2010), the top end of the Northern Territory and the north east of Queensland (Begg, 1981).

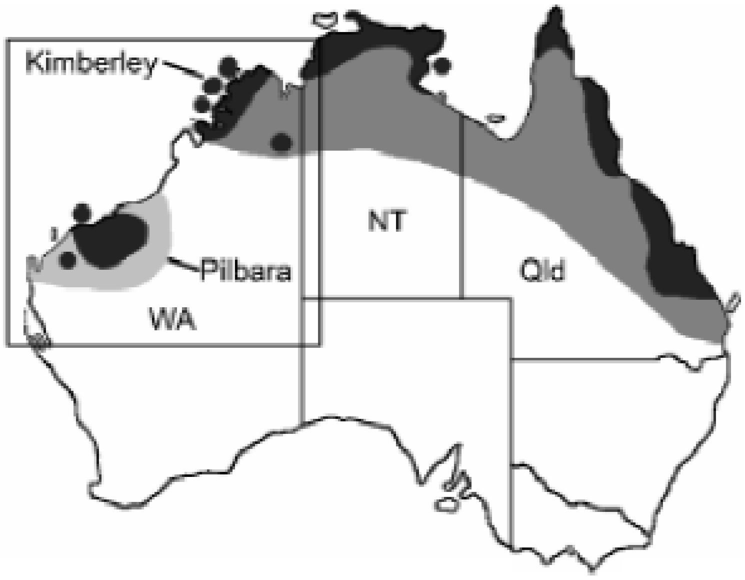


Figure 1. Range contraction of the Northern quoll (Dasyurus hallucatus) showing the current surviving populations (dark grey), historic (>30 years) (mid grey), and Late-Holocene sub-fossil (pale-grey) distributions (How et al., 2009)

In Western Australia the Northern quoll now occurs within two distinct regions, the Kimberly and the Pilbara, separated by the Great Sandy Desert (Spencer, 2010). The Northern quoll was previously common throughout the Pilbara region, well into the arid zone (Braithwaite & Griffiths, 1994). Records of the Northern quoll are common within 200km of the Pilbara coastline especially north of the Fortescue Marsh (Turpin & Bamford, 2014). Further inland populations are scattered around areas close to Newman, South of Nullagine and from the Little Sandy Desert (Turpin & Bamford, 2014). A recent range extension has been recorded from the Broadhurst and Throssell Ranges on the edge of the Little Sandy Desert in Western Australia (Turpin & Bamford, 2014).

Rocky areas have been identified as preferred habitat for the Northern quoll due to the limited impacts of threatening processes such as grazing (Burnett, 1997) and because fewer predators are found in these locations (Oakwood, 2000). Oakwood (2000) recorded higher mortality rates due to predation in areas of forest, woodland and riparian habitat. The greatest declines across the range of the Northern quoll occurred within savannah, the first to experience local extinctions (Oakwood, 2002). Within rocky habitat Northern quoll are more common (Begg, 1981), live longer, have smaller home ranges (Braithwaite & Griffiths, 1994), occur at a higher density (Bradley, Kemper, Kitchener, Humphreys, & How, 1987;

Oakwood, 2000) and are protected from predators. Rocky habitat also provides a greater number of denning sites, retain more water, provide greater refuge from fire, support greater food resources, productivity and floristic diversity and typically are not used for livestock grazing (Turpin & Bamford, 2014).

Northern quoll are sexually dimorphic with maturity occurring by 11 months of age (Oakwood, 2002). Breeding is synchronous and occurs just once each year (O'Donnell, Webb, & Shine, 2010). Occurring within a 2 week time period between May to June, it can be as short as a few days. However, the timing of mating within the Pilbara region is not well defined and may be influenced by minor inter-annual and geographic variation in addition to local cues (How *et al*., 2009; Oakwood, 2000).

Male Northern quoll weigh on average 760g (Oakwood, 2002). Males are thought to have larger body mass due to inter male competition for females, to maintain large home ranges and to reduce dietary competition between the sexes (Cooper & Withers, 2010). Males commit entirely to obtaining mates during the breeding season which may be detrimental to future mating attempts (Humphries & Stevens, 2001). High intensity fighting between males results in only the youngest and fittest surviving to mate (Humphries & Stevens, 2001). Complete post-mating die off (selemaparity) has been recorded at some sites such as Kapalga Research Station in Kakadu National Park, NT, but appears to be incomplete in the Pilbara (Dickman, 1992). In response to the physical effort of seeking mates males are known to experience weight loss, lice and tick infestations (Oakwood & Spratt, 2000) and a decline in haematocrit and plasma albumin (Rankmore, 2008). Post-mating, few males are observed due to die off events and dispersion from the population (Oakwood, 2000). Northern quoll are the largest animal to experience this suicidal reproduction (Fisher et al., 2014).

Female Northern quoll weigh on average 460g (Oakwood, 2002) and can breed in their first year (Begg, 1981). Females have a highly synchronised single oestrus in the winter (Humphries & Stephens 2001). On average females bear 7 young per litter, though few successfully carry the maximum number of young through to term (Begg, 1981). Young are carried in the pouch throughout August and into September for 60-70 days and suckling continues until December (Begg, 1981). Females rear young alone, carrying in the pouch throughout August and into September for 60-70 days (Begg, 1981). Suckling continues until December in a succession of nursery dens for a further 3 months (Oakwood, 2002). First year litters are generally larger and male sex-biased while second year and beyond litters tend towards producing females (Oakwood, 2000). Few females survive to produce a second or third litter as many to most females also die off after the breeding season. Few females in the wild have been known to survive for a maximum of three years (Oakwood, 2000).

1.4.2 Threats

Table 1. Relevant Authority and Listing identifying the legal status of the Northern quoll.

Authority	**State**	**Listing**
Australian Environment and Biodiversity Act (EPBC 1999)		Endangered
Territory Parks and Wildlife Conservation Act 2000	NT	Critically endangered
Western Australian Wildlife Conservation Act 1950	WA	Schedule 1 – 'Fauna that is rare or is likely to become extinct'
Nature Conservation (Wildlife) Regulation 2006	Qld	Least Concern
IUCN Red List		Endangered
Wildlife Conservation (Specially Protected Fauna) Notice 2012(2).		Specially Protected Fauna

The Northern quoll (*Dasyurus hallucatus*) provides an example of a nationally threatened and declining mammal species. Relevant listings for this endangered species are outlined in table 1. This species is susceptible to threats due to aspects of its biology and demography including short life span, assumed male semelparity, low density distributions and large home ranges (Cardoso *et al*., 2009). In recent decades declines have been linked to numerous threatening processes including habitat removal, predation by feral and domestic animals, inappropriate fire regimes, and the degradation and fragmentation associated with pastoralism (Cardoso *et al*., 2009; Hill & Ward, 2010; Pollock, 1999; Turpin & Bamford, 2014). Distribution and abundance is also temporally dependent upon feral predator abundance, grazing pressure, fire frequency and intensity, annual rainfall, and habitat complexity (Turpin & Bamford, 2014).

Declines across much of the Northern quolls range has been catastrophic, extensive and rapid due to predation on the introduced cane toad (*Rhinella marina*) (Woinarski *et al*., 2015). The cane toad has now reached the Kimberly in Western Australia and is expected to eventually colonize the Pilbara (Turpin & Bamford, 2014). Currently the Pilbara population is the last intact population of the Northern quoll in Australia having experienced no major decline in connection to the spread of the cane toad (Spencer, 2010). Remnant populations which have survived in the north of Australia are restricted to areas close to the coast and include high altitude and rocky habitat (Burnett, 1997). Populations within the Kimberly region have already suffered range contractions due to cane toad invasion, therefore, the Pilbara region has become the last stronghold for the Northern quoll (Spencer, 2013).

2 Project Significance

The Northern quoll (*Dasyurus hallucatus*) provides an example of a nationally threatened and declining mammal species. It is likely to be further impacted by the current increase in infrastructure barriers due to the proliferation of mining activity throughout much of its range. The Pilbara population of the Northern quoll is of high conservation value because it is the last intact population of the Northern quoll in Australia, is geographically isolated, has moderate levels of genetic diversity, and it is the only population currently not exposed to the impacts of the introduced cane toad (Cardoso *et al*., 2009; How *et al*., 2009; Spencer, 2010). The lack of systematic and large scale surveying across the north of Australia has made assessment of the decline of this species difficult to ascertain (Pollock, 1999).

A new threat is emerging within the Pilbara from the impacts of mining activities which are contributing significantly to Northern quoll habitat loss (McGrath, 2011). Important Northern quoll habitat in the Pilbara includes highly weathered outcrops of granite, basalt, lateritic and ironstone forming a number of geological features such as boulder piles, cliff lines, mesa edges and gorges particularly when these formations are in association with waterholes and drainage lines (Johnson & Anderson, 2014). The pastoral areas of the Pilbara are known to contain the greatest areas of this rock pile habitat outside of the Kimberly Region (Burbidge & McKenzie, 1989). Mineral exploration within the Pilbara region often results in the removal and degradation of this habitat (McGrath, 2011). The region is undergoing an unprecedented rate of development in infrastructure corridors, namely rail, to transport minerals and connect mine sites to ports (EPA, 2014). The Northern quoll is likely to be further impacted by the current increase in infrastructure barriers due to the proliferation of mining activity throughout much of its range (Cramer *et al*., 2015).

Environmental impact assessments for the Pilbara mining industry has led to an increase in information on the current distribution of the species. Unfortunately, records are often biased towards mining tenement areas (Cramer *et al*., 2015). A recent expert workshop identified the need to gain a greater understanding of the ecology of the Northern quoll within the Pilbara in order to make informed decisions and to determine likely significant impacts to the Northern quoll (McGrath, 2011).

2.1 Study Aims and Objectives

This study aims to expand the limited ecological knowledge on the Northern quoll, the effects of mining infrastructure on quoll movements, the use of underpasses to move between areas of prime habitat, and the use of foraging habitat and den sites. These aspects will be investigated to provide conservation measures to mitigate the impacts of infrastructure barriers on the Northern quoll within the Pilbara region. Within the scope of the study is the opportunity to identify important foraging habitat and to assess the importance of characteristic habitat features. The research questions this thesis aims to answer include;

1. What is the Northern quoll's average home range?

   Home range will be estimated from GPS data to produce an accurate nocturnal foraging home range and will be compared to estimates from the literature.

2. What are the important features of preferred nocturnal foraging habitat for the Northern quoll?

   Habitat preferences will be defined by presence data and analysed in Arc Map 10.2.2 to establish the importance of the variables vegetation, geology, elevation, distance from permanent water and distance from rail infrastructure. I hypothesise that the most important variable for nocturnal foraging will be defined by geology and rock structure.

3. To what degree does infrastructure inhibit or facilitate movement?

   I hypothesise that the Northern quoll will make use of rail underpasses, to cross infrastructure barriers, to access foraging habitat and to facilitate large scale movements within the landscape.

3 Site Description

3.1 Study sites

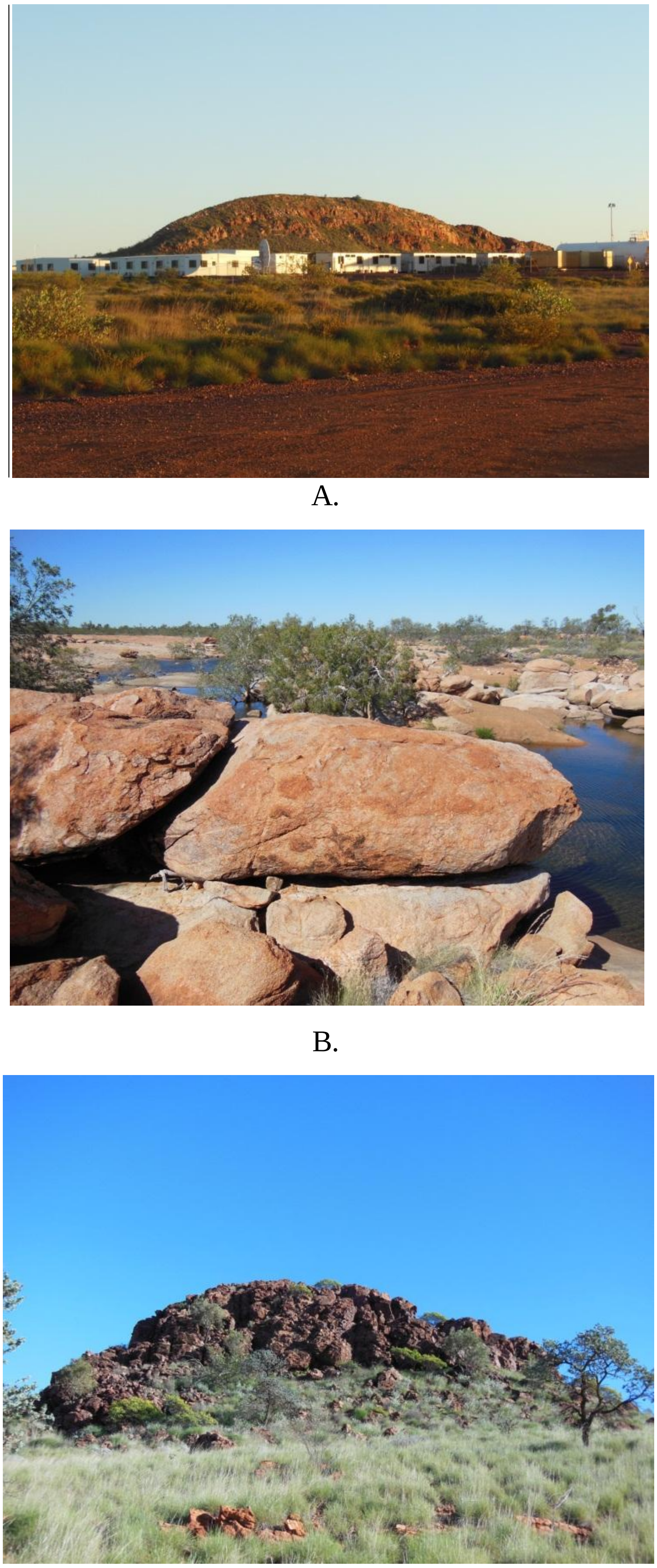
The Pilbara region has an arid to semi-arid climate (Leighton, 2004) with variable summer rains, averaging between 250-400mm per year (Maslin & van Leeuwen, 2008). Rainfall occurs during the summer months between December to March due to thunderstorm and cyclonic activity (McKenzie, van Leeuwen, & Pinder, 2009). Temperatures in the summer months exceed 40 degrees Celsius with milder winter maximums of 28 degrees (Maslin & van Leeuwen, 2008). The base elevation of the Pilbara is 700m above sea level with ranges and hills extending up to 1000 m in height (Baynes, Fookes, & Kennedy, 2005).

The vegetation of the region is comprised of extensive arid coastal plains, stony pavements and mountain ranges of spinifex grasslands and inland mountain ranges comprised of deep gorges and rough escarpments (Carwardine *et al*., 2014). Flora within the region is diverse with over 1000 native vascular species (Leighton, 2004). The predominant vegetation formations that occur include hummock grasslands of *Triodia sp.* with scattered snappy gums and wattle shrublands (Carwardine *et al*., 2014). The most common genera include *Acacia*, *Aristida*, *Ptilotus*, *Senna* and *Triodia* (Leighton, 2004). Many of these species are endemic to the region and specially adapted to its arid climate (Carwardine *et al*., 2014). The vegetation of the Pilbara region is varied and complex and is largely influenced by both geology and fire history (Maslin & van Leeuwen, 2008).

The Pilbara is a major mineral province which has been shaped over millions of years by weathering processes upon the structure of its underlying geology (Leighton, 2004). The northern region, the Pilbara block, is dominated by granite terrain, the south by rugged sediments of the Hamersley Basin and the east by sedimentary rocks overlain with eolian sands in the Canning Basin (Maslin & van Leeuwen, 2008). The Chichester subregion, within which the study sites fall, are characterised by undulating Achaean terrain of granite and greenstone forming tors, nubbins, domes, minor sandy plains, stony granitic plains with significant areas of rugged basaltic and sandstone, ranges ridges and plateau (McKenzie *et* al., 2009). Shallow stony red brown soil profiles are most extensive on hills and ranges with very stony surfaces on rock outcrops (McKenzie *et al*., 2009). These areas are dominated by acacia shrubland communities over hard hummock grasslands (McKenzie *et al*., 2009)

The study sites for this project are situated within or near to the Roy Hill Special Rail Lease (SRL). The area is made up of a rail corridor starting at the Roy Hill Mine, 110km North of the township of Newman, extending Northwest for over 330km to the Port Hedland in the Pilbara Region of Western Australia (Johnson & Anderson, 2014). Trapping sites were chosen based on previous quoll surveys, the presence of high quality rocky habitat and the locality to infrastructure barriers, road, rail and underpasses. Two sites were chosen as known locations for Northern quoll activity from the Department of Parks and Wildlife (DPaW) regional monitoring sites. Presence of Northern quoll activity at Rail Camp 1 was established through anecdotal evidence from employees of Roy Hill Holdings Pty Ltd whom reported sightings of Northern quoll in and around the camp villages.

Figure 2. Roy Hill Special Rail Lease (SRL), extending from Port Hedland to Roy Hill Mine, within the Pilbara Region displaying the location of trapping sites along the SRL. Site A Rail Camp 1, site B Indee Station and site C Quoll Knoll and Mesa 228.



A.

B.

C.

Figure 3. Trap locations A (Back Rock at Roy Hill Rail Camp 1) B (Indee Station on the Turner River) and C (Quoll Knoll on Roy Hill Special Rail Lease), where cage trapping to locate and collar Northern quoll was undertaken.

3.1.1 Site A. Rail Camp 1

Site A is situated approximately 57km from Port Hedland at section 57 of the Roy Hill Special Rail Lease (RSL). (Longitude 118.6467, Latitude -20.807) The Roy Hill campsite is approximately 1.8km from the rail line with a large quarts/granite escarpment to the southeast of the camp, 400m away. This outcrop is a 500m section of a long escarpment spanning approximately 5km. Cage trapping was undertaken within the camp at the mess hall and at locations in and around camp accommodations. This was focused on the northeast end of the rocky outcrop at the closest extent to the camp. The location of Northern quoll cage traps and remote cameras at this site are displayed in Figure 4 and 5.

The vegetation on rocky crests is predominantly hard *Triodia sp*. with small *Acacia* shrubs, and soft grasses. On slopes mid to low shrubs of *Acacia* sp. over hard *Triodia* are dominant with isolated *Ficus brachypoda*. Vegetation surrounding the rocky outcrop is predominantly flat floodplain dominated by *Triodia lanigera* and *T. wiseanna* with dense *Acacia* shrublands of *A. inequalilatera* and *A. bivenosa* in drainage lines. The vegetation at site A has been classified into six floristic classes which are described below in Table 2.

Table 2. Description of each floristic classification identified at site A, Rail Camp 1.

Category Type	**Description**	**Example Image**
Site A. Rail Camp 1		
Low shrubs and herbs	Rocky crests/slopes with clumped *Triodia epectia* and *T. lanigera* with scattered shrubs including *Acacia arida*, on rocky slopes.	

Category Type	**Description**	**Example Image**
Acacia shrubland	Open medium shrubland of mixed *Acacia sp.* including *A. inaequilatera* and *A. bivenosa* over low hummock grassland.	
Low dense shrubland	Dominated by *Acacia bivenosa* and *A. cyperophylla* with understory of *Triodia sp.* hummock grasses.	
Shrub steppe	Dominated by *Triodia epectia* and *T. lanigera* with scattered shrubs *Acacia ancistropcarpa, A. pyrifolia* and *A. bivenosa* on slopes. Isolated *Ficus Branchypoda* present.	
Open hummock grassland	Sparse open low grassland with few mixed *Acacia* shrubs *A. Arida*, *A. ancistropcarpa and A. bivenosa* over *Triodia epectia* and *T. lanigera*.	

Category Type	**Description**	**Example Image**
Closed hummock grassland	Closed dense hummock grassland dominated by *Triodia epectia* and *T. lanigera* on sand flood plains.	

3.1.2 Site B. Indee Station

Site B is located 3.7km south west of Rail Camp 1 (Longitude 118.5867, Latitude -20.8766) on Indee station 52km south of Port Hedland. This is a DPaW regional monitoring site and is situated at the base of Red Rock on the Turner River. The trapping site is made up of large rolling granite boulders with some areas of shale to the south. The location of Northern quoll cage trap transects at this site are displayed in Figure 4.

Vegetation is restricted to sandy edges of the riverbed and is dominated by *Acacia bivenosa* and *Acacia cyperophylla* with hummock grasses. Sparse scattered trees of *Corymbia aspera* occur within *Acacia* dominated shrublands on drainage lines and hummock grasslands of *Triodia* sp. on floodplains. The vegetation at site B has been classified into five floristic classes which are described below in Table 3.

Table 3. Description of each floristic classification identified at site B, Indee Station.

Category Type	**Description**	**Example Image**
Site B. Indee Station		
Acacia shrubland (flood plains)	Dominated by *Acacia bivenosa* and *Acacia cyperophylla* with understory of *Triodia sp.* hummock grasses	

Category Type	**Description**	**Example Image**
Tree steppe	Low scattered eucalypt trees *Corymbia aspera* over mid sparse shrubland of low acacia shrubs *A. stellaticepts* and *A.bovenosa* with *Triodia lanigeria* and *wiseanna*	
Hummock grassland	Open hummock grassland with few to no trees or shrubs made up predominantly of *Triodia epactia* and *T. lanigera*	
Shrub Steppe	Low *Acacia* shrubs *A. stellaticepts* and *A.bovenosa* with *Triodia lanigeria* and *T. wiseanna*	
Open Rocky Grassland	Riverine rocky areas with large bare open rocky boulders, some *Cyperus vaginatus* at water edges and soft grasses.	

3.1.3 Site C. Rail Camp 4 (Quoll Knoll and Mesa 228)

Site C lies to the central and eastern extent of the Chichester Ranges on the SRL (Johnson & Anderson, 2014) section 255-288 (Longitude 119.2627, Latitude -22.1379) it is situated 5.7 km North of Rail Camp 4. Two trap sites were established in this area from recent surveying by DPaW as part of their regional monitoring project. Infrastructure corridors within the area include a light vehicle access track, a wide heavy vehicle road and a heavy rail line in construction, which comprises of a deep cutting line and steep embankment (Johnson & Anderson, 2014). Quoll Knoll is situated directly beside the Roy Hill rail line with a light vehicle access track between the upper and two lower sections. There are a number of underpasses constructed to aid water movement during the wet season beneath the rail line in the immediate vicinity of Quoll Knoll. The location of Northern quoll cage traps and remote cameras at these sites are displayed in Figures 4 and 5.

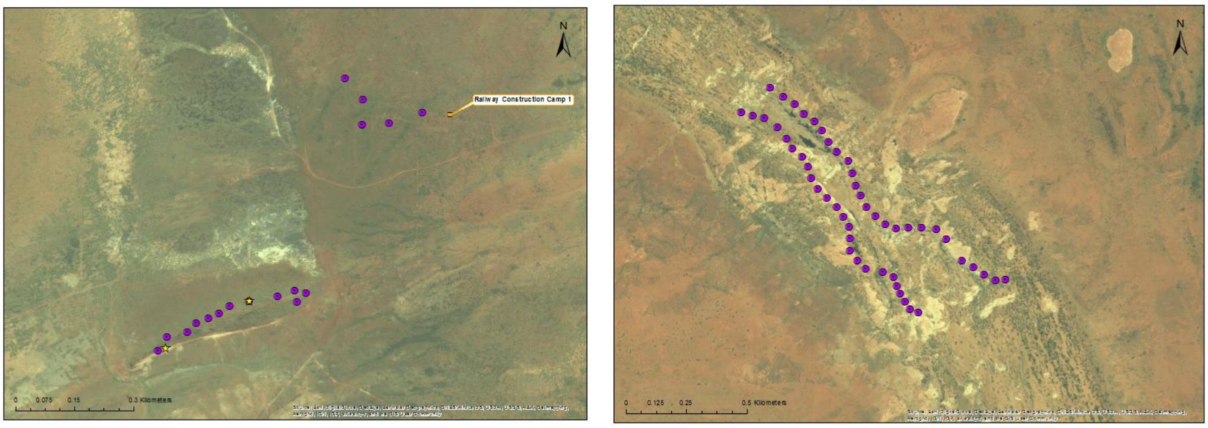
Quoll Knoll is a small basalt outcrop comprising of three sections and is surrounded by lower slopes and minor stony plains. Vegetation consists of shrubs of *Acacia* sp., mixed herbs and soft grasses on rocky extremities with grasslands dominated by *Triodia* sp. with scattered *Corymbia hammersleyana* and *Acacia inaequilatera* on slopes. The Gully at the base of Quoll Knoll is predominantly made up of *Aca*cia and *Grevillea sp.* shrub community over an open mixed tussock grass layer.

Mesa 228 is a long lateritic ridge mesa, approximately 1km long with numerous caves and crevices along the upper breakaway ridge (Dunlop, Cook, & Morris, 2014). Vegetation on the upper flats consists of shrubs and small trees dominated by *Acacia* sp., *Eremophila* sp. and *Eucalyptus brevifolia* over an open tussock grass layer. Slopes are comprised of *Triodia wiseana* and *T. basedowii* hummock grassland with irregularly scattered trees of *Eucalyptus brevifolia* and tall shrubs of *Acacia* and *Senna* sp. The vegetation at site A has been classified into six floristic classes which are described below in Table 4.

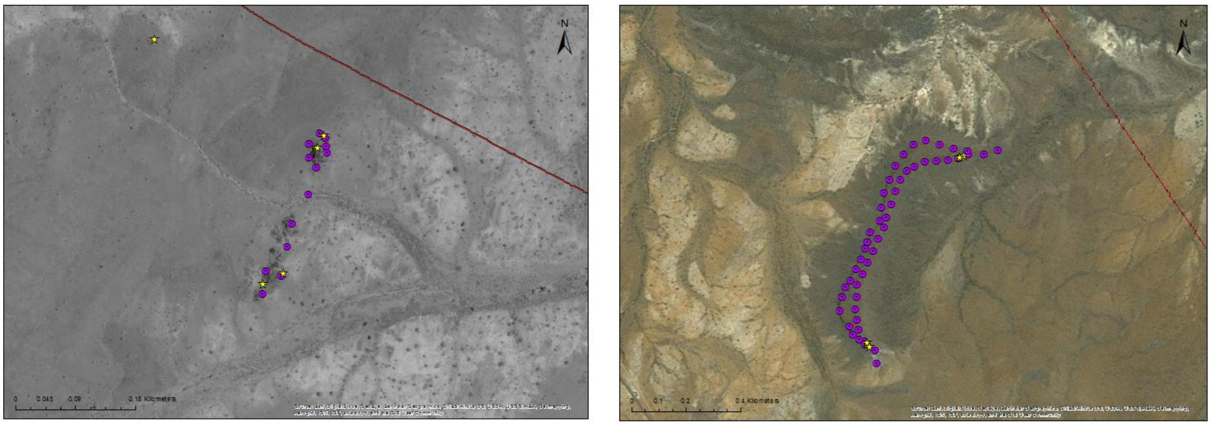
Table 4. Description of floristic classifications occurring at site C, Quoll Knoll and Mesa 228.

Category Type	**Description**	**Example Image**
Site C. Quoll Knoll and Mesa 228		
Low Shrubs and Herbs (rocky crests of small hills)	Restricted to rocky crests of hills with medium to low height shrubs, Acacia arida, A. inaequilatera herbs including *Gomphrena cunninghamii* and grasses *Paspalidium clementii, Cymbopogon ambiguous* and *Bulbostylis barbata.*	
Low sparse woodland	Comprised of *Triodia wiseana* and *T. basedowii* hummock grassland with irregularly scattered trees of *Eucalyptus brevifolia* and tall shrubs of *Acacia* and *Senna* sp.	
Acacia Shrubland (Riparian)	Closed medium *Acacia bivenosa* or *Grevillea wickhammii* shrub community with a low shrub layer of *Scaevola spinescens* and *Cassia* and *Senna* sp. over open mixed tussock grass layer.	

Category Type	**Description**	**Example Image**
Closed hummock grassland	Closed hummock grassland of *Triodia wiseana* and *T. basedowii*	
Open hummock grassland	Open hummock grassland with few to no trees made up predominantly of *Triodia* sp. with few scattered low shrubs of *Acacia*, *Senna*, *Ptilotus and Solanum* sp.	
Shrub Steppe (low hills and plains)	Sparse low woodlands of *Corymbia hammersleyana* and *Acacia inaequilatera* over open *Triodia* sp. Often just *Acacia inaequilatera* and *Triodia* sp. with some low shrubs.	



A. Back Rock at Rail Camp 1 B. Indee Station



C. Quoll Knoll Mesa 228

Figure 4. Location of cage trap transects identified by purple mark and camera traps marked with a yellow star at each study site.

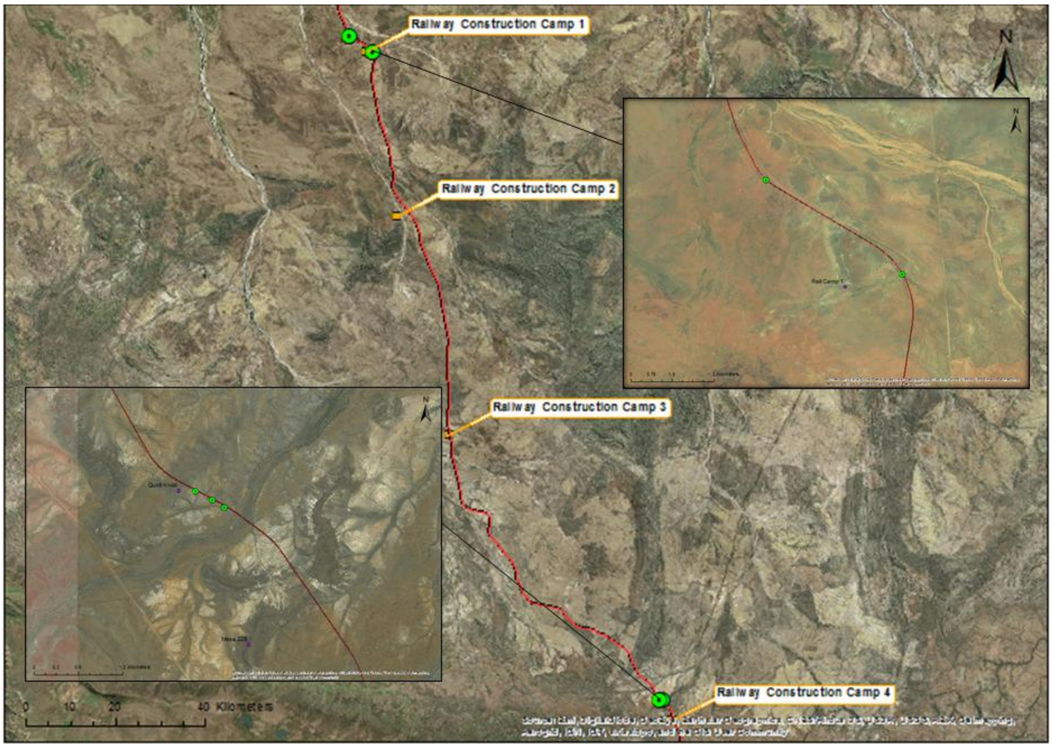


Figure 5. Position of Ecologia Environment infra-red cameras along the Roy Hill Holdings Pty Ltd ore rail line.

4 Methods

4.1 Cage Trapping

Cage trapping was undertaken at three sites to capture Northern quoll. The dates trapping was undertaken, the number of traps set and the total number of trap nights are outlined in table 5. Trapping procedures adhered to the *EPBC Act 1999 referral guidelines for the endangered Northern quoll, Dasyurus hallucatus*, and the *DEC Nature Conservation Service, Biodiversity Standard Operating Procedure, Cage traps for live capture of terrestrial vertebrates* (Freegard & Richter, 2011). Targeted trapping was undertaken with small Sheffeild wire cages (45 cm x 17 cm x 17 cm, Sheffield Wire co, Welshpool WA) using the methodology described by Dunlop *et al* (2014). The number of traps used was dependant on the trapping site. Traps were placed in transect style at least 50m apart and locations were marked with flagging tape, numbered and a GPS location recorded for each (Dunlop *et al*., 2014). Traps were baited with universal bait of peanut butter and oats with sardines and were rebaited every second day (Dunlop *et al*., 2014). Traps were opened at dusk and closed no less than three hours after sunrise (Freegard & Richter, 2011). A set of standard measurements was taken from each animal including weight, sex, pes (hind leg), head length, and reproductive condition (Dunlop *et al*., 2014). Each was implanted with a unique passive implanted transponder (PIT) and an ear tissue sample sent to the Western Australian Museum for inclusion in the Northern quoll population genetic study undertaken by Parks and Wildlife and Murdoch University (Johnson & Anderson, 2014). Quolls were released from the point of capture immediately after processing was completed.

Table 5. Dates cage trapping was undertaken, the number of traps used and the number of trap nights, at each study site.

Location	Date opened	Date closed	No Traps	No trap nights
Quoll Knoll	13/06/2015	24/06/2014	13	11
Quoll Knoll	29/06/2015	1/07/2015	6	2
Quoll Knoll	13/07/2015	16/07/2015	10	3
Mesa 228	13/06/2015	18/06/2015	12	5
Mesa 228	19/06/2015	23/06/2014	50	4
Mesa 228	13/07/2015	16/07/2015	6	3
RC1	2/07/2015	4/07/2015	18	2
RC1	15/07/2015	16/07/2015	18	1
Indee Station	1/07/2015	4/07/2015	50	4
Indee Station	16/07/2015	17/07/2015	16	1

4.2 GPS Collaring

A GPS collar trial for Northern quoll was undertaken by the DPaW at Native Animal Rescue during April 2015. The trial was required to establish if collars are detrimental to quoll movement or mortality, the accuracy of the locational data retrieved from the collars, and the battery life of the device.

In the field 10 Northern quoll were fitted with a custom GPS pinpoint 50 collar VHF100-150mm (Sirtrack Ltd) weighing approximately 20g. Collars were fitted to Northern quoll at three locations on or near the Roy Hill Special Rail Lease. Collaring took place during June and July of 2015 (Table 3). The weight of the collar is critical for animal welfare and it is recommended that for mammals, the device weigh no more than five percent of the animal's body weight (Latham *et al*., 2015). Only individuals weighing over 380g and in good condition were fitted with a collar. Collars were set for two different regimes, a high fix rate of eight fixes per night for six nights, or at a low fix rate of four fixes per night for 11 nights. Collars were set to record data points between 18:00PM-06:00AM at four or two hour intervals to conserve battery life, dependant on fix rate. A maximum of 50 data points could be collected before collars were retrieved, downloaded and recharged. Homing, using a VHF receiver and antennae, was used to locate quolls within their burrows during the day. Once maximum data collection was reached individuals were target trapped using VHF signal to retrieve collars.

Table 6. Dates collars were attached and removed from Northern quoll for the duration of the study.

Collar Number	PIT tag ID	Name	Date collared	Date Removed
1	361953828	LV	3/07/2015	16/07/2015
2	362045294	Dozer	23/06/2015	n/a
3	700257	Chopper	1/07/2015	17/07/2015
4	163700079	Roller	15/06/2015	24/06/2015
4	163700079	Roller	24/06/2015	14/07/2015
5	361953781	Semi	3/07/2015	15/07/2015
6	955922	Furphy	1/07/2015	n/a
7	953468	Donga	2/07/2015	15/07/2015
8	44748	Crusher	1/07/2015	17/07/2015
9	3024287	Haul Pac	4/07/2015	18/07/2015
10	953384	Loco	1/07/2015	17/07/2015

4.3 Camera Trapping

Remote infra-red cameras were deployed at cage trapping sites to supplement cage trapping data and to assess presence and activity in the area (Dunlop *et al*., 2014). Cameras were randomly placed along each transect at locations where it was suitable to attach a camera and where likely activity may occur. Cameras were in place for the duration of cage trapping at all sites except for Indee Station (Table 7).

Table 7. Dates camera trapping was undertaken, the number of cameras used and the number of trap nights, at each study site.

Location	Date Set	Date Removed	No cameras	No trap nights
Quoll Knoll	14/06/2015	24/06/2015	4	10
Quoll Knoll	29/06/2015	14/07/2015	4	15
Quoll Knoll road culvert	1/07/2015	15/07/2015	1	14
Mesa 228	14/06/2015	24/06/2015	4	10
Back Rock at RC1	1/01/1900	16/07/2015	2	15

Ecologia Environment consultancies deployed nine remote infra-red cameras at underpasses within close proximity to two trapping sites, Quoll Knoll and RC1, to assess the use of underpasses by Northern quoll. The duration of the camera deployment, the model and settings of each camera are described in table 8. Cameras were used to record the movements of wildlife at the openings of rail underpasses. At each underpass two cameras were set up on the east and west side of the Roy Hill rail line. An additional camera was placed directly overlooking the rail line at Quoll Knoll. Cameras were placed to one side of an underpass at a 45 degree angle to the opening. Each was cable tied to a large rock or peg for stability at a height of approximately 0.5m off the ground.

Table 8. Camera models and settings used at each underpass monitored by Ecologia Environment.

Culvert Number	Date Set	Date Removed	Camera Model	No triggers	Interval	No trap nights
51600	30/05/2015	15/07/2015	PC900	10	1s	60
51600	9/05/2015	15/07/2015	PC900	3	10s	67
57372	10/05/2015	15/07/2015	HC500	3	10s	66
57372	9/05/2015	15/07/2015	Bushnell 119415	1	n/a	67
225689	9/05/2015	14/07/2015	HC500	3	10s	67
225689	9/05/2015	13/07/2015	PC900	3	10s	67
225887	7/05/2015	14/07/2015	HC500	3	10s	69
225887	7/05/2015	14/07/2015	HC500	3	10s	69
	8/05/2015	27/07/2015	HC500	3	10s	68

4.4 Vegetation and Habitat Assessment

Detailed maps of the Quoll Knoll site and the surrounding area, within a 5km radius, were created from aerial Landsat images supplied by Roy Hill Iron Ore. Vegetation classification was defined by similarities in floristic array and structure in a desktop survey and then further evaluated on ground in the field. Vegetation was stratified into the major units; woodland, shrubland, savannah, steppe and succulent steppe as pre-determined by Beard (1975) for the Pilbara region. Dominant or common species within each stratified floristic community were sampled to create a field herbarium. Specimens were given a field id number, collection number and life form type and pressed for species identification to species or sub-species level where possible (Clarke, 2009). These species were used to form the basis of the floristic classifications at each site.

A habitat survey was undertaken at each trap site where Northern quoll were captured and where daytime den locations were identified by VHF radio tracking. This survey also recorded; the dominant plant species, the presence or absence of litter, the percentage of bare ground, soil substrate classification, and an estimated percentage of ground cover within a 2m x 2m plot. Plots were selected based on presence of Northern quoll within cage traps or when radio tracked to den sites. Soil substrates were defined by size class into the following categories; fine alluvial soil, fine rocks (<5mm), small rocks (5-10mm), medium rocks (10-20mm), large rocks (20-50mm) and extra-large rocks (>50mm) (Osman, 2012). The presence of denning habitat, such as rocky crevices, was noted and photos were taken to record similarities in structure.

4.5 Data Analysis

4.5.1 Home Range

Traditional methods for home range analysis such as Kernel home range are based on VHF technology (Walter, Fischer, Baruch-Mordo, & VerCauteren, 2011). Early attempts to calculate an animal's home range have evolved from the Minimum Convex Polygon (MCP) technique (Kie et al., 2010). Kernel Density Estimate (KDE) analysis has become one of the most accepted methods to use with GPS technology (Calenge & Dufour, 2006; Kie *et al.*, 2010; Walter *et* al., 2011). However, it has been criticised due to errors in bandwidth selection and violation of independence assumptions, especially when used with large datasets (Walter *et al.*, 2011). The MCP 95% method is commonly used as it allows comparison of data between studies (Taylor 2007). However, the KDE analysis is used to investigate the intensity of use within the home range area, an estimate which the MCP cannot make (Taylor 2007). KDE can be described as a frequency of animal locational distribution over a multi-dimensional area (Kie *et al*., 2010). This shows the intensity of an animal's use of an area within their home range (Kie *et al*., 2010). Five percent of the most extreme locations can be removed from the data set to produce the 95% MCP and KDE. This is said to account for any unusual large scale movements outside of an individual's normal activities (Calenge & Dufour, 2006).

Nocturnal GPS coordinate data collected from GPS collars, trap capture points and day time den points were collated and imported into ArcMap 10.2.2. Locational data was entered for individual animals and the Tracking Analysis tool used to track quoll movements over time using Track Intervals to Line (Lo, 2007). Home range estimate was achieved using the Minimum Bounding Geometry tool within the Data Management toolbox in Arc GIS (ESRI, n.d.). The convex null geometry type was selected to set a minimum home range polygon for each individual. Calculate geometry was used to calculate the area KDE analysis was performed on each individual using the Kernel Density tool within the Spatial Analyst Toolset with resolution set to 1m (ESRI, n.d.).

R package adehabitatHR was used to calculate the area within for both MCP home range and KDE to the 95% (Calenge 2006). The smoothing parameter (h) was set to 1 and computed by Least Squared Cross Validation (Calenge 2006). This calculation was compared to MCP results calculated in ArcMap with the same results achieved at the 100%.

4.5.2 Habitat Selection

Mapping to determine habitat selection was undertaken in ArcMap 10.2.2. Map layers digital elevation model (DEM), Normalized Difference Vegetation Index (NDVI), and water courses were downloaded from Geosciences Australia. Landscape variable layer geology was received from Roy Hill Holdings Pty Ltd. Vegetation mapping using the DEM and NDVI layers was undertaken using isoclustering to perform an unsupervised classification.

The unsupervised isocluster classification was performed on each trapping area independently using Landsat8 imagery and DEM layer to produce nine floristic classes overall. The display was clipped so that analysis was only performed on a small area to reduce the amount of time required for processing and due to differences in vegetation classifications between sites (ESRI, 2013). Isoclusters were smoothed using the bilinear interpolation parameter and then converted to polygons (ESRI, n.d.). Hill shade and 5m contours were added to aid in the editing of polygons to match in field stratification of floristic array (ESRI, n.d.). Output Isoclusters were assigned to a floristic class from landscape knowledge and observations. Polygons were edited where necessary so that classifications closely matched the landscape. Areas which overlapped with home range polygons were the focus of editing.

The clip tool within the analysis toolset was used to calculate the area of each floristic and geological class used by each animal as defined by both the MCP 95% and KDE 95% (ESRI, 2013). Once defined, data was transported to excel for further analysis. Simple calculations were performed to determine the percentage of use by individuals within each floristic class and geological series. A 10km² area surrounding each study site was selected within GIS and the total floristic and geologic classifications within that area was calculated. The percentage of uses within the total area was calculated for each individual to determine use versus availability of these variables for the Northern quoll.

A distance from rail and distance to water was measured using the Euclidean Distance tool within the Spatial Analyst toolset (ESRI, 2012). The pixel tool was used to define the elevation, distance to rail line and distance to closest drainage point in the landscape for each coordinate (ESRI, 2012). An average of each of these variables was determined for each animal. Raw data was investigated and descriptive statistics produced in SPSS.

4.5.3 Infrastructure Barriers

Infra red camera images were sorted by removing false triggers including set up images, workmen and machinery, which were common due to rail construction. From each camera the total number of images, each species present and the total number of images for each species was recorded.

A detection rate for the Northern quoll was calculated by dividing the total number of images of Northern quoll by the total number of images recorded. The Relative abundance index (RAI) was calculated by defining the proportional abundance of Northern quoll at Quoll Knoll (O'Connell, Nichols, & Karanth, 2011). This was achieved by relating animal abundance to photo detection rates (Jenks *et al*., 2011). The RAI was calculated as the sum of all individuals detected, for all camera traps, over all nights, multiplied by 100 and divided by the total number of camera trap nights (Jenks *et al*., 2011).

Camera trap data to assess underpass use by Northern quoll was supplied by Roy Hill Holdings Pty Ltd and collected by Ecologia Environmental. This data was analysed in the same manner.

5 Results

At site A a total of three individuals were captured and collared between the 1- 4 July 2015. This was assumed to be the extent of the population at this location because no further individuals were captured at this site for the duration of the trapping period. The male (Donga) utilised areas within the mining camp which was not observed from either of the females (LV and Semi). All collars were retrieved at this site, two from deceased individuals.

At site B the population of Northern quoll is large with up to 20 individuals captured in one trap night (total of 50 traps) during annual monitoring in 2015. A total of five individuals were collared at this site; two females and three males. One female was radio located numerous times between the 1 -16 July 2015. There was no evidence of this female within the trapping area at the time of collar retrieval. Collars retrieved from three male quolls, Haul Pac, Chopper and Crusher, recorded data at this location.

A total of four individuals were captured across site C, a male on mesa 228 and two females and a male at Quoll Knoll. There was evidence of free roaming males entering and leaving the population with two resident females making up the base population. One male and one female were collared here. The female (Roller) remained in the local area of Quoll Knoll for the duration of the field work. The male (Dozer) was tracked for one night but left the local area the following day. No further trace of this male was detected.

Collars had the potential to record 50 GPS coordinates per deployment. Satellite fix attempts were not always achieved by the device resulting in null data collection for that attempt. On average 42 out of possible 50 satellite fix attempts were achieved in the field. The satellite fix rate achieved from all collars resulted in a 29% success rate. The mean number of fixes recorded from all collars was 12.6 ± 8.2. Collar fix rate at site C was well below the average at just 5.2% affecting the total overall average. These results are displayed below in table 9. Below average collar fix rates may be due to the thick ironstone rock and cave network at site C and the inability of the device to achieve satellite fixes through this substrate. Removing this site from the calculations, in-field collar performance increased to 37% for all other sites.

Table 9. Success rate of satellite fixes achieved from Northern quoll GPS collars in the field.

Collar ID	PIT Tag ID	Name	Potential Fixes	Fix Attempts	No Satellite Fixes	Success Rate (%)
1	361953828	LV	50	46	21	45.6
3	700257	Chopper	50	43	16	37.2
4	163700079	Roller	50	38	2	5.2
4	163700079	Roller	50	38	2	5.2
5	361953781	Semi	50	40	7	17.5
7	953468	Donga	50	41	9	21.9
8	44748	Crusher	50	47	25	53.2
9	3024287	Haul Pac	50	44	19	43.2
mean			**50**	**42.12**	**12.62**	**28.6**
SD			**0**	**3.21**	**8.26**	**17.4**

5.1 Home Range Analysis

Collars retrieved from seven Northern quoll produced 100 nocturnal GPS locations in total. In addition trap site locations and day time den habitat points were included to produce 131 locations overall. The number of locations varied between each individual based on the number of fixes produced by each collar and the number of other locations recorded. The total number of locations recorded for individuals ranged from ten to 32 points (Table 10).

Table 10. Home range estimates from Northern quoll location data at three trap sites with 100% and 95% Minimum Convex Polygon calculated in R.

Animal	Sex	Location	Weight	No. of days Collared	No. of GPS location	No. of other location	Total locations	100% MPC Home Range (ha)	95% MCP Home Range (ha)
Semi	F	RC1	390g	11	7	3	10	6.767	**6.137**
LV	F	RC1	365g	11	21	3	24	37.227	**31.965**
Donga	M	RC1	530g	11	9	4	13	80.689	**65.237**
Haul Pac	M	Indee	860g	11	18	2	20	133.6	**127.49**
Chopper	M	Indee	540g	11	16	5	21	7.85	**5.320**
Crusher	M	Indee	540g	11	25	7	32	70.85	**34.07**
Roller	F	Quoll Knoll	380g	12	4	6	11	3.352	**2.192**

The MCP home range calculated from location data was achieved for seven individuals, three females and four males at different locations (Table 10). Mean male home range (MCP 95%) was 58.03 ± 5.65ha. For females the mean home range (MCP 95%) was much smaller, just 13.43 ± 2.74ha. The largest male recorded the greatest individual home range estimate of 127.5ha. The mean core home range size estimate (MCP 95%) differed between the sexes, females recording a much smaller home range (13.43 ± 2.74ha) when compared to males (58.03 ± 5.65ha) (Table 11). Two females recorded similar home range estimates though each was located at different sites. The smallest home range was recorded by a second year female, of good weight, who later died due to unknown causes.

Table 11. Results of the Minimum Convex Polygon home range estimates calculated at the 50%, 80% and 95% displayed in hectares.

	Minimum Convex Polygon		
	50%	**80%**	**95%**
Semi	0.98	4.52	6.13
LV	12.32	20.38	31.96
Donga	17.7	18.32	65.23
Haul Pac	16.7	73.82	127.49
Chopper	1.15	3.16	5.32
Crusher	6.53	15.53	34.07
Roller	0.98	1.75	2.19
Mean Male ± SD			**58.03 ± 5.65**
Mean Female ± SD			**13.43 ± 2.74**

Figure 5 represent the accuracy of the home range size versus level to the 100th percentile for each animal. The smooth linear increase in MCP level as home range size increases demonstrates a good representation of home range size from the data collected. Based on these graphs it is unnecessary to exclude any percentage of the calculated home range from home range estimates. The only individual to exhibit a small difference is Semi, with a levelling off at the home range level of 75. Therefore, home range for this individual may be better represented at the 75th percentile of 1.13ha. Home range has been calculated to the 100th percentile for ease of comparison with other studies. As a caution, generally home range should be reported at the 95% excluding 5% of all locations. These locations can be considered as explorations outside of normal activities and therefore not within core home range areas.

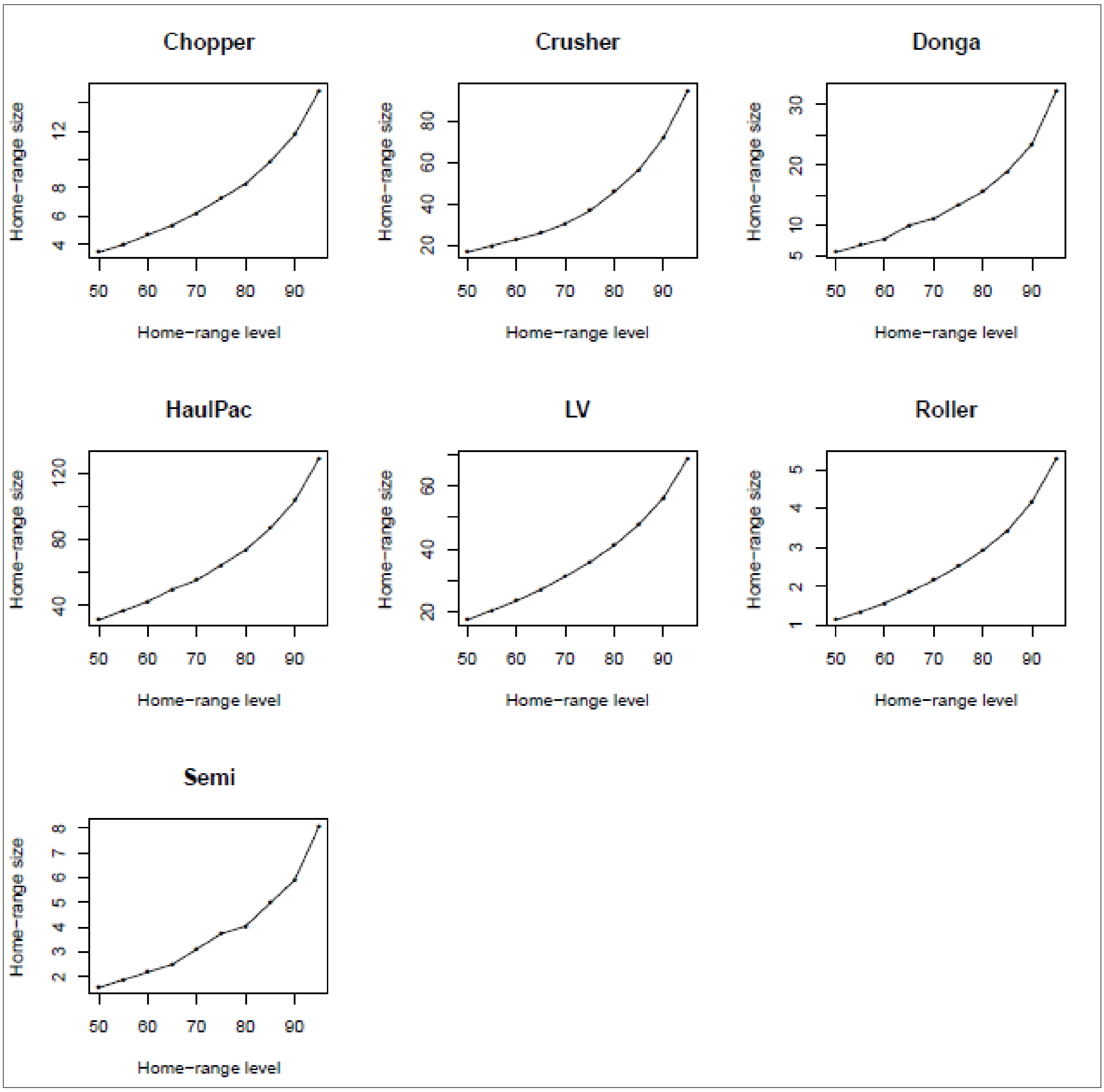


Figure 5. Graphs displaying the accuracy of MCP home range estimates for each Northern quoll GPS collared in the Pilbara.

Mean male KDE 95% home range was determined in Arc Map. For males the mean is 143.293 ± 151.016 ha. For females the mean home range is 45.932 ± 35.102 ha. Differences between MCP home range and KDE home range are substantial and in all cases the calculated KDE is much greater than the MCP.

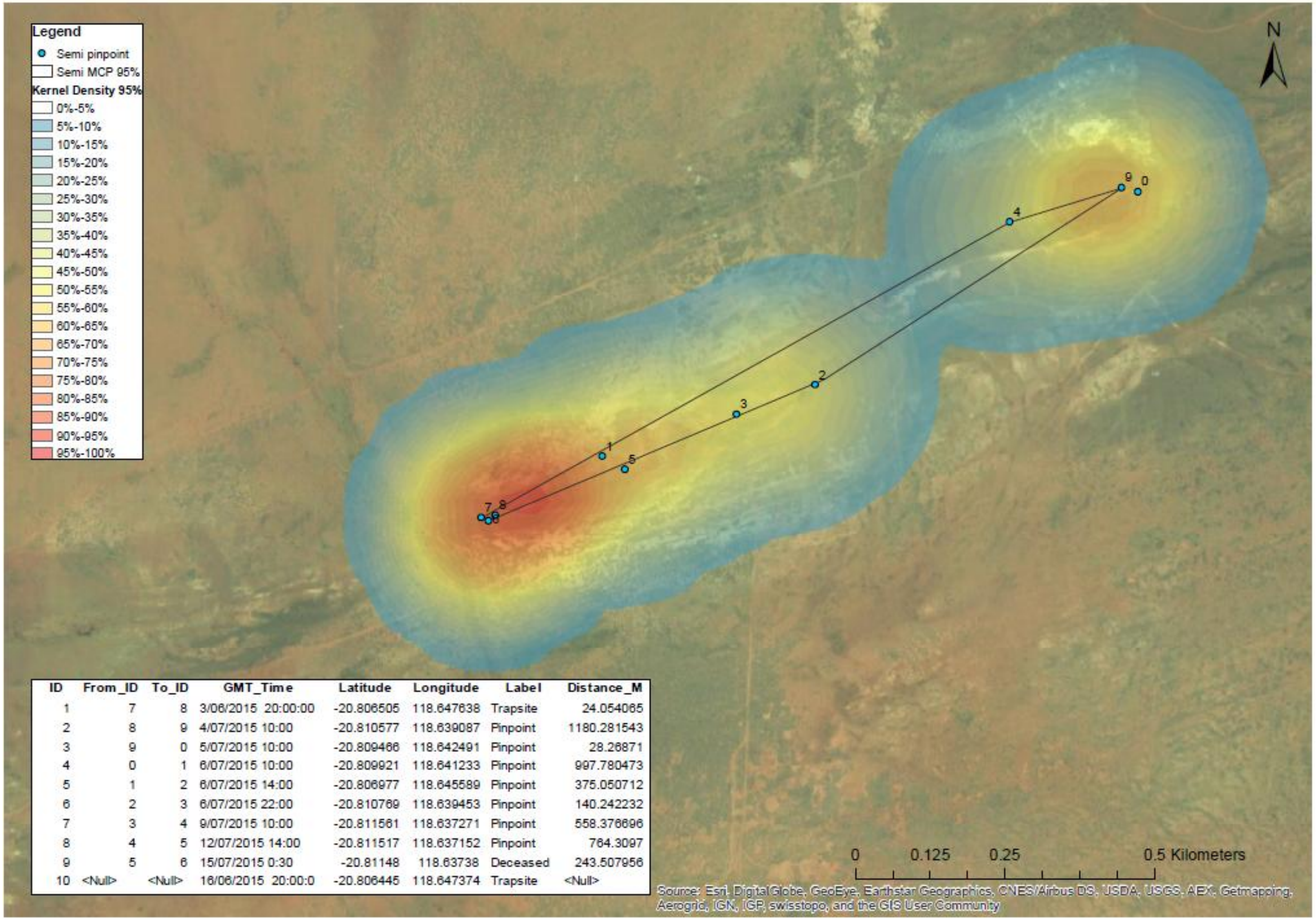
Table 12. Comparison of Minimum Convex Polygon home range with Kernel Density home range estimates in hectares.

	MPC 95%	**KDE 95%**
Semi	6.13	71.63
LV	31.96	60.22
Donga	65.23	162.51
Haul Pac	127.49	348.84
Chopper	5.32	14.58
Crusher	34.07	47.22
Roller	2.19	5.93
Mean Male ± SD	58.03 ± 5.65	143.29 ± 151.01
Mean Female ± SD	13.43 ± 2.74	45.93 ± 35.10

Tables in Figures 6-12 display the movement between each data point, in a straight line, with the distance between each given in metres. The greatest single move between 2 consecutive points was recorded by the largest male at site A, travelling 2.6km in 24 hours. The largest female single move recorded was 1.2km at site B over 4 four hours. Consecutive locations recorded in a single night were used to calculate the greatest move recorded from an individual in a single night. Across all individuals the greatest distance recorded from a total of 4 data points was 5018.715m. This was recorded by male Crusher at site B. The greatest move during a single night for a female was recorded by LV from 4 data points at site A, with a total distance of 2859.8m.

Figures 6-12 overlay quoll coordinates MPC home range and KDE home range upon the landscape for each individual. Areas within the boundary of the polygon make up the MCP 95% home range of nocturnal foraging habitat. Areas defined by red in KDE 95% indicate a high density of data points within and are an indication of core areas of use determined by the clustering of coordinates. Core use areas are where the greatest numbers of coordinates were recorded and are areas which animals frequent most often. The scale of home range use decreases from areas defined in red to areas defined by blue. Areas defined by blue identify areas of few data points and are frequented less often. This is demonstrated in Figure 6, the first of seven home range maps. Each individual demonstrates multiple centres of activity within their home range with a well-defined area of core use, and one or two secondary areas of lesser use. There is limited overlap of core areas at each site suggesting each animal has their own defined denning area. Areas within the MCP 95% not defined within the KDE 95% indicate areas of little to no use.

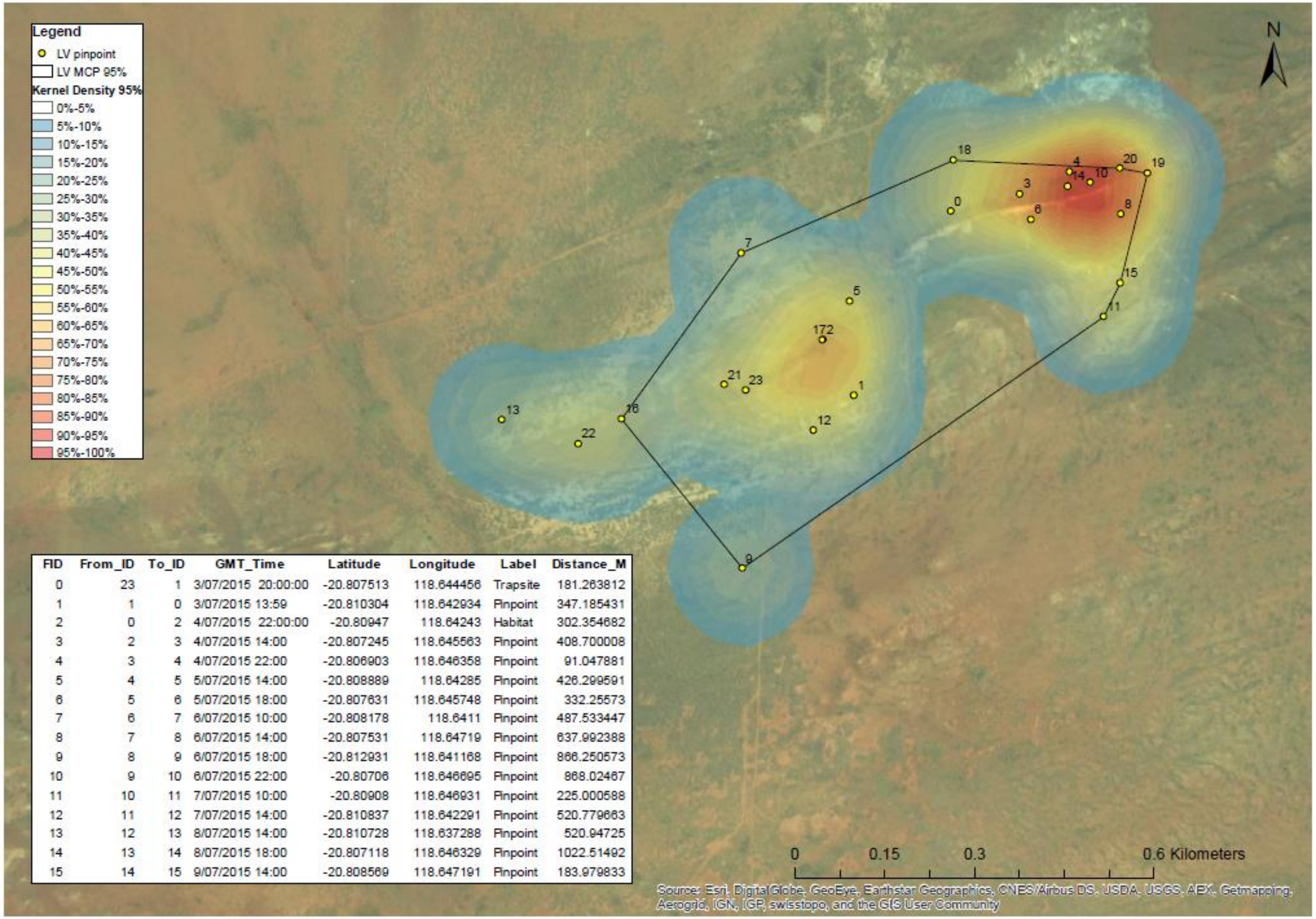
Quoll coordinates demonstrate linear movements which coincide with rocky linear landscape features. Movements at site A coincide with the mining village and large quartz outcrop. In Figure 7, LV demonstrates the greatest variation in movement away from rocky areas into lower spinifex plains surrounding site A. Only the male at this site demonstrates interactions with the mining camp. Locations recorded at site B are restricted to areas within the Turner River. The animals collared at this site do not move outside of the bounds of the riverbed. Points at site C are associated with granite rocky outcrops and a small seasonal drainage line. At sites A and C home ranges are intersected by gravel roads with core areas of use on both sides.



ID	From_ID	To_ID	GMT_Time	Latitude	Longitude	Label	Distance_M
1	7	8	3/06/2015 20:00:00	-20.806505	118.647638	Trapsite	24.054065
2	8	9	4/07/2015 10:00	-20.810577	118.639087	Pinpoint	1180.281543
3	9	0	5/07/2015 10:00	-20.809466	118.642491	Pinpoint	28.26871
4	0	1	6/07/2015 10:00	-20.809921	118.641233	Pinpoint	997.780473
5	1	2	6/07/2015 14:00	-20.806977	118.645589	Pinpoint	375.050712
6	2	3	6/07/2015 22:00	-20.810769	118.639453	Pinpoint	140.242232
7	3	4	9/07/2015 10:00	-20.811561	118.637271	Pinpoint	558.376696
8	4	5	12/07/2015 14:00	-20.811517	118.637152	Pinpoint	764.3097
9	5	6	15/07/2015 0:30	-20.81148	118.63738	Deceased	243.507956
10	<Null>	<Null>	16/06/2015 20:00:0	-20.806445	118.647374	Trapsite	<Null>

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6. MCP 95% and KDE 95% home range for individual Semi with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.



FID	From_ID	To_ID	GMT_Time	Latitude	Longitude	Label	Distance_M
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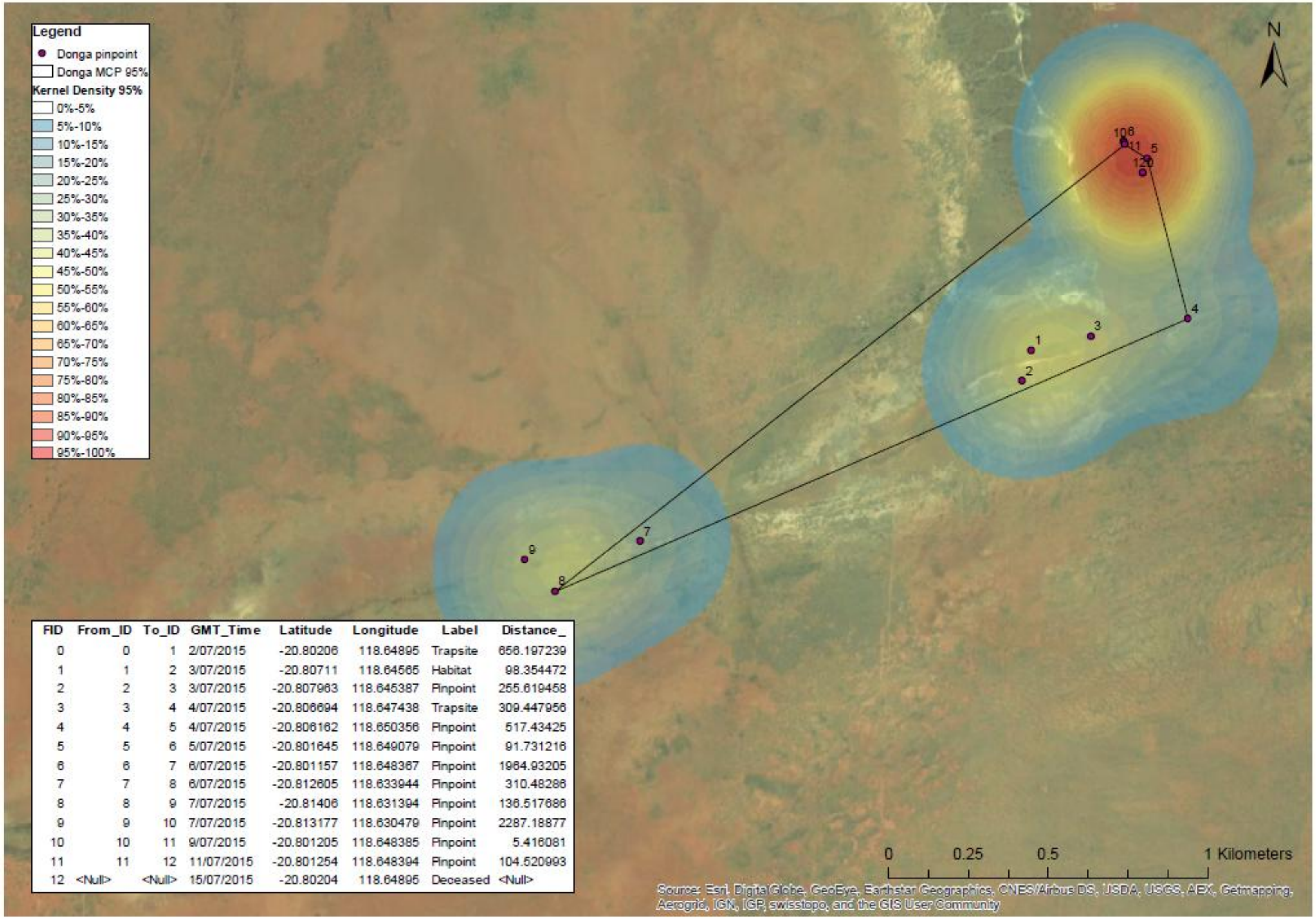
1	1	0	3/07/2015 13:59	-20.810304	118.642934	Pinpoint	347.185431
2	0	2	4/07/2015 22:00:00	-20.80947	118.64243	Habitat	302.354682
3	2	3	4/07/2015 14:00	-20.807245	118.645563	Pinpoint	408.700008
4	3	4	4/07/2015 22:00	-20.806903	118.646358	Pinpoint	91.047881
5	4	5	5/07/2015 14:00	-20.808889	118.64285	Pinpoint	426.299591
6	5	6	5/07/2015 18:00	-20.807631	118.645748	Pinpoint	332.25573
7	6	7	6/07/2015 10:00	-20.808178	118.6411	Pinpoint	487.533447
8	7	8	6/07/2015 14:00	-20.807531	118.64719	Pinpoint	637.992388
9	8	9	6/07/2015 18:00	-20.812931	118.641168	Pinpoint	866.250573
10	9	10	6/07/2015 22:00	-20.80706	118.646695	Pinpoint	868.02467
11	10	11	7/07/2015 10:00	-20.80908	118.646931	Pinpoint	225.000588
12	11	12	7/07/2015 14:00	-20.810837	118.642291	Pinpoint	520.779663
13	12	13	8/07/2015 14:00	-20.810728	118.637288	Pinpoint	520.94725
14	13	14	8/07/2015 18:00	-20.807118	118.646329	Pinpoint	1022.51492
15	14	15	9/07/2015 14:00	-20.808569	118.647191	Pinpoint	183.979833

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7. MCP 95% and KDE 95% home range for individual LV with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.



FID	From_ID	To_ID	GMT_Time	Latitude	Longitude	Label	Distance_
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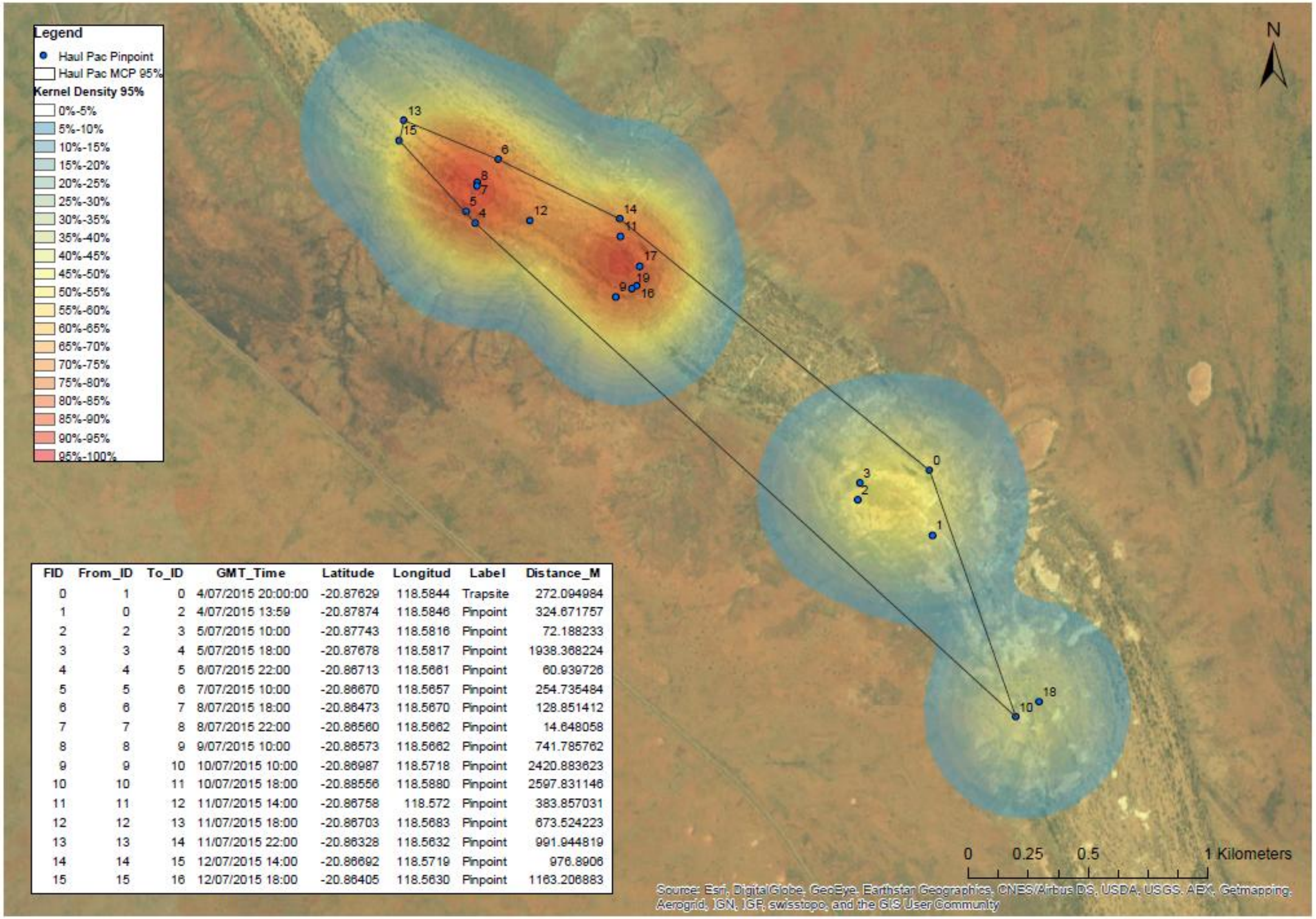
1	1	2	3/07/2015	-20.80711	118.64565	Habitat	98.354472
2	2	3	3/07/2015	-20.807963	118.645387	Pinpoint	255.619458
3	3	4	4/07/2015	-20.806694	118.647438	Trapsite	309.447956
4	4	5	4/07/2015	-20.806162	118.650356	Pinpoint	517.43425
5	5	6	5/07/2015	-20.801645	118.649079	Pinpoint	91.731216
6	6	7	6/07/2015	-20.801157	118.648367	Pinpoint	1964.93205
7	7	8	6/07/2015	-20.812605	118.633944	Pinpoint	310.48286
8	8	9	7/07/2015	-20.81406	118.631394	Pinpoint	136.517686
9	9	10	7/07/2015	-20.813177	118.630479	Pinpoint	2287.18877
10	10	11	9/07/2015	-20.801205	118.648385	Pinpoint	5.416081
11	11	12	11/07/2015	-20.801254	118.648394	Pinpoint	104.520993
12	<Null>	<Null>	15/07/2015	-20.80204	118.64895	Deceased	<Null>

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 8. MCP 95% and KDE 95% home range for individual Donga with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.



FID	From_ID	To_ID	GMT_Time	Latitude	Longitud	Label	Distance_M
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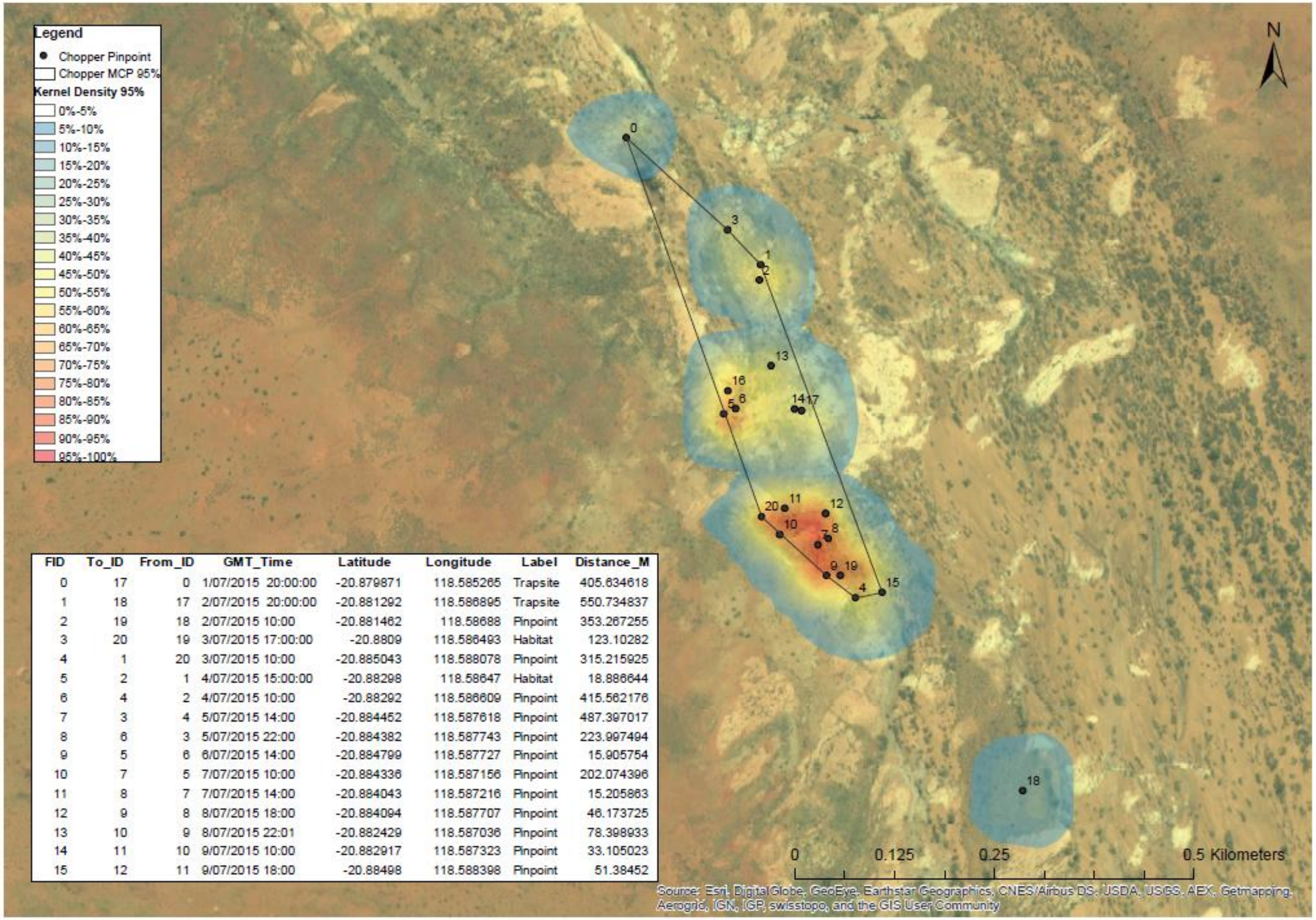
1	0	2	4/07/2015 13:59	-20.87874	118.5846	Pinpoint	324.671757
2	2	3	5/07/2015 10:00	-20.87743	118.5816	Pinpoint	72.188233
3	3	4	5/07/2015 18:00	-20.87678	118.5817	Pinpoint	1938.368224
4	4	5	6/07/2015 22:00	-20.86713	118.5661	Pinpoint	60.939726
5	5	6	7/07/2015 10:00	-20.86670	118.5657	Pinpoint	254.735484
6	6	7	8/07/2015 18:00	-20.86473	118.5670	Pinpoint	128.851412
7	7	8	8/07/2015 22:00	-20.86560	118.5662	Pinpoint	14.648058
8	8	9	9/07/2015 10:00	-20.86573	118.5662	Pinpoint	741.785762
9	9	10	10/07/2015 10:00	-20.86987	118.5718	Pinpoint	2420.883623
10	10	11	10/07/2015 18:00	-20.88556	118.5880	Pinpoint	2597.831146
11	11	12	11/07/2015 14:00	-20.86758	118.572	Pinpoint	383.857031
12	12	13	11/07/2015 18:00	-20.86703	118.5683	Pinpoint	673.524223
13	13	14	11/07/2015 22:00	-20.86328	118.5632	Pinpoint	991.944819
14	14	15	12/07/2015 14:00	-20.86692	118.5719	Pinpoint	976.8906
15	15	16	12/07/2015 18:00	-20.86405	118.5630	Pinpoint	1163.206883

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

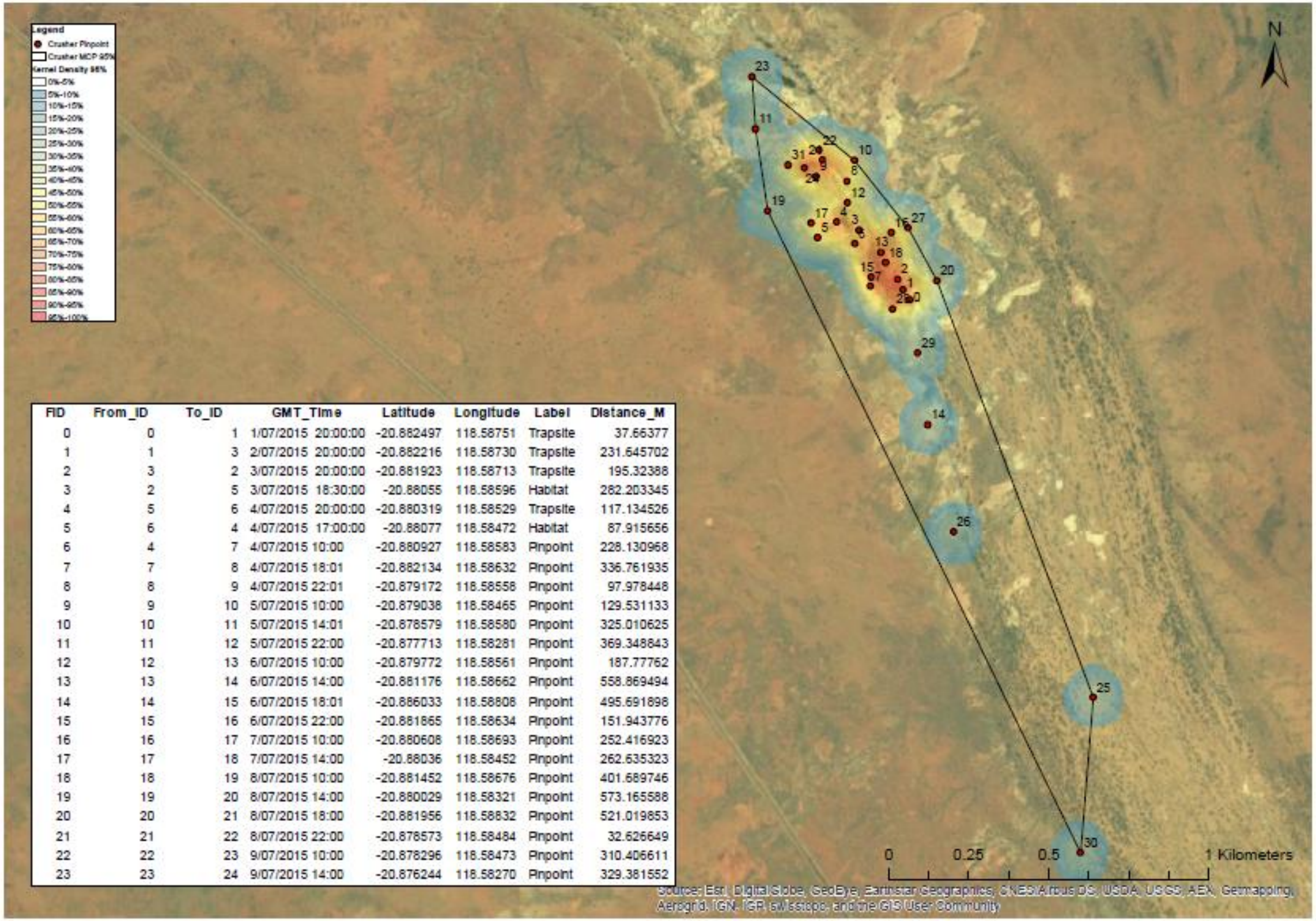
Figure 9. MCP 95% and KDE 95% home range for individual Haul Pac with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.



FID	To_ID	From_ID	GMT_Time	Latitude	Longitude	Label	Distance_M
0	17	0	1/07/2015 20:00:00	-20.879871	118.585265	Trapsite	405.634618
1	18	17	2/07/2015 20:00:00	-20.881292	118.586895	Trapsite	550.734837
2	19	18	2/07/2015 10:00	-20.881462	118.58688	Pinpoint	353.267255
3	20	19	3/07/2015 17:00:00	-20.8809	118.586493	Habitat	123.10282
4	1	20	3/07/2015 10:00	-20.885043	118.588078	Pinpoint	315.215925
5	2	1	4/07/2015 15:00:00	-20.88298	118.58647	Habitat	18.886644
6	4	2	4/07/2015 10:00	-20.88292	118.586609	Pinpoint	415.562176
7	3	4	5/07/2015 14:00	-20.884452	118.587618	Pinpoint	487.397017
8	6	3	5/07/2015 22:00	-20.884382	118.587743	Pinpoint	223.997494
9	5	6	6/07/2015 14:00	-20.884799	118.587727	Pinpoint	15.905754
10	7	5	7/07/2015 10:00	-20.884336	118.587156	Pinpoint	202.074396
11	8	7	7/07/2015 14:00	-20.884043	118.587216	Pinpoint	15.205863
12	9	8	8/07/2015 18:00	-20.884094	118.587707	Pinpoint	46.173725
13	10	9	8/07/2015 22:01	-20.882429	118.587036	Pinpoint	78.398933
14	11	10	9/07/2015 10:00	-20.882917	118.587323	Pinpoint	33.105023
15	12	11	9/07/2015 18:00	-20.88498	118.588398	Pinpoint	51.38452

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 10. MCP 95% and KDE 95% home range for individual Chopper with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.



FID	From_ID	To_ID	GMT_Time	Latitude	Longitude	Label	Distance_M
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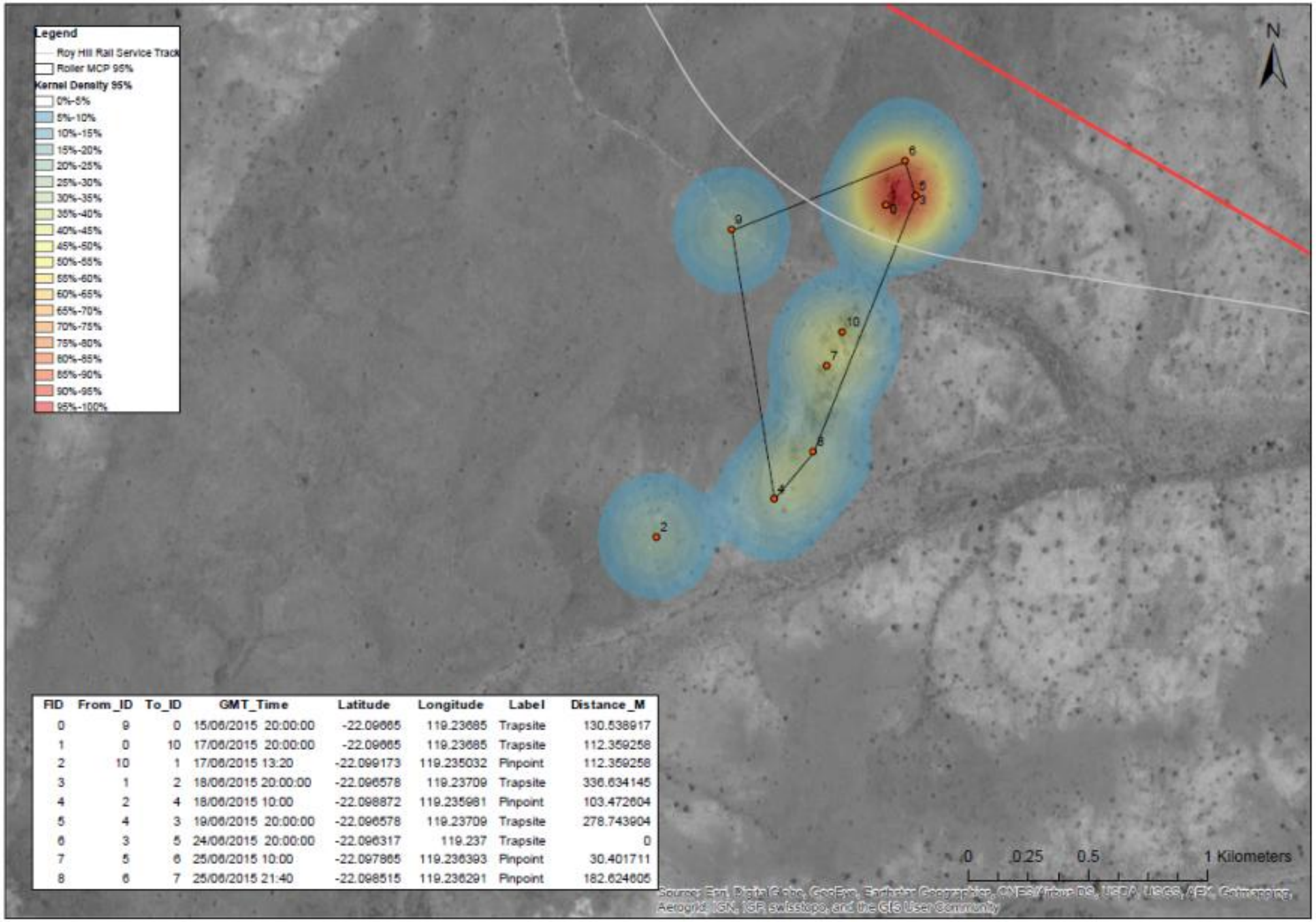
1	1	3	2/07/2015 20:00:00	-20.882216	118.58730	Trapsite	231.645702
2	3	2	3/07/2015 20:00:00	-20.881923	118.58713	Trapsite	195.32388
3	2	5	3/07/2015 18:30:00	-20.88055	118.58596	Habitat	282.203345
4	5	6	4/07/2015 20:00:00	-20.880319	118.58529	Trapsite	117.134526
5	6	4	4/07/2015 17:00:00	-20.88077	118.58472	Habitat	87.915656
6	4	7	4/07/2015 10:00	-20.880927	118.58583	Pinpoint	228.130968
7	7	8	4/07/2015 18:01	-20.882134	118.58632	Pinpoint	336.761935
8	8	9	4/07/2015 22:01	-20.879172	118.58558	Pinpoint	97.978448
9	9	10	5/07/2015 10:00	-20.879038	118.58465	Pinpoint	129.531133
10	10	11	5/07/2015 14:01	-20.878579	118.58580	Pinpoint	325.010625
11	11	12	5/07/2015 22:00	-20.877713	118.58281	Pinpoint	369.348843
12	12	13	6/07/2015 10:00	-20.879772	118.58561	Pinpoint	187.77762
13	13	14	6/07/2015 14:00	-20.881176	118.58662	Pinpoint	558.869494
14	14	15	6/07/2015 18:01	-20.886033	118.58808	Pinpoint	495.691898
15	15	16	6/07/2015 22:00	-20.881865	118.58634	Pinpoint	151.943776
16	16	17	7/07/2015 10:00	-20.880608	118.58693	Pinpoint	252.416923
17	17	18	7/07/2015 14:00	-20.88036	118.58452	Pinpoint	262.635323
18	18	19	8/07/2015 10:00	-20.881452	118.58676	Pinpoint	401.689746
19	19	20	8/07/2015 14:00	-20.880029	118.58321	Pinpoint	573.165588
20	20	21	8/07/2015 18:00	-20.881956	118.58832	Pinpoint	521.019853
21	21	22	8/07/2015 22:00	-20.878573	118.58484	Pinpoint	32.626649
22	22	23	9/07/2015 10:00	-20.878296	118.58473	Pinpoint	310.406611
23	23	24	9/07/2015 14:00	-20.876244	118.58270	Pinpoint	329.381552

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 11. MCP 95% and KDE 95% home range for individual Crusher with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.



FID	From_ID	To_ID	GMT_Time	Latitude	Longitude	Label	Distance_M
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1	0	10	17/06/2015 20:00:00	-22.09665	119.23685	Trapsite	112.359258
2	10	1	17/06/2015 13:20	-22.099173	119.235032	Pinpoint	112.359258
3	1	2	18/06/2015 20:00:00	-22.096578	119.23709	Trapsite	336.634145
4	2	4	18/06/2015 10:00	-22.098872	119.235981	Pinpoint	103.472604
5	4	3	19/06/2015 20:00:00	-22.096578	119.23709	Trapsite	278.743904
6	3	5	24/06/2015 20:00:00	-22.096317	119.237	Trapsite	0
7	5	6	25/06/2015 10:00	-22.097865	119.236393	Pinpoint	30.401711
8	6	7	25/06/2015 21:40	-22.098515	119.236291	Pinpoint	182.624605

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 12. MCP 95% and KDE 95% home range for individual Roller with table displaying movement of individual from ID to ID, the time reference recorded (GMT), the coordinate reference number, and the distance between each location in metres.

Home range of individuals overlapped at Sites A and B (Figure 13). At site C home range of Roller also overlapped with a juvenile female too small to collar. A male was also trapped at this site in the remaining days of the trapping period, while retrieving collars. At site A the home ranges of two females have near complete overlap (yellow and bright blue). Female home ranges fall within that of the male (purple) who’ s home range extends beyond the females, at either extent of their range. At site B the smallest home range demonstrated by Chopper (grey) overlaps completely with both other males in the area. Crusher’s range (red) also overlaps with both males with some exploratory movements beyond the home range of Haul Pac (blue). Haul Pac has two areas of defined KDE home range. One area overlaps with the other males in the area, while the other is used by him alone.

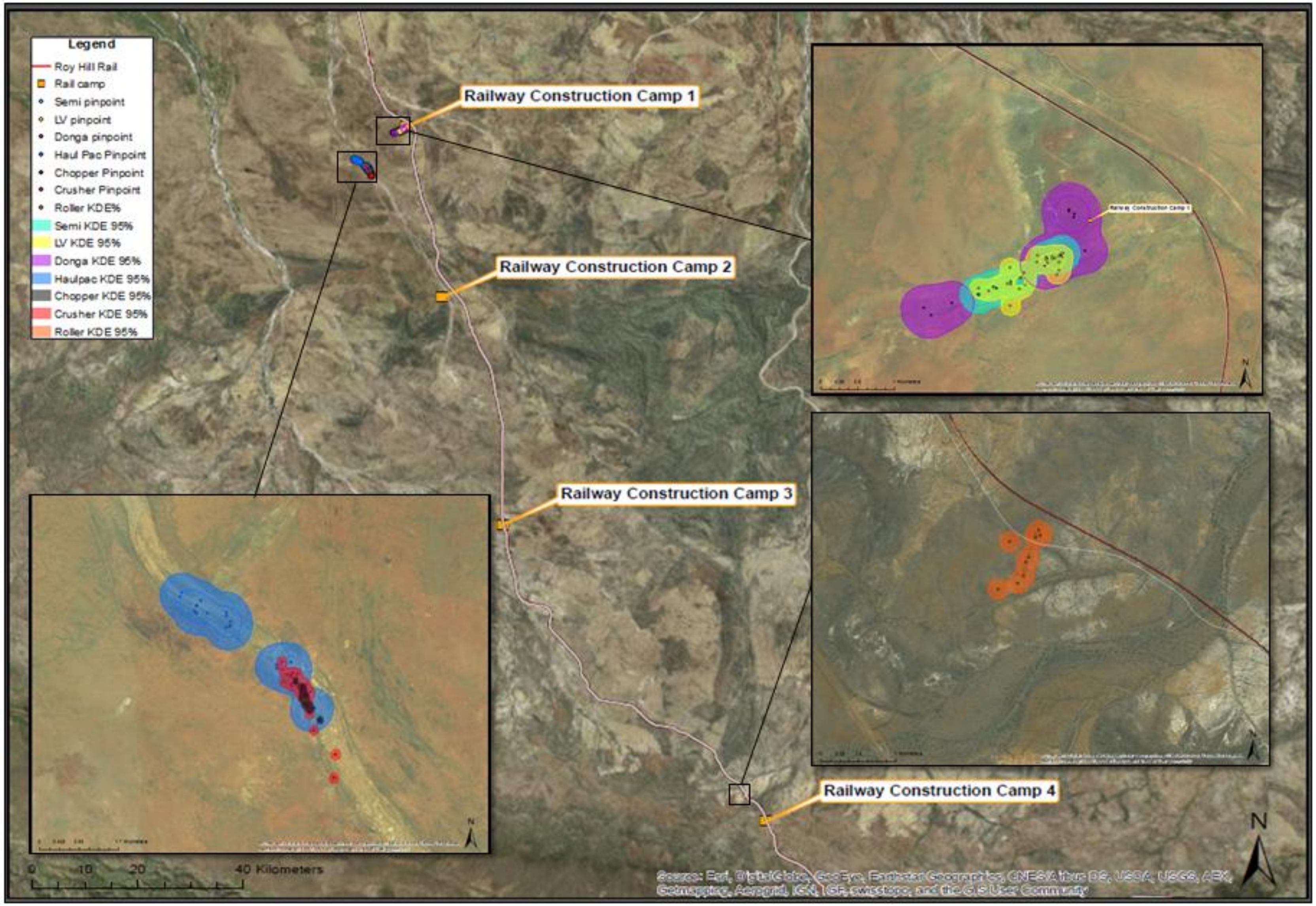


Figure 13. Map displays the overlap of KDE 95% home range areas between individuals at each location. Each animal KDE is indicted by a different colour.

5.2 Characteristics of Foraging Habitat

Five variables were assessed at each site including floristic classification, geological series, distance to rail, distance to water and site elevation. Categorical data, floristic and geological, were determined based on a percentage of use within KDE home range and compared to the total availability of each category within a $10km^2$ area locally. Areas of use were taken from a binary isocluster using the KDE 95% cut off value. Numerical variables were collated using GIS layers, Euclidean distance and digital elevation at each site to determine important habitat features used by Northern quoll. Few trends were observed when all data was compiled across all three sites. This is due to differences in floristic array and geological substrates at each location.

5.2.1 Floristic Community Data

Isocluster analysis performed in GIS produced 6 floristic classifications at site A and C and 5 classifications at site B. Trends were more apparent when data was investigated by trap site. Displayed below in Table 13 is the percentage of each floristic classification used by Northern quoll per site. The most frequented floristic community by Northern quoll at site A was shrub steppe. At site B open rocky grassland was the most frequently utilised community. Only one individual was collared at site C who demonstrated a strong floristic relationship for low sparse woodland (Table 13).

Table 13. The percentage of each floristic community used at each study site determined by the area within KDE home range.

	Floristic Community Used (%)		
Classification	**Site A**	**Site B**	**Site C**
Low shrubs and herbs	12.47	-	28.94
Acacia shrubland	10.28	6.07	7.36
Low sparse woodland		8.04	35.56
Open hummock grassland	8.69	-	7.74
Closed hummock grassland	13.50	-	3.81
Shrub steppe	43.28	9.83	6.39
Low dense shrubland	8.42	-	-
Hummock grassland		5.21	-
Open grassland		70.31	-

Site A- Rail Camp 1

At site A, six floristic classifications were determined from GIS mapping. The largest floristic class in this area was defined as *Acacia* shrubland. Second in total area was the classification of closed hummock grassland while the least common association was low sparse woodland (Figure 14). When occurrences at this site were combined, three individuals demonstrated no presences within low sparse woodland. Presences were most frequent within shrub steppe and *Acacia* shrubland. 43% of all available shrub steppe was utilised by the individuals at this site (see Table 13).

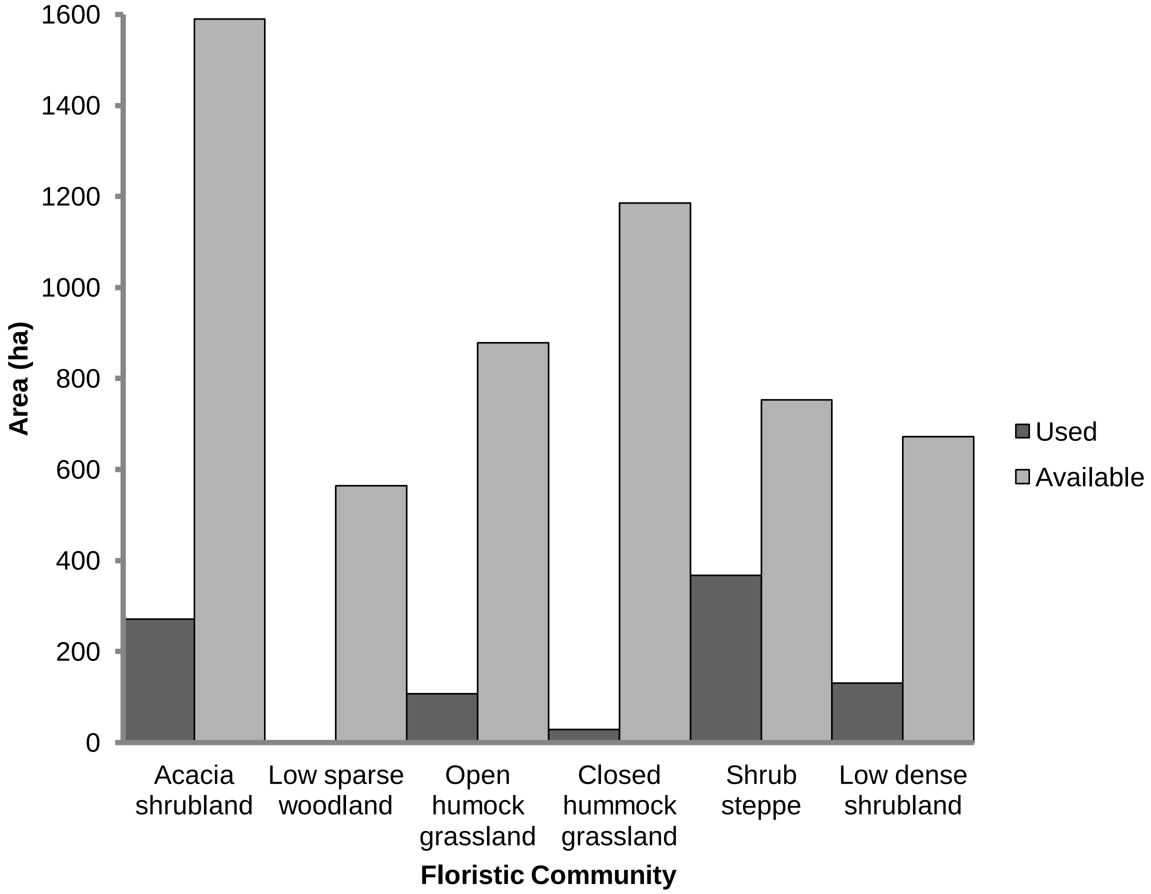


Figure 14. Habitat selection of floristic communities by Pilbara Northern quoll based on movement data from Rail Camp 1.

Site B- Indee Station

Presence data was combined at Site B to find trends in the use of floristic and geological categories by Northern quoll. Of the 5 floristic categories hummock grassland is the largest covering more than 1000ha. The least available class was open rocky grassland which covers approximately 300ha. Open rocky grassland appears to be preferred by Northern Quoll at this site and presences occurred within 70% of this floristic community. Use of all other floristic classifications was similar with presences occurring within 38-51ha of each (Figure 15).

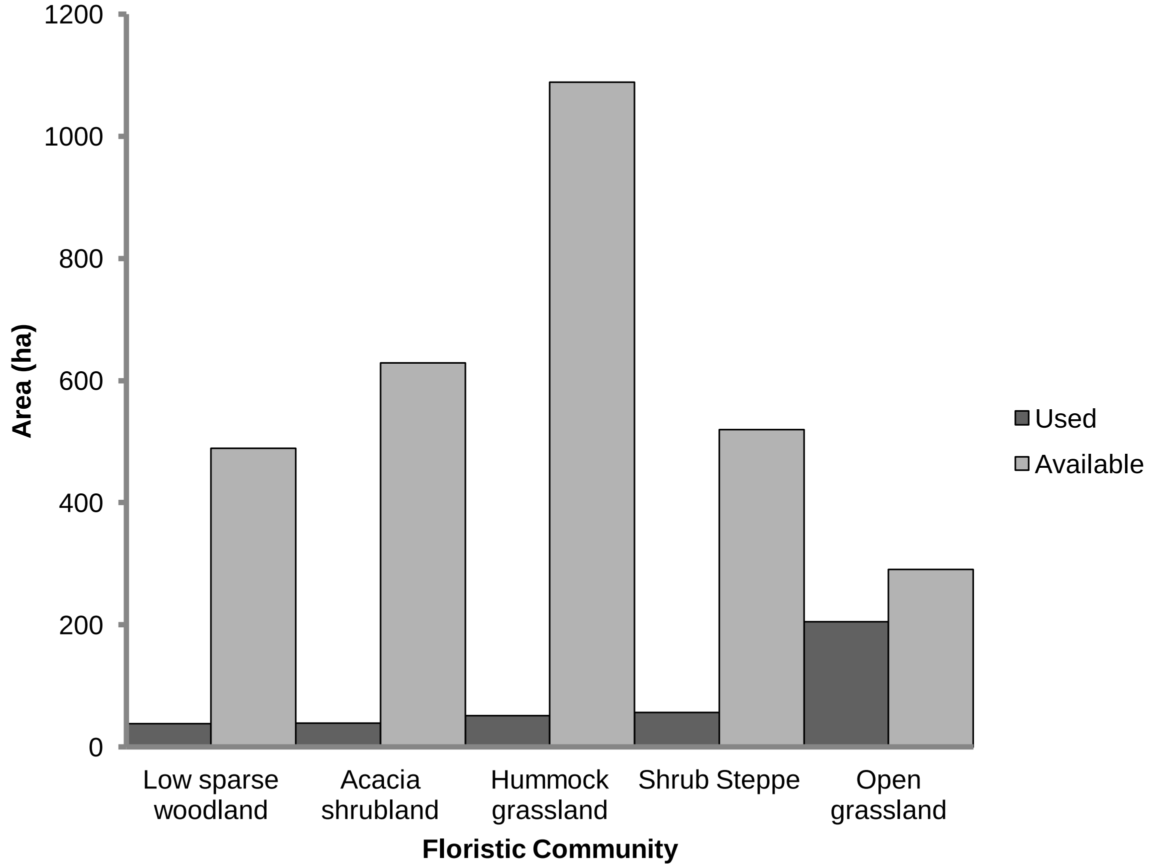


Figure 15. Habitat selection of floristic communities by Pilbara northern quoll based on movement data from Indee Station.

Site C- Quoll Knoll

Presence data at site C determined the use of only three out of the six floristic categories defined. The largest, shrub steppe covered more than 1000ha and this was utilised most often. Low dense shrubland was the second largest category utilised with 22% of the 600ha used. The least available class was low herbs and shrubs which covered only 9.95ha. Low herbs and shrubs was well utilised by the individual at this site with presences occurring within 51% of this floristic community (Figure 16).

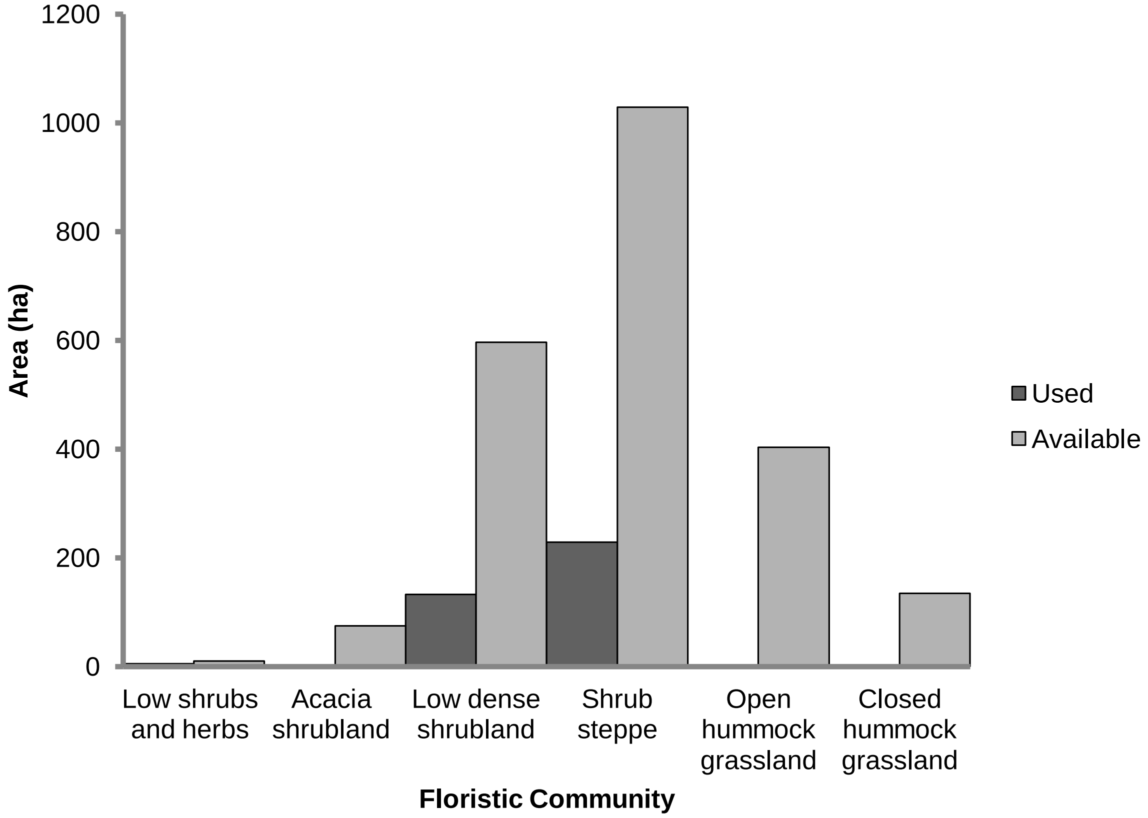


Figure 16. Habitat selection of floristic communities by Pilbara northern quoll based on movement data from Quoll Knoll.

5.2.2 Geological Series Data

Geological Series data has previously been mapped for the whole Pilbara region and is based on 100k Geological Series data from the Geological Survey of Western Australia. This data set contains 177 categories in total, only 21 of these categories were utilised by Northern Quoll across all trapping sites (Description of each category located in Appendix 6).

Commonalities in geologic substrate were most apparent at site A with all individuals demonstrating most frequent use of metamorphosed Chert (AGlc). All individuals at site B utilised different substrates. However, the categories AgLmp and AgLmf are strongly related with both categories comprised of biotite monzogranite. These categories are differentiated by the strength of the foliation in the substrate. Only one individual was collared at site C who demonstrated a strong geological link towards talc-carbonate and talc-chlorite-carbonate schist (A-Pl-mutk).

Table 14. The percentage of each geological series used at each study site determined by the area within KDE home range.

	Geology Series Used (%)		
Geologic Series	**Site A**	**Site B**	**Site C**
Abus	7.14	4.285714	-
ADmhl	2.38	-	-
AGlc	73.80	-	-
AGli	4.76	-	-
Czaf	7.14	-	-
AgLmf	-	50	-
AgLmp	-	30	-
Qaa	-	1.42	-
Qao	4.76	14.28	-
_R2-g-pg	-	-	11.11
A-FO-sr	-	-	11.11
A-PI-mutk		-	77.77

Site A- Rail Camp 1

Geology at site A is differentiated into 11 categories. The most common is Alluvium (Qao) which is comprised of clay, silt, and sand in channels on floodplains. Also common in this area is metamorphosed Chert (AGlc). This is the category most commonly utilised by the Northern quoll collared at this site with approximately 75% of this substrate used. Other categories with minimal use when compared to availability within the local area were talc-tremolite-chlorite schist (Abus) and limonite deposits (Czaf) (Figure 17).

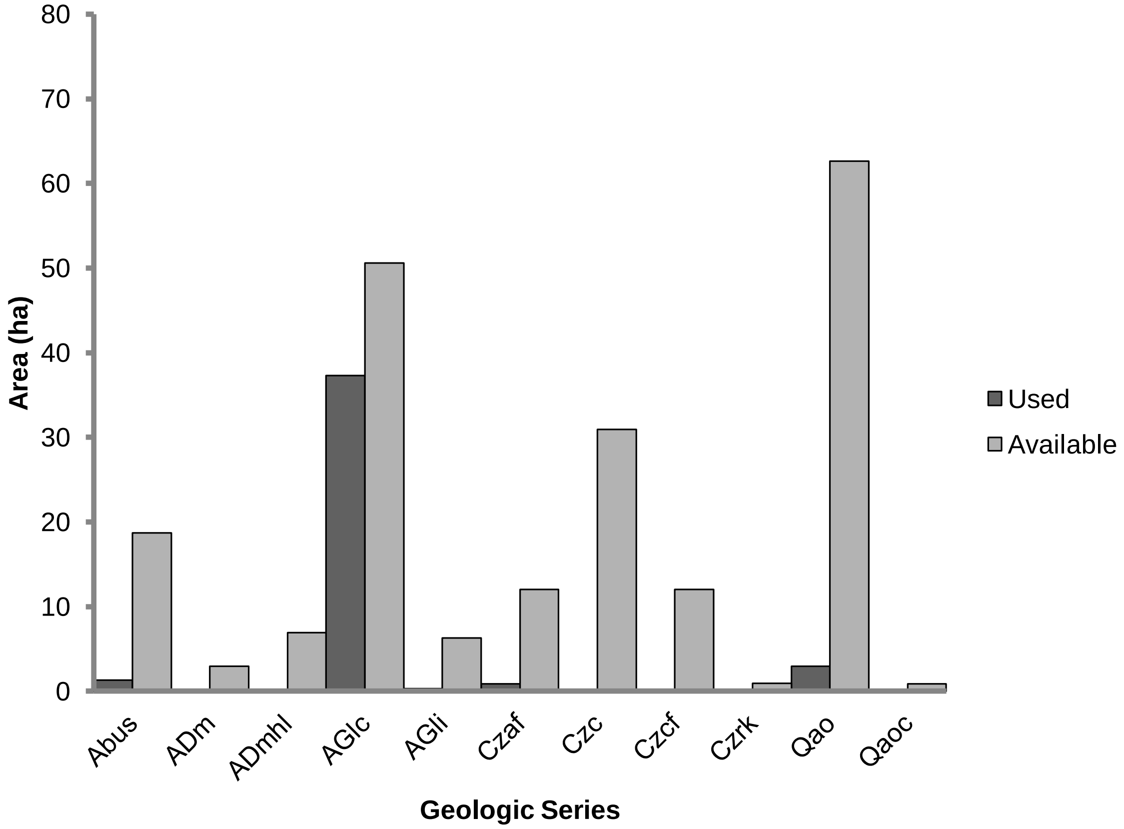


Figure 17. Habitat selection of geological series by Pilbara northern quoll determined from movement data at Rail Camp 1.

Site B- Indee Station

Use of geological substrates at Site B is clearly defined in just five of the available 13 categories. The greatest available substrate in the area is alluvial sand, silt, and clay (Qaoc) with 81ha. Clay, silt, sand, and gravel in rivers (Qaa) is the next most available substrate but use of this extremely limited by Northern quoll at this site. Strongly foliated biotite monzogranite (AgLmf) covers the third largest area (72ha) and is the most common substrate of use at this site. A total of 50% of the available Aglmf is used by Northern quoll at this site. The secondary substrate of importance is weakly foliated biotite monzogranite (AgLpe) with 23% of this substrate used overall (Figure 18).

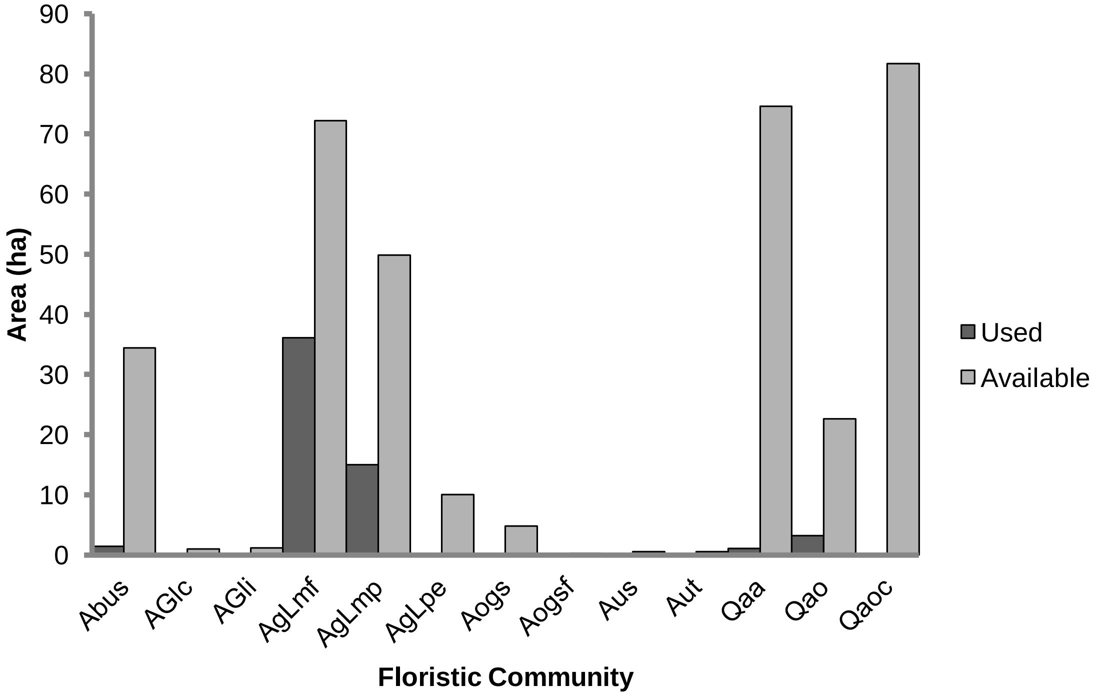


Figure 18. Habitat selection of geological series by Pilbara northern quoll determined from movement data at Indee Station.

Site C- Quoll Knoll

Use of geological substrates at Site C is clearly defined within only three of the available geological categories. The greatest available substrate in the area is alluvial sand, silt, and gravel (_A2) with 402ha present. Three most common substrates at this site contained no presences of Northern quoll within. The most commonly used substrate by Northern quoll at this site was eluvial and colluvial sand, gravel, and silt overlying, and derived from granitic rocks (_R2-g-pg) and pebbly coarse-grained sandstone (A-FO-sr). Talc-carbonate and talc-chlorite-carbonate schist (A-PI-mutk) makes up a very small percentage of floristic categories within the local area. It is not demonstrated well within the graph but 75% of this category is utilised by the individual at this site (Figure 21).

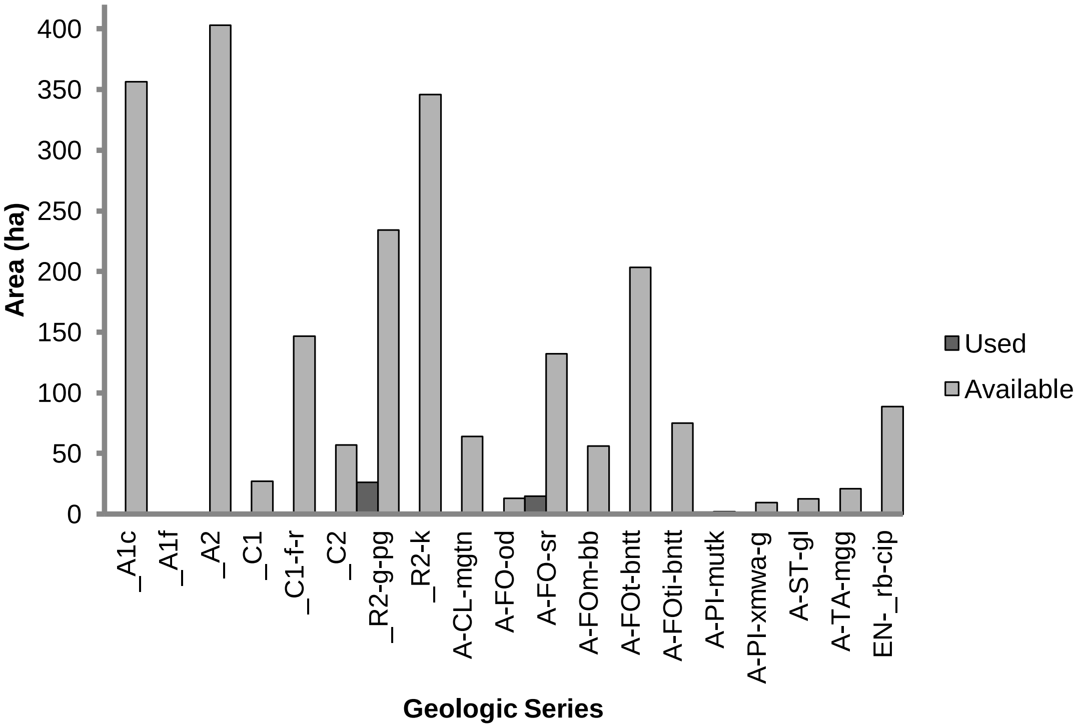


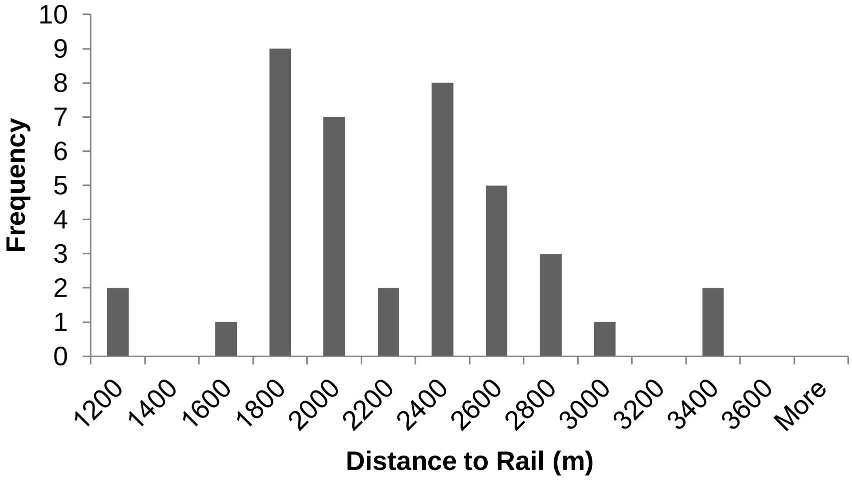
Figure 19. Habitat selection of geological series by Pilbara northern quoll determined from movement data at Quoll Knoll.

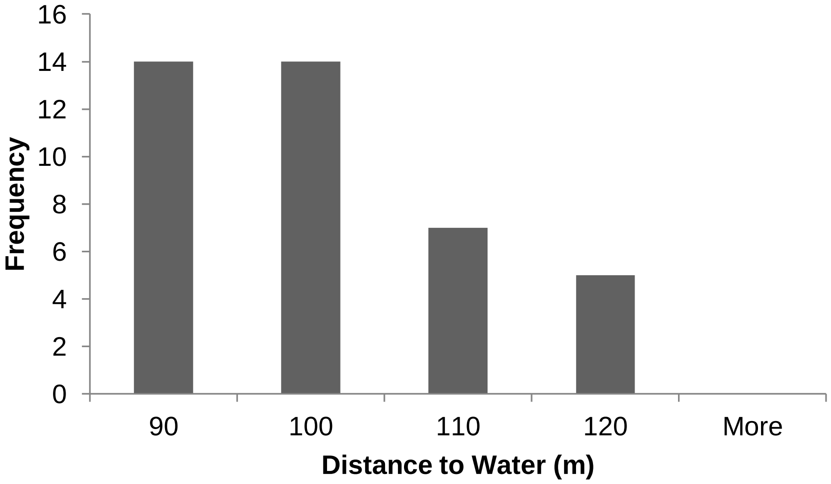
5.2.3 Numerical Variables

Site A- Rail Camp 1

All locations recorded for individuals at Rail Camp 1 were located within 1200 to 3400m from rail infrastructure. The most locations were recorded within 1700-1900m of the rail. Donga ventured the closest and furthest from the line with a minimum distance of 1093m and maximum distance of 3269m (Figure 16).

Access to water for the individuals at rail camp 1 occurred at a distance of between 1400-3600m. Most commonly coordinates recorded at this site fall within 80-110m above sea level. Summary statistics of the variables for each individual at Site 1 are displayed below in Table 15.





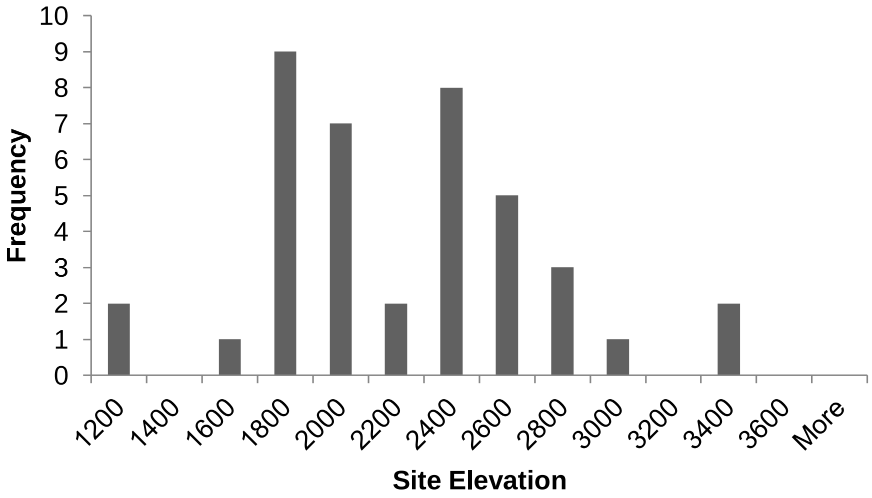


Figure 20. Combined data from all individuals at Rail Camp 1 displaying the frequency of each coordinate from Distance to rail, distance to water and Digital elevation.

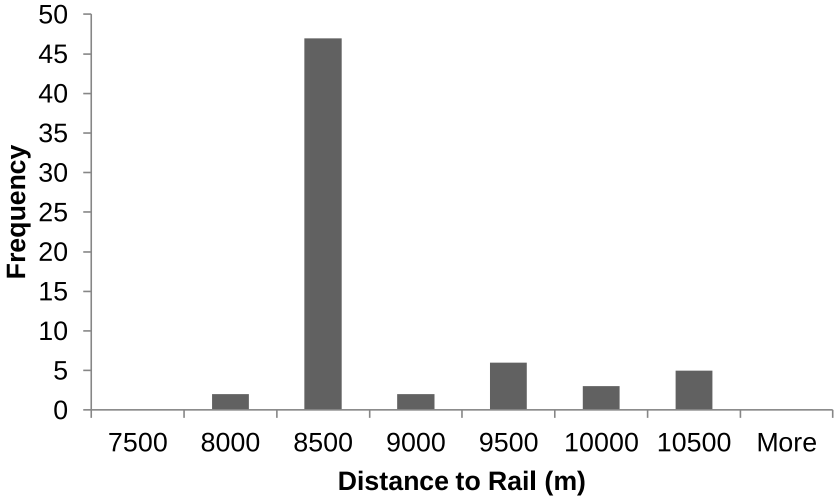
Site B-Indee Station

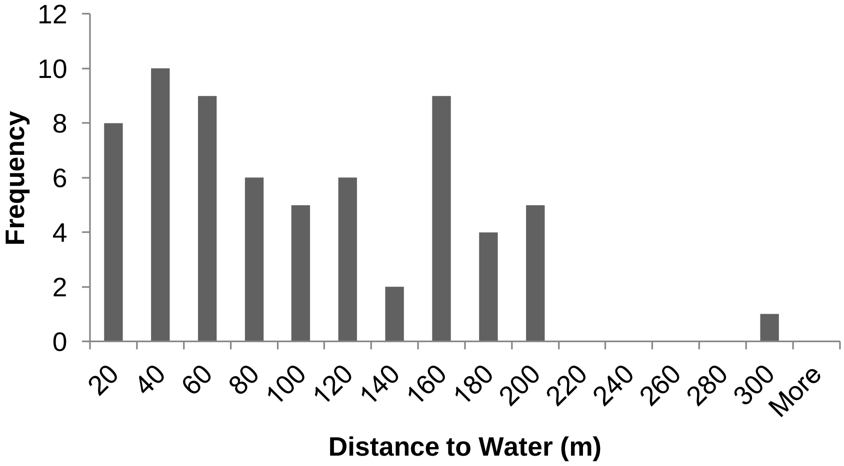
All locations recorded for individuals at Site B were located within 8000-11000m from rail infrastructure. The greatest number of locations was recorded at a distance between 8000-8500m from the rail (Figure 17).

Access to water for individuals at Indee Station occurred at a distance of 0 -200m. Frequently individuals were located within 40m of access to free water. Coordinates recorded at this site fall within 85-100m above sea level but are most common between 95-100 m. Summary statistics of the variables for each individual at site 2 are displayed below in Table 15 .

Table 15. Summary statistics of the numerical variables distance to rail, distance to water and digital elevation for each individual.

		Distance To Rail			**Distance to Water**			**Digital Elevation**		
Site	**Animal**	**Min**	**Max**	**Quartile Range**	**Min**	**Max**	**Quartile Range**	**Min**	**Max**	**Quartile Range**
A	Semi	1640.12	2706.51	914.74	1160	2772	966.85	82.13	102.03	17.15
	LV	1687.72	2590.6	590.46	1640.4	2755.3	643.96	83.38	117.13	18.92
	Donga	1092.89	3269.07	2176.0	1340	3452.1	1795.9	84.32	110.25	12.58
B	Haul Pac	7987.24	10348.5	1425.5	1	282.84	281.84	82.89	97.3	5.11
	Chopper	7910.9	8262.91	72.32	20	184.39	113.38	88.99	94.12	1.1
	Crusher	7989.79	8483.11	187.7	1	184.39	84.85	84	92.83	1.86
C	Roller	113.14	472.02	213.54	493.96	640	84.88	383	396	6.5





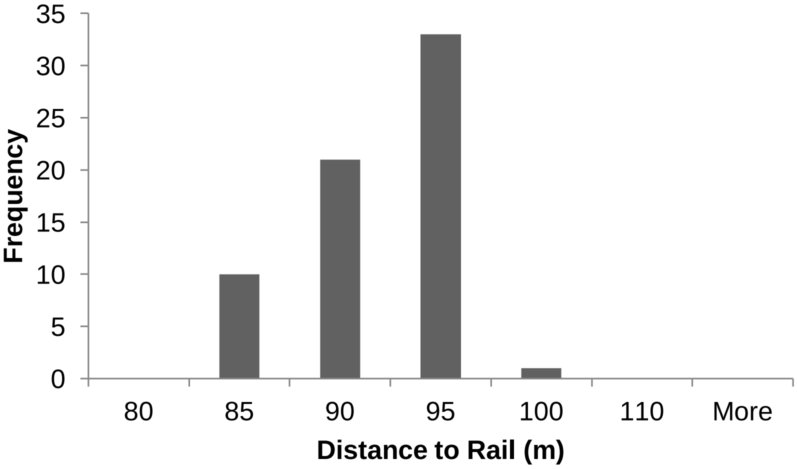
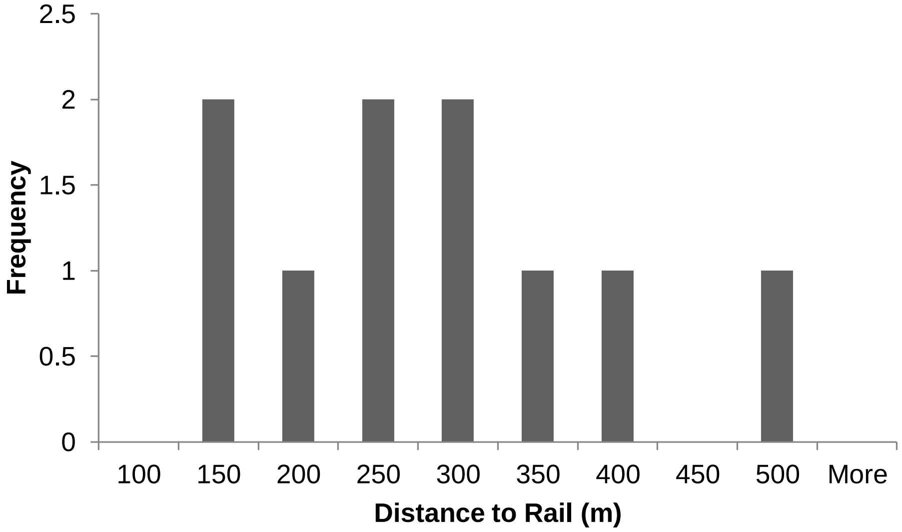
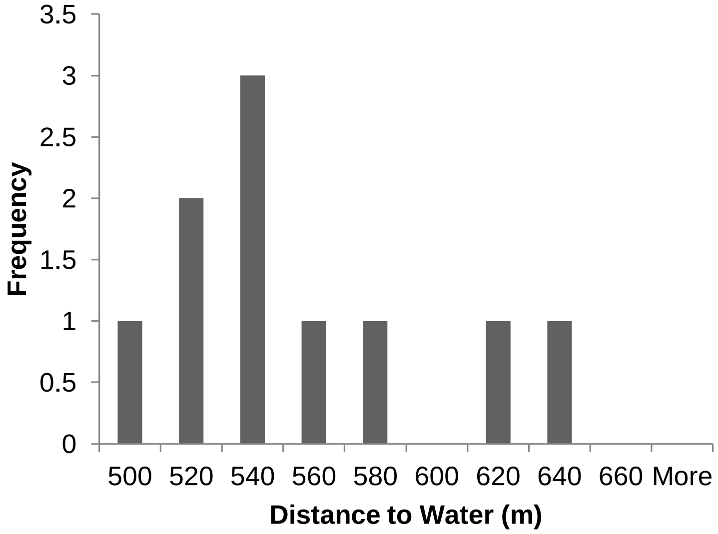


Figure 21. Combined data from all individuals at Indee Station displaying the frequency of each coordinate from Distance to rail, distance to water and Digital elevation.

Site C-Quoll Knoll

All locations recorded for the individual at Site C were located within 150-500m from rail infrastructure. The individual at Quoll Knoll was potentially within distance a distance of 500-640m to water. Most commonly this individual was located within 540m of access to free water. Coordinates recorded at this site fall within 384-396m above sea level but are most common at an elevation between 386-388 m. Summary statistics of the variables for each individual are displayed in Table 15.





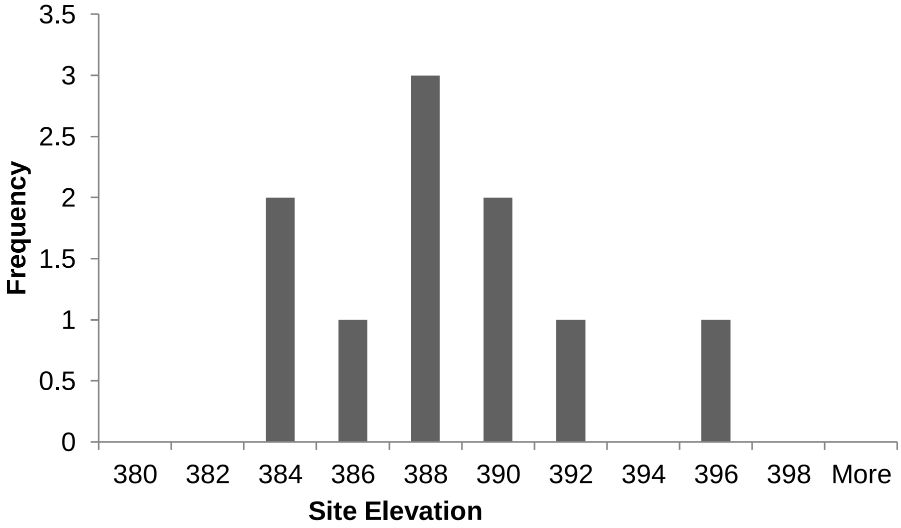


Figure 22. Combined data from the individual at Quoll Knoll displaying the frequency of each coordinate from Distance to rail, distance to water and Digital elevation.

5.3.4 Summary

Due to variation in topography at each site, the trends observed were limited to comparing similarities between individuals at each site. Site C had only one collared individual so observations were limited to preferences from just one animal. It is difficult to determine similarities between floristic preferences whereas preference for metamorphosed rock is more apparent. Distance to landscape features, rail and water, show no pattern to determine a preference or avoidance for these features. The elevation of sites A and B are similar, although site A is elevated from the surrounding landscape. This is less apparent at site B. Elevation at site C is much greater than either of the other study sites.

Preferential use of floristic array and geological substrates were investigated for each individual animal. Notes and GIS maps of this analysis are presented in Appendix 7 and 8.

5.3 Infrastructure Barriers

Presences of Northern quoll were only recorded by camera traps at Quoll Knoll. No other study sites recorded Northern quoll activity on camera. Other species were recorded including Rothschild's rock wallaby (*Petrogale rothschildi*) at Rail Camp 1, common rock rat (*Zyzomys argurus*) and Torresian crow (*Coruvs orru*) at Mesa 228. At Quoll Knoll painted finch (*Emblema pictum),* spinifex pigeon (*Geophaps plumiferum*), Torresian crow, and common rock rats were recorded. Quoll Knoll demonstrated the greatest amount of activity when compared to all other sites.

A total of 8 camera trap images of Northern quoll were recorded at Quoll Knoll over a total of 114 trap nights. Northern quolls were active throughout the day with activity observed during day light, dusk and dawn (half light) and at night (Figure 23). Activity was recorded consecutively on the 5 July from two different cameras, potentially from the same individual (Table 16). This equates to a detection rate of 1.26% and a relative abundance index of 7 at this site.

Table 16. Date and time of presences recorded by camera traps of Northern quoll at Quoll Knoll.

Date	Time	Camera No.	
14/07/2015	8:01:00 AM	QN55	Half light
15/06/2015	8:56:33 AM	QN56	Daylight
17/06/2015	6:18:11 AM	QN56	Half light
3/07/2015	3:26:14 AM	QN56	Daylight
5/07/2015	5:12:06PM	QN56	Dark
5/07/2015	5:45:12 PM	QN56	Dark
10/07/2015	2:16:53PM	QN56	Daylight
5/07/2015	7:56:32 PM	QN53	Dark

Figure 23. Day and night recorded images of Northern quoll at Quoll Knoll.

Cameras set at underpasses by Ecologia Environment resulted in 600 trap nights and the detection of three individual northern quoll in the vicinity of underpass openings. Other species recorded included euro (*Macropus robustus*), domestic cattle (*Bos Taurus*), spinifex pigeon, Torresian crow and willy wagtail (*Rhipidura leucophrys*). Feral cats and feral dogs were present at six of nine camera locations.

Ecologia Environment cameras resulted in a detection rate of 0.32% for Northern quoll and a relative abundance index of 1.5 individuals. For predators the detection rate was 2.66% and the RAI was 4.17 individuals. Cats were present at both sites where Northern quoll were detected. Predators were only recorded on cameras which were located at underpass openings.

Figure 24. Three images captured of Northern quoll at the entrance to underpasses below Roy Hill Rail line.

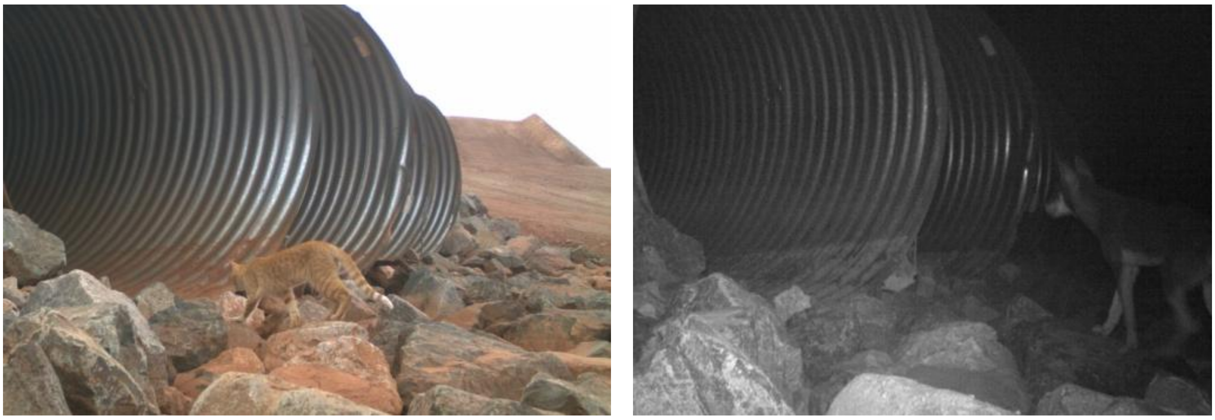


Figure 25. Images captured by camera traps displaying the use of rail underpasses by feral cats and dogs.

Crossing events through underpasses should be detectable by paired camera trap images from cameras on the east and west side of a single underpass. No paired footage of Northern quoll activity was recorded.

6. Discussion

6.1 Home Range Analysis

This study produced 131 locations for seven Northern quoll at three different sites in the Pilbara. This data was used to undertake home range analysis using more accurate GPS technology and spatial analysis. From this MCP and KDE home range estimates, and the maximum distances travelled in the course of a nights foraging, were calculated for males and females. Northern Quolls demonstrated interactions with human infrastructure and roads, but were not observed to cross deep rail cuttings.

Previous home range studies of Northern quoll have used radio telemetry and grid trapping studies to successfully record locational data for the Northern quoll (Begg, 1981; Braithwaite & Griffiths, 1994; Cook, 2010; Johnson & Oates, 2014; King, 1989; Oakwood, 2002; Schmitt et al., 1989). Radio telemetry data collection has been limited to day time due to the constraints of tracking individuals on foot in rocky terrain at night (Cook, 2010; Johnson. B. & Oates, 2014; King, 1989) Current estimates for female home range vary from 2.3ha to 219.6ha, while for males estimates vary from 1.77ha to 1089.8ha (see Table 17). Previous estimates for Northern quoll are markedly different from one another. This could be due to differences in habitat type, methods of data collection and differences in calculation of home range estimates. Data collected from these studies have been produced from radio tracking efforts so are generally limited to daytime den locations and therefore, may not be an accurate representation of the nocturnal foraging home range for the Northern quoll.

Table 17. A comparison of the current Northern quoll home range estimates from the Literature.

Author	**Male**	**Female**	**Maximum Distance Travelled**
Henderson (2015) MCP 95%	58.032ha	13.431 ha	5.02km (1 night)
Johnson & Oates, (2014) MCP 95%	1097.8ha	9.7ha	3.3km
(Cook, 2010) MCP	74.8ha	11.6ha	
(Oakwood, 2002) MCP	99ha	35ha	1.53km (1 day)
(Braithwaite & Griffiths, 1994) Index of Movement	1.77ha	16.56ha	-
(Schmitt *et al*., 1989) MCP	1.8ha	2.3ha	2.5km(1day)
(King, 1989) MCP	382.4ha	219.6ha	3.5km(7days)
(Begg, 1981) Mean distance between captures	94ha	11ha	1.2km

The most commonly quoted estimates are from Oakwood (2002) using the Minimum Convex Polygon method of analysis. Schmitt, Bradley *et al* (1989) use the same method of calculation to produce much smaller estimates within rocky country, but differences could also be due to the size of the cage trapping grids used (Braithwaite & Griffiths, 1994). Estimates by Oakwood (2002) were also achieved using a grid-trapping study and was therefore constrained by its size and layout (King, 1989). King (1989) used radio telemetry to record the longest move for an individual Northern quoll of 3.5km. Most recent studies by Cook (2010) and Johnson & Oats (2014) also use radio tracking techniques to determine MCP home range estimates.

Estimates from this study, determined by GPS tracking, were used to produce MCP home range in order to make comparisons with current literature. These estimates were based on night time foraging movements rather than day time den locations. Making comparisons between all studies is difficult due to differences in trapping locations and habitat type, the length of time tracking was undertaken, the number of animals tracked and differences in seasonal timing of tracking. Johnson & Oats (2014) and Cook (2010) have suggested that previous home range estimates are an underrepresentation of the total area of activity for Northern quoll because nocturnal foraging is not included. Nocturnal foraging incorporates long distance movements which are generally confined within a home range area. However, MPC home range estimates from this study using GPS coordinates are similar to and fall within the estimates achieved from radio tracking by Cook (2010), Johnson & Oats (2014), Oakwood (2002), King (1989) and Begg (1981). The results of tracking analysis in Figure 7 and 9 show that during nocturnal foraging Northern quoll traverse large distances with a male (Haul Pac) travelling up to 5km and a female (LV) up to 2.8km in the course of a single nights movements.

Kernel density analysis produced a greater estimate of home range size based on an intensity of use determined from coordinates (Kie *et al*., 2010). High density of coordinates defined areas of core use and highlighted more than one area of core habitat use for each individual. Core areas are those which are associated with food acquisition, shelter and reproduction (Haby *et al*., 2013). These are likely to be situated close to preferred den sites with observations from movement data indicating that individuals potentially forage in a pattern which involves moving between den sites. Core areas defined by Kernel analysis (Figures 6-12) showed little overlap between individuals suggesting each individual has their own defined territories. Outer areas of Kernel home range, with low intensity of use, are where overlap of home ranges occurred for both males and females.

Well demonstrated by the movements of Semi (Figure 6), Haul Pac (Figure 9) and Roller (Figure 12), Northern quoll at all sites were closely linked to narrow linear landscape features. These include rocky granite, quartz and ironstone rocky outcrops and open riverine areas with large granite boulders. Commonalities between features were distinctly linked to hard complex rocky substrates which have previously been defined as preferred habitat (Begg, 1981; Bradley *et al*., 1987; Braithwaite & Griffiths, 1994; Burnett, 1997; Oakwood, 2002). Movements away from these areas were observed by only 2 individuals and one of these was in interaction with human habitation at Rail Camp 1 (see Figure 9). It is possible that the presence of human infrastructure, and the availability of resources within these areas, such as rubbish, scraps and insects attracted to the artificial light, attracts Northern quoll to move outside of their normal home range. There is the potential for additional predation by feral species which are also attracted to these areas. Although foraging was not completely confined to rocky habitat, many of the requirements for survival must be available within this habitat as few animals demonstrated movements away from these areas.

Landscape barriers including rail and gravel roads were present at two of the three sites. Home ranges incorporated areas on either side of light vehicle gravel roads with repeated daily crossings from 5 individuals at two sites. Traffic at Quoll Knoll is busy with wide heavy vehicles and small light vehicles utilising this road frequently, especially at dawn and dusk. A number of studies document the susceptibility of Australian fauna to vehicle induced mortality (Rico *et al.*, 2007; Taylor & Goldingay, 2010). Marsupial carnivores have a high risk of road mortality as they are attracted to roadsides to scavenge on carcasses of road kill (Jones, 2014). Road mortality was a major cause of death in a three year study of Northern quoll, undertaken by Oakwood (2000), and was the cause of 20% of all known deaths. Road induced mortality has the potential to cause reductions in the total population size of wildlife (Taylor & Goldingay, 2010) and it is thought to cause populations to become locally extinct (Rico *et al.*, 2007). Management of traffic volumes at important sites could be the key to managing the potential for vehicle induced mortalities.

This site, Quoll Knoll, is the closest in proximity to rail infrastructure. No coordinates were recorded on the far side of the rail line (visible in figure 12), suggesting that the collared individual at this site made no attempts to cross the rail. There is the potential for Northern quoll to utilise rail and road underpasses to mitigate the effects of these infrastructure barriers within the landscape (Jones, 2014). Conservation measures such as underpasses, are used to link isolated and vacant population units, to restore local extinctions, to reduce the probability of regional extinction and to facilitate range adjustments in line with climate change (Dennis *et al.*, 2013). These may be beneficial for large scale movements and dispersal of young but it is yet unknown if these structures are utilised by Northern quoll to facilitate small scale movements such as daily foraging. Given there is a tendency for Northern quoll to utilise linear landscape features, it is likely that rail infrastructure will only pose an issue when it crosses these features. Dispersing males such as the male collared at Quoll Knoll are most likely to be impacted by rail infrastructure barriers.

6.2 Characteristics of Foraging Habitat

An unsupervised isocluster classification was performed using Landsat imagery to identify floristic classification at each site. Coordinates were overlaid upon the layers; floristic classification, geological series and digital elevation to investigate use of these variables within foraging habitat. Euclidian distance to line was performed on drainage lines and rail infrastructure to calculate an average distance of each coordinate from these landscape features. Coordinates were combined at each site to investigate trends in preferential habitat use.

In order to protect and manage high quality habitat for conservation it is important to understand the broad and fine scale requirements of each species, especially within core areas of habitat (Haby *et al*., 2013). The selection of habitat is a behavioural choice made when selecting resources altering the density and distribution of individuals across different habitats (Chetkiewicz *et al*., 2006). Resources are spread across the landscape at a variety of spatial and temporal scales (Chetkiewicz *et al*., 2006; Dennis *et al*., 2013). Animals must move to forage, sleep, avoid predators, find mates or avoid territories. Throughout these movements animals are continuously assessing habitat for suitability in order to maximise individual fitness (Chetkiewicz *et al*., 2006). The use of habitat by an individual is a behavioural choice made when selecting resources (Chetkiewicz *et al*., 2006). This alters the density and distribution of individuals across different habitats according to the spread of resources across the landscape (Chetkiewicz *et al*., 2006; Dennis *et al*., 2013).

Until recently, preferred habitat for the Northern quoll has generally been described as ‘complex rocky areas’ (Begg, 1981; Bradley *et al*., 1987; Burnett, 1997; Oakwood, 2002; Turpin & Bamford, 2014). Rocky areas include ranges, escarpments, gorges, and boulder fields and are often present in association with major drainage lines and treed creek lines (Turpin & Bamford, 2014). The key reason for this association is the apparent creation of refuge habitat from introduced predators (Oakford, 2000; Turpin and Bamford, 2014). Rocky habitat is also expected to provide a greater number of den sites, retain more water, provide greater refuge from fire, support greater food resources, productivity and floristic diversity for the Northern quoll (Turpin & Bamford, 2014). Johnson & Oats (2014) state that within rocky habitat likely preferences are related to areas that are; elevated from the surrounding habitat, have a slope of 2-10°, are highly rough, rather than a level surface, with vegetation not necessarily being an important factor (Johnson & Oates, 2014) . This research indicates that Northern quoll may prefer areas of sparse vegetative cover (Johnson & Oates, 2014).

Results from this study suggest limited preferential use of a specific floristic community across all sites (Table 13). Site preferences included low dense shrub land, shrub steppe, low sparse woodland and open rocky grassland. Very little similarity can be determined between each of these classifications other than the presence of dominant species of *Acacia* and *Triodia*. In the three areas of this study, Northern quoll were not observed to use hummock grasslands or low lying open sloping plains and floodplains especially those in association with sand, silt and clay. Vegetative preferences have been linked to higher floristic diversity and productivity found within rocky habitat (Braithwaite & Griffiths, 1994) as well as greater prey density in these areas. This is in contrast to the availability of resources availability in the surrounding landscape (Burnett, 1997) .

Use of habitat by Northern quolls was influenced by vegetation in association with local geomorphology. Coordinates fell within well defined geological classifications but few patterns in the spread of locations across vegetation classifications were observed. This is demonstrated in figures 33-39 of Appendix 8. Trends in locational data were closely linked to geological substrates. Coordinates for each animal fell within only two to three substrates in an area and recorded movements rarely strayed from within geologically mapped categories. At each site there was a strong preference for rock type and often the availability of this substrate within the landscape was fully utilised by one or two animals (Table 14). This suggests that the geology of the landscape is an important factor for determining foraging habitat for the Northern quoll.

The formation and geological structure of the rock is potentially the determining factor relating to habitat preference for the Northern quoll. The importance is not necessarily the presence of rock but the shelter created by cracks and crevices in the rock. Geologic substrates of preference are defined as metamorphosed chert, biotite monzogranite and talc-carbonate/talc-chlorite-carbonate schist (Table 14). Metamorphic rocks form under intense heat and pressure altering the composition of the original igneous, sedimentary or metamorphic rock (Palmer & Johnson, 2010). This process causes segregation of the minerals within the rock forming planar foliation (Palmer & Johnson, 2010). Minerals form parallel to each other and at right angles to major stress points (Palmer & Johnson, 2010). Highly grained examples such as shale split easily along grain lines while low grade forms schist and course grade layered rock such as gneiss. Metamorphosed rock with planar structures such as shale, shist, chert and quarts were observed to be preferred habitat for Northern quoll at Sites A and B and granite rocks at site C.

This could be more closely linked to den site preferences and protection from predators, such as Dingoes, feral Cats snakes, owls and kites (Turpin & Bamford, 2014). Areas with round open cavernous limonite caves such as those available at Mesa 228, recorded no presences of Northern quoll. This suggests that the size, shape and dimension of the opening to den sites are important. Northern quoll have a specially adapted pes for movement along rocks and can move with speed and ease along rocky substrates (Begg, 1981). This adaptation and the provision of refuge habitat created by rocky crevices may be linked to the preference for rocky habitat (Oakford, 2000; Turpin & Bamford, 2014).

Habitat at Indee Station defies suggestions that elevation, slope and rugosity are important factors for habitat selection (Johnson & Oates, 2014). Although this site is situated at elevation similar to Rail Camp 1 it does not exhibit sloping hills or highly rugose surfaces on rock outcrops which are available at Site A and C. It is generally on the same elevation as the surrounding shrub and spinifex covered plains. The rugosity of the geological substrate is minimal with level flat surfaces, made up of large boulders. Individuals were confirmed to utilise open areas, as determined by multiple sets of quoll tracks observed in river sands. These areas displayed very little cover from vegetation or rocky crevices for protection.

The population at this site is made up of numerous individuals with highly overlapping home ranges as demonstrated in Figure 13. Therefore resources are expected to be abundant, in order to support this population. Access to free water is the most identifiable difference in resource availability when compared to other sites; all animals at this site were within 200m of water at all times. Northern quoll can survive without water but are known to regularly drink free water when available (Braithwaite & Griffiths, 1994). The presence of free water is more likely to impact the availability of key resources from primary productivity such as fruits and insect abundance in this area (Braithwaite & Griffiths, 1994).

6.3 Impacts of Infrastructure Barriers

Three camera traps placed in key locations at the entrance of underpasses located along Roy Hill rail infrastructure captured Northern quoll activity. Presences from Northern quolls were limited to night time activity. Other faunal species were observed to use underpasses including, feral cats and dogs. This creates an increased risk of predation at these sites. No paired crossing events were observed from Northern quoll which would confirm the use of underpasses to cross rail infrastructure.

Underpasses located along Roy Hill rail infrastructure have been engineered to facilitate the movement of water through the landscape and to prevent flooding, especially during the wet season and consequently these underpasses are not designed as habitat corridors to create habitat connectivity pathways for wildlife (Dennis *et al.*, 2013). Barriers for wildlife are often created by avoidance of infrastructure corridors such as roads, due to the presence of a hostile environment (McGregor, 2004). Previous studies indicate that the width of the barrier, independent of the surface structure (sealed or dirt), and the volume of the traffic within the area is important to the movements of small mammals (Rico *et al*., 2007). Linear clearings, such as roads, may not create barriers for all species but can still contribute to the mortality of populations through possible vehicle collision (Rico *et al.*, 2007).

Northern quoll activity was observed at entrances to rail underpasses along the Roy Hill railway line. Activity was demonstrated at underpasses in the vicinity of Quoll Knoll in Figure 22. Other fauna observed to utilise underpasses included euro, domestic cattle, and feral cats and dogs. Crossing events were recorded from both euro and feral Cats, but not Northern quoll. Activity of Northern quoll was limited to night (Figure 24), which differed from presences observed at Quoll Knoll in during day light (Table 16). This could be related to the presence of introduced predators seen at underpasses in Figure 25, but not observed elsewhere. Feral cats were present at all sites that recorded the presence of Northern quoll. The presence of feral cats and dogs at these sites creates the increased potential for Northern quoll to be predated upon at these sites.

Quolls were observed to utilise and possibly forage around the rocks surrounding underpass entrances. These rocks present potential foraging habitat for the Northern quoll due to the size, placement and the availability of rocky habitat. A collared male was tracked to rocks surrounding the opening of an underpass during the day, which suggest a further potential for underpasses to be used as denning habitat.

7. Conclusion

GPS location data was collected from seven Northern quolls at three different sites in the Pilbara and was used to determine new home range estimates using two different techniques. Estimates were compared to those from previous studies that did not include nocturnal foraging data (Cook, 2010; Johnson & Oates, 2014). Both KDE and MCP home range estimates from this study fall within estimates achieved from radio tracking techniques. It is possible that prior home range estimates using radio tracking are an over-estimate of home range size for the Northern quoll. This is because GPS telemetry allows for greater precision and more accurate locational data collection which is unbiased, frequent, and can be collected at night (Hebblewhite & Haydon, 2010). However differences between each of the studies such as habitat type, the length of time tracking was undertaken, the number of animals tracked, differences in seasonal timing of tracking and differences in calculation of home range estimates make comparisons between all studies difficult to determine.

It was observed that within home ranges, male Northern quoll can move up to 5km per night while female can move up to 2.8km per night (Table 11). Therefore, Northern quoll traverse large distances in the course of a single nights foraging. Kernel analysis identified that each individual displayed two to three core areas of foraging habitat which are likely to be situated close to preferred den sites. Observations from movement data indicated that Northern quoll forage in a pattern which involved moving from one den site to another. These observations are demonstrated in Figures 6-12 of individual Northern quoll home range estimates. Core home range areas which were defined by Kernel analysis showed little overlap between individuals suggesting each individual has their own defined territories.

Results of this study suggest limited preferential use of a specific floristic community across all sites. Northern quoll may prefer areas of lower vegetative cover (Johnson & Oates, 2014) but preferences are more likely to be determined by vegetation associations with local geomorphology and vegetation structure, rather than species composition (refer to Appendix 7). Areas which were rarely utilised by Northern quoll included hummock grasslands and low lying open sloping plains and floodplains especially when in association with sand, silt and clay on floodplains. It was observed that elevation, slope and rugosity are not necessarily important factors for habitat selection (see Figures 20, 21 and 22).

The geology of the landscape is an important factor for determining foraging habitat for the Northern quoll. At each site there was a preference for a certain rock type and often the availability of this substrate within the landscape was fully utilised by one or two animals. This suggests that the geology of the landscape is an important factor for determining foraging habitat for the Northern quoll. Preferred geologic substrates were defined as metamorphosed chert, biotite monzogranite and talc-carbonate/talc-chlorite-carbonate schist (see Table 14). The potential determining factor for preferential habitat use for the Northern quoll is the formation and geological structure of the rock. The importance of this habitat type may not be determined by the presence of rock but the shelter created by the structure and shape of the denning habitat it provides. The likely cause and determining factor for den site preferences is protection from predators. This makes the size, shape and dimension of openings to den sites important. In this study the most important factors driving habitat selection appeared to be; the availability of free water and, rocky substrates, with planar foliation which, provide protection from predation.

Northern quoll demonstrated interaction with roads and human infrastructure and avoidance of rail infrastructure. Home ranges incorporated areas on either side of light and heavy vehicle gravel roads with repeated crossings by numerous individuals (Figure 12). An individual male demonstrated interactions with human habitation within the Roy Hill Camp 1 village (Figure 9). Although Northern quoll do not seem to be affected by human disturbances, there is the potential for increased vehicle induced mortalities in areas such as Quoll Knoll, where vehicle use is relatively frequent.

Roy Hill rail was not yet in full operation with test haulage beginning towards the end of trapping period. The long term impacts of these disturbances and the increased use of the rail line especially at Quoll Knoll are yet unknown. No coordinates were recorded on the far side of the rail line, suggesting that the collared individual at this site made no attempts to cross the rail (Figure 12). Although presences of Northern quoll were apparent at rail underpasses, no paired footage from camera trap data was recorded, to indicate successful crossing. There is the potential for Northern quoll to utilise rail and road underpasses which may be beneficial for large scale movements and dispersal of young. Unfortunately, it is yet unknown whether or not these structures are utilised by Northern quoll to facilitate landscape movements or if they create potential foraging and den site habitat. The presence of feral cats and dogs at rail underpasses may also increase the potential for the predation of Northern quoll at these sites by creating focal points for predators (Taylor & Goldingay, 2010).

This study of the Northern quoll in the Pilbara region has provided new data generated by GPS which is a more reliable technique than the traditional radio tracking method. It has also allowed for the collection of nocturnal foraging data, which is an important addition to current knowledge. Using this new data collection technique the calculation of home range estimates and a maximum distance moved during nocturnal foraging was calculated for males and females. Further investigation of this data has developed good information on the relationship of geology to habitat preference for the Northern quoll. Finally, it is important to acknowledge that no evidence was produced of Northern quoll crossing rail infrastructure during this study.

7.1 Recommendations for further study

Results of this study are limited to Northern quoll within the Pilbara region and apply to nocturnal foraging habitat within the areas of study. Results could have been improved by increasing the duration of the study and the redeployment of collars on the same individuals to increase data collection.

Further study and investigation of nocturnal GPS data is required to establish habitat selection and preferences that are common across the Pilbara region. This will require larger samples of individuals, over a greater number of sites and collaring for longer periods of time. As GPS telemetry technology improves it will be possible to collect a larger number of coordinates from individual collars. This will improve data collection rates and allow for greater statistical investigation of data. It will be beneficial to include the collection of diurnal activity. Until collar technology allows for a greater number of satellite fixes per collar, it will be necessary to make a trade off between the amount of nocturnal data collected and the inclusion of day time recordings. Until this time the inclusion of radio tracked data during daylight hours in addition to nocturnal data collection will be valuable. Increasing the sample size over a larger number of test sites within the Pilbara will also help to determine regional preferences rather than site specific preferences.

Further investigation of den site preferences could help to determine the common characteristics of geology and rock formations for the Northern quoll within the Pilbara. Further study is also required to investigate the hypothesis that; the properties of the rock type, such as planar cracks and crevices found in metamorphosed rock formations, are expected to be favoured habitat for den sites and that; Northern quoll do not stray far from these substrates during foraging to ensure that protection from predation is closely available.

Suggestions for management of the Northern quoll at sites such as Quoll Knoll include the continuation of feral predator control, and the management of traffic volume and speed. It is recommended that Roy Hill continue camera monitoring of rail underpasses to determine if these areas are used during foraging activity and as den sites and to determine if Northern quoll utilise underpasses to cross rail cuttings.

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Appendix 1: Raw Trap Site Coordinate

	lat	lon	ele	time	magvar	geoidheight	name	cmt	desc	src	sym	type
1	-22.1179	119.246	434.409	2015-06-19T07:02:08Z			01S	Messa			Flag, Blue	user
2	-22.1176	119.2456	436.2192	2015-06-19T07:08:48Z			02S	Messa			Flag, Blue	user
3	-22.1173	119.2454	429.753	2015-06-19T07:13:33Z			03S	Messa			Flag, Blue	user
4	-22.1169	119.2454	425.3956	2015-06-19T07:17:20Z			04S	Messa			Flag, Blue	user
5	-22.1166	119.2453	425.7688	2015-06-19T07:20:21Z			05S	Messa			Flag, Blue	user
6	-22.1162	119.2454	423.0162	2015-06-19T07:23:56Z			06S	Messa			Flag, Blue	user
7	-22.1158	119.2454	422.5684	2015-06-19T07:29:33Z			07S	Messa			Flag, Blue	user
8	-22.1154	119.2456	416.662	2015-06-19T07:36:22Z			08S	Messa			Flag, Blue	user
9	-22.1151	119.2457	416.0649	2015-06-19T07:40:29Z			09S	Messa			Flag, Blue	user
10	-22.1147	119.2459	414.4973	2015-06-19T07:43:28Z			10S	Messa			Flag, Blue	user
11	-22.1143	119.2461	413.3123	2015-06-19T07:45:52Z			11S	Messa			Flag, Blue	user
12	-22.1139	119.2463	412.4073	2015-06-19T07:51:22Z			12S	Messa			Flag, Blue	user
13	-22.1136	119.2464	409.2162	2015-06-19T07:55:02Z			13S	Messa			Flag, Blue	user
14	-22.1131	119.2465	405.3719	2015-06-19T07:58:08Z			14S	Messa			Flag, Blue	user
15	-22.1127	119.2467	406.3516	2015-06-19T08:01:46Z			15S	Messa			Flag, Blue	user
16	-22.1123	119.2468	406.1184	2015-06-19T08:05:00Z			16S	Messa			Flag, Blue	user
17	-22.112	119.247	407.1168	2015-06-19T08:07:41Z			17S	Messa			Flag, Blue	user
18	-22.1119	119.2473	407.8725	2015-06-19T08:10:34Z			18S	Messa			Flag, Blue	user
19	-22.1117	119.2476	407.2007	2015-06-19T08:12:46Z			19S	Messa			Flag, Blue	user
20	-22.1117	119.248	405.1853	2015-06-19T08:15:32Z			20S	Messa			Flag, Blue	user
21	-22.1117	119.2484	406.249	2015-06-19T08:34:47Z			21S	Messa			Flag, Blue	user
22	-22.1116	119.2487	404.6721	2015-06-19T08:36:22Z			22S	Messa			Flag, Blue	user
23	-22.1115	119.2491	403.963	2015-06-19T08:37:31Z			23S	Messa			Flag, Blue	user
24	-22.1115	119.2496	400.2027	2015-06-19T08:40:51Z			24S	Messa			Flag, Blue	user
25	-22.1113	119.25	400.9865	2015-06-19T08:45:41Z			25S	Messa			Flag, Blue	user
26	-22.1184	119.246	405.5124	2015-06-12T04:02:33Z			N1	Messa			Flag, Green	user
27	-22.1178	119.2457	423.7067	2015-06-12T04:10:19Z			N2	Messa			Flag, Green	user
28	-22.1176	119.2455	422.7496	2015-06-19T07:09:41Z			N3	Messa			Flag, Green	user

	lat	lon	ele	time	magvar	geoidheight	name	cmt	desc	src	sym	type
29	-22.1174	119.2453	420.8681	2015-06-19T07:12:43Z			N4	Messa			Flag, Green	user
30	-22.1172	119.2451	429.6962	2015-06-19T07:18:42Z			N5	Messa			Flag, Green	user
31	-22.1167	119.2448	429.1349	2015-06-19T07:23:28Z			N6	Messa			Flag, Green	user
32	-22.1162	119.2449	427.1043	2015-06-19T07:27:26Z			N7	Messa			Flag, Green	user
33	-22.1159	119.245	427.4134	2015-06-19T07:32:19Z			N8	Messa			Flag, Green	user
34	-22.1156	119.2452	426.9364	2015-06-19T07:37:20Z			N9	Messa			Flag, Green	user
35	-22.1153	119.2453	426.357	2015-06-19T07:43:40Z			N10	Messa			Flag, Green	user
36	-22.1149	119.2455	427.1138	2015-06-19T07:49:47Z			N11	Messa			Flag, Green	user
37	-22.1146	119.2457	425.7123	2015-06-19T07:53:10Z			N12	Messa			Flag, Green	user
38	-22.1144	119.2457	425.1453	2015-06-19T07:56:11Z			N14	Messa			Flag, Green	user
39	-22.1141	119.2458	416.2282	2015-06-19T08:03:33Z			N15	Messa			Flag, Green	user
40	-22.1137	119.2462	418.4862	2015-06-19T08:06:52Z			N16	Messa			Flag, Green	user
41	-22.1132	119.2462	414.2466	2015-06-19T08:10:03Z			N17	Messa			Flag, Green	user
42	-22.1128	119.2463	410.4274	2015-06-19T08:12:36Z			N18	Messa			Flag, Green	user
43	-22.1123	119.2465	401.0958	2015-06-19T09:01:58Z			N19	Messa			Flag, Green	user
44	-22.1119	119.2467	394.8344	2015-06-19T09:07:48Z			N20	Messa			Flag, Green	user
45	-22.1115	119.2469	397.4845	2015-06-19T09:11:40Z			N21	Messa			Flag, Green	user
46	-22.1112	119.2472	396.1793	2015-06-19T09:14:24Z			N22	Messa			Flag, Green	user
47	-22.111	119.2476	397.0475	2015-06-19T09:16:33Z			N23	Messa			Flag, Green	user
48	-22.1112	119.2481	404.4745	2015-06-19T09:18:56Z			N24	Messa			Flag, Green	user
49	-22.1113	119.2486	405.8015	2015-06-19T09:23:19Z			N25	Messa			Flag, Green	user
50	-22.1114	119.249	403.7293	2015-06-19T09:24:58Z			N26	Messa			Flag, Green	user
51	-22.0963	119.237	404.026	2015-06-12T02:22:02Z			QN2	QK			Flag, Green	user
52	-22.0965	119.2368	400.7183	2015-06-16T07:58:58Z			QN3NEW	QK			Flag, Green	user
53	-22.0966	119.2368	399.6079	2015-06-12T02:29:16Z			QN4	QK			Flag, Green	user
54	-22.0968	119.237	396.199	2015-06-12T02:33:10Z			QN5	QK			Flag, Green	user
55	-22.0966	119.2371	377.8143	2015-06-16T07:53:30Z			QN6NEW	QK			Flag, Green	user
56	-22.0965	119.2371	357.9786	2015-06-18T22:56:36Z			QN7	QK			Flag, Green	user
57	-22.0964	119.2371	371.407	2015-06-18T23:12:59Z			QN8	QK			Flag, Green	user

	lat	lon	ele	time	magvar	geoidheight	name	cmt	desc	src	sym	type
58	-22.0975	119.2366	389.8623	2015-06-12T03:01:20Z			LN3	QK			Flag, Green	user
59	-22.0978	119.2365	391.3754	2015-06-12T03:04:08Z			LN4	QK			Flag, Green	user
60	-22.0982	119.2365	394.7906	2015-06-12T03:07:12Z			LN5	QK			Flag, Green	user
61	-22.0985	119.2362	391.3657	2015-06-12T03:13:17Z			LN6	QK			Flag, Green	user
62	-22.0982	119.2363	397.0847	2015-06-16T08:31:14Z			LN8NEW	QK			Flag, Green	user
63	-22.0971	119.2368	358.8164	2015-06-18T08:18:12Z			LN9	QK			Flag, Green	user
64	-20.8016	118.6485	86.16016	2015-09-20T13:55:58Z			RC17	RC1			Flag, Blue	user
65	-20.8026	118.6489	87.16797	2015-09-20T13:56:23Z			RC18	RC1			Flag, Blue	user
66	-20.8024	118.6503	85.75781	2015-09-20T13:56:33Z			RC19	RC1			Flag, Blue	user
67	-20.8026	118.6495	85.51953	2015-09-20T13:58:01Z			RC20	RC1			Flag, Blue	user
68	-20.8021	118.649					RC21	RC1			Trapsite	
69	-20.8065	118.6476	70.25135	2015-07-02T05:37:26Z			BR1	Back Rock			Flag, Green	user
70	-20.8067	118.6474	107.9889	2015-07-02T05:41:50Z			BR2	Back Rock			Flag, Green	user
71	-20.8064	118.6474	104.6959	2015-07-02T05:46:27Z			BR3	Back Rock			Flag, Green	user
72	-20.8066	118.647	109.8385	2015-07-02T05:52:57Z			BR4	Back Rock			Flag, Green	user
73	-20.8067	118.6463	103.7013	2015-07-02T05:57:47Z			BR5	Back Rock			Flag, Green	user
74	-20.8068	118.6459	100.8375	2015-07-02T06:02:50Z			BR6	Back Rock			Flag, Green	user
75	-20.807	118.6456	102.6543	2015-07-02T06:06:21Z			BR7	Back Rock			Flag, Green	user
76	-20.8071	118.6454	101.2053	2015-07-02T06:08:40Z			BR8	Back Rock			Flag, Green	user
77	-20.8072	118.6451	98.68501	2015-07-02T06:16:56Z			BR9	Back Rock			Flag, Green	user
78	-20.8074	118.6449	101.8533	2015-07-02T06:22:27Z			BR10	Back Rock			Flag, Green	user
79	-20.8075	118.6445	100.1781	2015-07-02T06:27:45Z			BR11	Back Rock			Flag, Green	user
80	-20.8078	118.6443	99.61408	2015-07-02T06:33:05Z			BR12	Back Rock			Flag, Green	user
81	-20.8743	118.5823	91.2027	2014-08-24T06:30:55Z			IS01E	Indee			Flag, Blue	user
82	-20.8752	118.5812	70.69865	2015-06-30T05:51:21Z			IS01W1	Indee			Flag, Blue	user
83	-20.8746	118.5828	79.65612	2015-06-30T05:53:39Z			IS02E	Indee			Flag, Blue	user
84	-20.8753	118.5817	71.67838	2015-06-30T05:55:07Z			IS02W	Indee			Flag, Blue	user
85	-20.8749	118.5832	80.74781	2015-06-30T05:54:59Z			IS03E	Indee			Flag, Blue	user
86	-20.8754	118.5821	71.85566	2015-06-30T05:57:34Z			IS03W	Indee			Flag, Blue	user

	lat	lon	ele	time	magvar	geoidheight	name	cmt	desc	src	sym	type
87	-20.8753	118.5836	80.87844	2015-06-30T05:59:20Z			IS04E	Indee			Flag, Blue	user
88	-20.8757	118.5826	72.80739	2015-06-30T06:00:36Z			IS04W	Indee			Flag, Blue	user
89	-20.8755	118.584	80.30927	2015-06-30T06:07:24Z			IS05E	Indee			Flag, Blue	user
90	-20.8762	118.5829	84.40544	2015-06-30T07:39:22Z			IS05W	Indee			Flag, Blue	user
91	-20.8759	118.5842	80.7758	2015-06-30T06:08:56Z			IS06E	Indee			Flag, Blue	user
92	-20.8765	118.5831	85.43182	2015-06-30T07:40:38Z			IS06W	Indee			Flag, Blue	user
93	-20.8763	118.5845	80.45856	2015-06-30T06:10:56Z			IS07E	Indee			Flag, Blue	user
94	-20.8768	118.5835	85.78639	2015-06-30T07:42:19Z			IS07W	Indee			Flag, Blue	user
95	-20.8767	118.5848	80.40257	2015-06-30T06:13:17Z			IS08E	Indee			Flag, Blue	user
96	-20.8772	118.5837	84.22816	2015-06-30T07:44:02Z			IS08W	Indee			Flag, Blue	user
97	-20.877	118.5852	80.75714	2015-06-30T06:16:45Z			IS09E	Indee			Flag, Blue	user
98	-20.8777	118.5838	84.3308	2015-06-30T07:45:32Z			IS09W	Indee			Flag, Blue	user
99	-20.8774	118.5854	80.08533	2015-06-30T06:18:33Z			IS10E	Indee			Flag, Blue	user
90	-20.878	118.5841	88.6509	2015-06-30T07:46:46Z			IS10W	Indee			Flag, Blue	user
91	-20.8779	118.5855	81.49426	2015-06-30T06:20:02Z			IS11E	Indee			Flag, Blue	user
92	-20.8784	118.5844	87.07402	2015-06-30T07:48:21Z			IS11W	Indee			Flag, Blue	user
93	-20.8783	118.5857	81.61556	2015-06-30T06:21:37Z			IS12E	Indee			Flag, Blue	user
94	-20.8787	118.5848	87.65252	2015-06-30T07:50:03Z			IS12W	Indee			Flag, Blue	user
95	-20.8787	118.5859	80.62651	2015-06-30T06:23:26Z			IS13E	Indee			Flag, Blue	user
96	-20.8791	118.585	88.13772	2015-06-30T07:51:20Z			IS13W	Indee			Flag, Blue	user
97	-20.8791	118.5862	81.5969	2015-06-30T06:25:23Z			IS14E	Indee			Flag, Blue	user
98	-20.8794	118.5852	85.81438	2015-06-30T07:52:56Z			IS14W	Indee			Flag, Blue	user
99	-20.8793	118.5866	81.69954	2015-06-30T06:26:33Z			IS15E	Indee			Flag, Blue	user
100	-20.8799	118.5853	85.2452	2015-06-30T07:55:58Z			IS15W	Indee			Flag, Blue	user
101	-20.8795	118.587	82.71658	2015-06-30T06:28:31Z			IS16E	Indee			Flag, Blue	user
102	-20.8803	118.5853	85.50646	2015-06-30T07:57:29Z			IS16W	Indee			Flag, Blue	user
103	-20.8795	118.5875	81.69954	2015-06-30T06:31:43Z			IS17E	Indee			Flag, Blue	user
104	-20.8807	118.5855	85.73973	2015-06-30T07:59:50Z			IS17W	Indee			Flag, Blue	user
105	-20.8795	118.5879	82.95918	2015-06-30T06:34:56Z			IS18E	Indee			Flag, Blue	user

	lat	lon	ele	time	magvar	geoidheight	name	cmt	desc	src	sym	type
106	-20.881	118.5859	85.61843	2015-06-30T08:03:38Z			IS18W	Indee			Flag, Blue	user
107	-20.8795	118.5885	82.95918	2015-06-30T06:45:30Z			IS19E	Indee			Flag, Blue	user
108	-20.8811	118.5865	83.36974	2015-06-30T08:13:33Z			IS19w	Indee			Flag, Blue	user
109	-20.8799	118.5888	83.86426	2015-06-30T06:46:41Z			IS20E	Indee			Flag, Blue	user
110	-20.8813	118.5869	84.26548	2015-06-30T08:18:54Z			IS20w	Indee			Flag, Blue	user
111	-20.8807	118.5894	84.4241	2015-06-30T06:49:39Z			IS21E	Indee			Flag, Blue	user
112	-20.8816	118.587	84.26548	2015-06-30T08:20:13Z			IS21W	Indee			Flag, Blue	user
113	-20.8809	118.5898	83.95757	2015-06-30T06:51:18Z			IS22E	Indee			Flag, Blue	user
114	-20.8819	118.5871	84.04154	2015-06-30T08:21:30Z			IS22W	Indee			Flag, Blue	user
115	-20.8812	118.5902	83.99489	2015-06-30T06:53:09Z			IS23E	Indee			Flag, Blue	user
116	-20.8822	118.5873	82.75391	2015-06-30T08:22:41Z			IS23W	Indee			Flag, Blue	user
117	-20.8814	118.5907	85.33851	2015-06-30T06:55:03Z			IS24E	Indee			Flag, Blue	user
118	-20.8825	118.5875	83.31375	2015-06-30T08:24:01Z			IS24W	Indee			Flag, Blue	user
119	-20.8814	118.591	89.51508	2014-08-25T09:24:08Z			IS25E	Indee			Flag, Blue	user
120	-20.8826	118.5878	88.43246	2014-08-25T09:33:31Z			IS25W	Indee			Flag, Blue	user

Appendix 2: Raw Cage Trap Data for Northern Quolls

Date													Samples collected		Collar				
d/m	Location	Trap Num	Species	Sex	PIT (use sticker new animals)	N/R/RT^	Tot Wt Bag Wt	Animal Wt (g)	Age	Short Pes	Head Length	Pouch*, Testes W	Scat	Tissue	Frequency	Tag ID	Schedule	Photo	Comments
15-Jun	Quoll Knoll	QN4	D.hallucatus	F	163700079	R	160/540	380	A2	30.5	63.78	D		☐	151.1	1	8	☐	Roller
15-Jun	Quoll Knoll	QN3	D.hallucatus	F	361955622	N	170/450	280	A1	28.5	62.7	U		☐				☐	Bobcat-juvenile to small to collar
17-Jun	Quoll Knoll	QN4	D.hallucatus	F	163700079	RT													collar check
18-Jun	Quoll Knoll	QN6	D.hallucatus	F	163700079	RT													
19-Jun	Quoll Knoll	QN6	D.hallucatus	F	163700079	RT													
19-Jun	Quoll Knoll	LN4	D.hallucatus	F	361955622	RT													
22-Jun	Quoll Knoll	QN3	D.hallucatus	F	361955622	RT													cat man caught closest trap QN3
23-Jun	Mesa 228	N12	D.hallucatus	M	362045294	N	170/820	650	A2	15.3	65			☐	151.12	2	5	☐	Dozer-Frequency 151.119
23-Jun	Quoll Knoll	QN3	D.hallucatus	F	361955622	RT													
24-Jun	Quoll Knoll	QN2	D.hallucatus	F	163700079	RT													
24-Jun	Quoll Knoll	QN6	D.hallucatus	F	361955622	RT													
1-Jul	Quoll Knoll	QN4	D.hallucatus	F	361955622	RT													
1-Jul	Indee Station	IS15W	D.hallucatus	F	700257	R	720/180	540	A2	31.2	69.9	D			151.137	3	4-Jan	☐	Chopper
1-Jul	Indee Station	IS24W	D.hallucatus	M	44748	R	895	540	A	35.2	68	26.6			151.237	8	4	☐	Crusher
1-Jul	Indee Station	IS1E	D.hallucatus	M	953384	N	700/190	510		34.4	23.6				151.275	10	4	☐	Loco
1-Jul	Indee Station	IS16E	D.hallucatus	F	955922	R	660/190	470		33.9	73.5	D			151.197	6	4	☐	Furphy
2-Jul	RC1	RC1(4)	D.hallucatus	M	953468	N	700/170	530	A	31.4	73.5	22.4		☐	151.219	7	4	☐	Donga
3-Jul	RC1	BR1	D.hallucatus	F	361953781	N	550/160	390	D	32.3	67.2		☐	☐	151.178	5	4	☐	Semi
3-Jul	RC1	BR11	D.halluc	F	361953	N	525/16	365	U	33.9	60.8			☐	151.99	1	4	☐	LV

Date					PIT		Tot Wt						Samples collected		Collar				
d/m	Location	Trap Num	Species	Sex	(use sticker new animals)	N/R/RT^	Bag Wt	Animal Wt (g)	Age	Short Pes	Head Length	Pouch*, Testes W	Scat	Tissue	Frequency	Tag ID	Schedule	Photo	Comments
			atus		828		0												
4-Jul	RC1	BR2	D.hallucatus	M	953468	RT													
4-Jul	RC1	BR3	D.hallucatus	F	361953781	RT										5			Pit tag not reading
4-Jul	Indee Station	IS7E	D.hallucatus	M	3024287	N													Haul Pac
14-Jul	Quoll Knoll	LN4NEW	D.hallucatus	F	361955622	RT	625/240	385											
14-Jul	Quoll Knoll	QN6NEW	D.hallucatus	M	362044643	N	750/200	550	A	36.5	71.6	22.6		☐					Breaker
15-Jul	Quoll Knoll	QN2	D.hallucatus	M	362044643	RT			D										Waxing/pouch developed
15-Jul	Quoll Knoll	QN3NEW	D.hallucatus	F	163700079	RT	670/200	470											
15-Jul	Quoll Knoll	LN4NEW	D.hallucatus	F	361955622	RT	690/200												
16-Jul	Quoll Knoll	LN4NEW	D.hallucatus	F	163700079	RT													
16-Jul	RC1	BRNew	D.hallucatus	F	953828	RT	820/160												LV collar removed
17-Jul	Indee Station	IST6	D.hallucatus	M	955379	RT		660	A					☐					
17-Jul	Indee Station	IST6	D.hallucatus	M	3024246	RT	590	1kg+	A					☐					
17-Jul	Indee Station	IST6	D.hallucatus	F	3699588	RT	700/190	430	A			D		☐					
17-Jul	Indee Station	IST6	D.hallucatus	F	1955922	RT		510	A			D		☐		6			
17-Jul	Indee Station	IST3	D.hallucatus	F	3700257	RT	700/190	510	A			D		☐		3			
17-Jul	Indee Station	IST8	D.hallucatus	F	2045701	RT	560/160	400	A			D		☐					
17-Jul	Indee Station	IST8	D.hallucatus	F	62044748	RT	940/190	750	A					☐		8			
17-Jul	Indee Station	IST9	D.hallucatus	M	3024287	RT	1020/180	860	A					☐		9			

Appendix 3: Raw Data collated from Northern Quolls GPS Collars

ID	Individual	GMT Time	Latitude	Longitude	Duration	DOP	Satellites	Elevation	Label	GPS notation
1	Semi	3/06/2015 20:00:00 PM	-20.8065	118.6476				70.25135	Trapsite	BR1
2	Semi	4/07/2015 10:00	-20.8106	118.6391	47	1.2	7		Pinpoint	
3	Semi	5/07/2015 10:00	-20.8095	118.6425	40	4.2	5		Pinpoint	
4	Semi	6/07/2015 10:00	-20.8099	118.6412	40	2	4		Pinpoint	
5	Semi	6/07/2015 14:00	-20.807	118.6456	48	2.2	4		Pinpoint	
6	Semi	6/07/2015 22:00	-20.8108	118.6395	37	1.8	5		Pinpoint	
7	Semi	9/07/2015 10:00	-20.8116	118.6373	59	9.2	4		Pinpoint	
8	Semi	12/07/2015 14:00	-20.8115	118.6372	47	1.8	3		Pinpoint	
9	Semi	15/07/2015 0:30	-20.8115	118.6374				91.90373	Deceased	DEATH5
10	Semi	16/06/2015 20:00:00 PM	-20.8064	118.6474				104.6959	Trapsite	BR3
11	Chopper	1/07/2015 20:00:00 PM	-20.8799	118.5853					Trapsite	IS15W
12	Chopper	2/07/2015 20:00:00 PM	-20.8813	118.5869					Trapsite	IS20w
13	Chopper	2/07/2015 10:00	-20.8815	118.5869	30	4.2	3		Pinpoint	
14	Chopper	3/07/2015 17:00:00 PM	-20.8809	118.5865				87.5659	Habitat	TAG3
15	Chopper	3/07/2015 10:00	-20.885	118.5881	45	4	4		Pinpoint	
16	Chopper	4/07/2015 15:00:00 PM	-20.883	118.5865					Habitat	IS
17	Chopper	4/07/2015 10:00	-20.8829	118.5866	53	3.2	3		Pinpoint	
18	Chopper	5/07/2015 14:00	-20.8845	118.5876	50	3.6	4		Pinpoint	
19	Chopper	5/07/2015 22:00	-20.8844	118.5877	39	4.2	4		Pinpoint	
20	Chopper	6/07/2015 14:00	-20.8848	118.5877	49	6.8	3		Pinpoint	
21	Chopper	7/07/2015 10:00	-20.8843	118.5872	21	6.8	5		Pinpoint	
22	Chopper	7/07/2015 14:00	-20.884	118.5872	42	2.2	4		Pinpoint	
23	Chopper	8/07/2015 18:00	-20.8841	118.5877	39	1.2	6		Pinpoint	
24	Chopper	8/07/2015 22:01	-20.8824	118.587	69	2.2	5		Pinpoint	
25	Chopper	9/07/2015 10:00	-20.8829	118.5873	37	1.6	6		Pinpoint	
26	Chopper	9/07/2015 18:00	-20.885	118.5884	44	16.8	3		Pinpoint	
27	Chopper	9/07/2015 22:00	-20.8827	118.5865	38	4.6	3		Pinpoint	
28	Chopper	10/07/2015 10:01	-20.8829	118.5874	69	4	4		Pinpoint	
29	Chopper	10/07/2015 14:01	-20.8872	118.5901	66	29.8	3		Pinpoint	
30	Chopper	10/07/2015 18:00	-20.8848	118.5879	49	4.2	3		Pinpoint	

ID	Individual	GMT Time	Latitude	Longitude	Duration	DOP	Satellites	Elevation	Label	GPS notation
31	Chopper	17/07/2015 20:00:00 PM	-20.8841	118.5869					Trapsite	IST3
32	Crusher	1/07/2015 20:00:00 PM	-20.8825	118.5875				83.31375	Trapsite	IS24W
33	Crusher	2/07/2015 20:00:00 PM	-20.8822	118.5873				82.75391	Trapsite	IS23W
34	Crusher	3/07/2015 20:00:00 PM	-20.8819	118.5871				84.04154	Trapsite	IS22W
35	Crusher	3/07/2015 18:30:00 AM	-20.8806	118.586					Habitat	IS
36	Crusher	4/07/2015 20:00:00 PM	-20.8803	118.5853				85.50646	Trapsite	IS16W
37	Crusher	4/07/2015 17:00:00 AM	-20.8808	118.5847					Habitat	IS
38	Crusher	4/07/2015 10:00	-20.8809	118.5858	25	1.6	6		Pinpoint	
39	Crusher	4/07/2015 18:01	-20.8821	118.5863	66	1.6	4		Pinpoint	
40	Crusher	4/07/2015 22:01	-20.8792	118.5856	67	1.2	7		Pinpoint	
41	Crusher	5/07/2015 10:00	-20.879	118.5847	50	2	4		Pinpoint	
42	Crusher	5/07/2015 14:01	-20.8786	118.5858	68	2.4	3		Pinpoint	
43	Crusher	5/07/2015 22:00	-20.8777	118.5828	51	2.2	4		Pinpoint	
44	Crusher	6/07/2015 10:00	-20.8798	118.5856	37	2.2	4		Pinpoint	
45	Crusher	6/07/2015 14:00	-20.8812	118.5866	44	2.2	5		Pinpoint	
46	Crusher	6/07/2015 18:01	-20.886	118.5881	68	7	3		Pinpoint	
47	Crusher	6/07/2015 22:00	-20.8819	118.5863	21	6.6	4		Pinpoint	
48	Crusher	7/07/2015 10:00	-20.8806	118.5869	49	6.4	3		Pinpoint	
49	Crusher	7/07/2015 14:00	-20.8804	118.5845	37	2	3		Pinpoint	
50	Crusher	8/07/2015 10:00	-20.8815	118.5868	21	23.6	4		Pinpoint	
51	Crusher	8/07/2015 14:00	-20.88	118.5832	37	1	7		Pinpoint	
52	Crusher	8/07/2015 18:00	-20.882	118.5883	37	1.2	6		Pinpoint	
53	Crusher	8/07/2015 22:00	-20.8786	118.5848	38	2.4	4		Pinpoint	
54	Crusher	9/07/2015 10:00	-20.8783	118.5847	39	14	4		Pinpoint	
55	Crusher	9/07/2015 14:00	-20.8762	118.5827	36	2	5		Pinpoint	
56	Crusher	10/07/2015 10:00	-20.8788	118.5843	38	2.6	3		Pinpoint	
57	Crusher	10/07/2015 14:00	-20.8937	118.5931	21	4.8	3		Pinpoint	
58	Crusher	10/07/2015 18:00	-20.889	118.5889	49	2.2	3		Pinpoint	
59	Crusher	10/07/2015 22:00	-20.8805	118.5874	37	1.4	6		Pinpoint	
60	Crusher	11/07/2015 18:00	-20.8828	118.587	39	1	5		Pinpoint	

ID	Individual	GMT Time	Latitude	Longitude	Duration	DOP	Satellites	Elevation	Label	GPS notation
61	Crusher	12/07/2015 10:01	-20.884	118.5878	67	6	4		Pinpoint	
62	Crusher	12/07/2015 14:00	-20.8981	118.5928	38	0.8	8		Pinpoint	
63	Crusher	16/07/2015 22:30:00 PM	-20.8787	118.5838				94.12999	Trapsite	IST8
64	Donga	2/07/2015 0:00	-20.8021	118.649					Trapsite	DONGA1
65	Donga	3/07/2015 23:30	-20.8071	118.6457				0	Habitat	Donga1
66	Donga	3/07/2015 14:00	-20.808	118.6454	29	4	3		Pinpoint	
67	Donga	4/07/2015 22:00	-20.8067	118.6474				107.9889	Trapsite	BR2
68	Donga	4/07/2015 10:00	-20.8062	118.6504	44	12.4	3		Pinpoint	
69	Donga	5/07/2015 14:00	-20.8016	118.6491	41	5.8	3		Pinpoint	
70	Donga	6/07/2015 14:00	-20.8012	118.6484	39	2.4	3		Pinpoint	
71	Donga	6/07/2015 22:00	-20.8126	118.6339	37	3.6	4		Pinpoint	
72	Donga	7/07/2015 10:00	-20.8141	118.6314	38	5	3		Pinpoint	
73	Donga	7/07/2015 14:00	-20.8132	118.6305	44	3.8	5		Pinpoint	
74	Donga	9/07/2015 18:00	-20.8012	118.6484	25	2	5		Pinpoint	
75	Donga	11/07/2015 18:00	-20.8013	118.6484	53	2.6	5		Pinpoint	
76	Donga	15/07/2015 0:00	-20.802	118.649					Deceased	
77	HaulPac	4/07/2015 20:00:00 PM	-20.8763	118.5845				80.45856	Trapsite	IS07E
78	HaulPac	4/07/2015 13:59	-20.8787	118.5846	50	2.2	5		Pinpoint	
79	HaulPac	5/07/2015 10:00	-20.8774	118.5816	38	5	5		Pinpoint	
80	HaulPac	5/07/2015 18:00	-20.8768	118.5817	39	5.6	3		Pinpoint	
81	HaulPac	6/07/2015 22:00	-20.8671	118.5662	44	3.8	3		Pinpoint	
82	HaulPac	7/07/2015 10:00	-20.8667	118.5658	51	1.6	6		Pinpoint	
83	HaulPac	8/07/2015 18:00	-20.8647	118.5671	39	1.4	6		Pinpoint	
84	HaulPac	8/07/2015 22:00	-20.8656	118.5662	43	2	3		Pinpoint	
85	HaulPac	9/07/2015 10:00	-20.8657	118.5662	51	1.2	5		Pinpoint	
86	HaulPac	10/07/2015 10:00	-20.8699	118.5718	40	2.8	3		Pinpoint	
87	HaulPac	10/07/2015 18:00	-20.8856	118.5881	49	1.6	5		Pinpoint	
88	HaulPac	11/07/2015 14:00	-20.8676	118.572	39	2.4	3		Pinpoint	
89	HaulPac	11/07/2015 18:00	-20.867	118.5684	36	2.4	3		Pinpoint	
90	HaulPac	11/07/2015 22:00	-20.8633	118.5633	37	1	6		Pinpoint	

ID	Individual	GMT Time	Latitude	Longitude	Duration	DOP	Satellites	Elevation	Label	GPS notation
91	HaulPac	12/07/2015 14:00	-20.8669	118.572	38	3	4		Pinpoint	
92	HaulPac	12/07/2015 18:00	-20.8641	118.5631	51	2.4	3		Pinpoint	
93	HaulPac	12/07/2015 22:01	-20.8694	118.5727	66	4.4	3		Pinpoint	
94	HaulPac	13/07/2015 10:00	-20.8687	118.5728	37	2.2	3		Pinpoint	
95	HaulPac	14/07/2015 14:00	-20.885	118.589	22	1.6	5		Pinpoint	
96	HaulPac	16/07/2015 8:46	-20.8695	118.5725				88.76994	Habitat	IST9
97	LV	3/07/2015 20:00:00 PM	-20.8075	118.6445				100.1781	Trapsite	BR11
98	LV	3/07/2015 13:59	-20.8103	118.6429	45	3.6	4			
99	LV	4/07/2015 22:00:00 PM	-20.8095	118.6424					Habitat	LV1
100	LV	4/07/2015 14:00	-20.8072	118.6456	46	6.6	3			
101	LV	4/07/2015 22:00	-20.8069	118.6464	38	2.6	5			
102	LV	5/07/2015 14:00	-20.8089	118.6429	22	5.6	3			
103	LV	5/07/2015 18:00	-20.8076	118.6457	49	4.2	3			
104	LV	6/07/2015 10:00	-20.8082	118.6411	45	16.8	3			
105	LV	6/07/2015 14:00	-20.8075	118.6472	37	4.4	3			
106	LV	6/07/2015 18:00	-20.8129	118.6412	38	16	3			
107	LV	6/07/2015 22:00	-20.8071	118.6467	38	3	3			
108	LV	7/07/2015 10:00	-20.8091	118.6469	46	6.4	3			
109	LV	7/07/2015 14:00	-20.8108	118.6423	49	5.8	3			
110	LV	8/07/2015 14:00	-20.8107	118.6373	40	6	3			
111	LV	8/07/2015 18:00	-20.8071	118.6463	37	1.6	4			
112	LV	9/07/2015 14:00	-20.8086	118.6472	40	14.4	3			
113	LV	9/07/2015 18:00	-20.8107	118.6392	37	1	8			
114	LV	10/07/2015 22:01	-20.8095	118.6424	51	6.8	4			
115	LV	11/07/2015 22:01	-20.8067	118.6445	50	4.8	3			
116	LV	16/07/2015 22:01	-20.8069	118.6476	23	6.2	3			
117	LV	21/07/2015 22:01	-20.8068	118.6472	47	2.6	3			
118	LV	23/07/2015 22:01	-20.8102	118.6409	21	1.2	5			
119	LV	27/07/2015 22:01	-20.8111	118.6385	22	2.6	5			
120	LV	16/03/2015 20:00:00 PM	-20.8102	118.6412				101.761	Trapsite	LV2

ID	Individual	GMT Time	Latitude	Longitude	Duration	DOP	Satellites	Elevation	Label	GPS notation
121	Roller	15/06/2015 0:00	-22.0966	119.2368				399.6079	Trapsite	QN4
122	Roller	17/06/2015 20:00:00 PM	-22.0966	119.2368				400.6079	Trapsite	QN5
123	Roller	17/06/2015 13:20	-22.0992	119.235	48	8.6	3		Pinpoint	
124	Roller	18/06/2015 20:00:00 PM	-22.0966	119.2371				377.8143	Trapsite	QN6NEW
125	Roller	18/06/2015 10:00	-22.0989	119.236	39	7.6	3		Pinpoint	
126	Roller	19/06/2015 20:00:00 PM	-22.0966	119.2371				378.8143	Trapsite	QN6NEW
127	Roller	24/06/2015 20:00:00 PM	-22.0963	119.237				404.026	Trapsite	QN2
128	Roller	25/06/2015 10:00	-22.0979	119.2364	34	2.8	5		Pinpoint	
129	Roller	25/06/2015 21:40	-22.0985	119.2363	49	3.8	4		Pinpoint	
130	Roller	14/07/2015 20:00:00 PM	-22.0969	119.2356				363.5203	Habitat	QNC2
131	Roller	16/07/2015 20:00:00 PM	-22.0976	119.2365				383.7868	Trapsite	LN4NEW

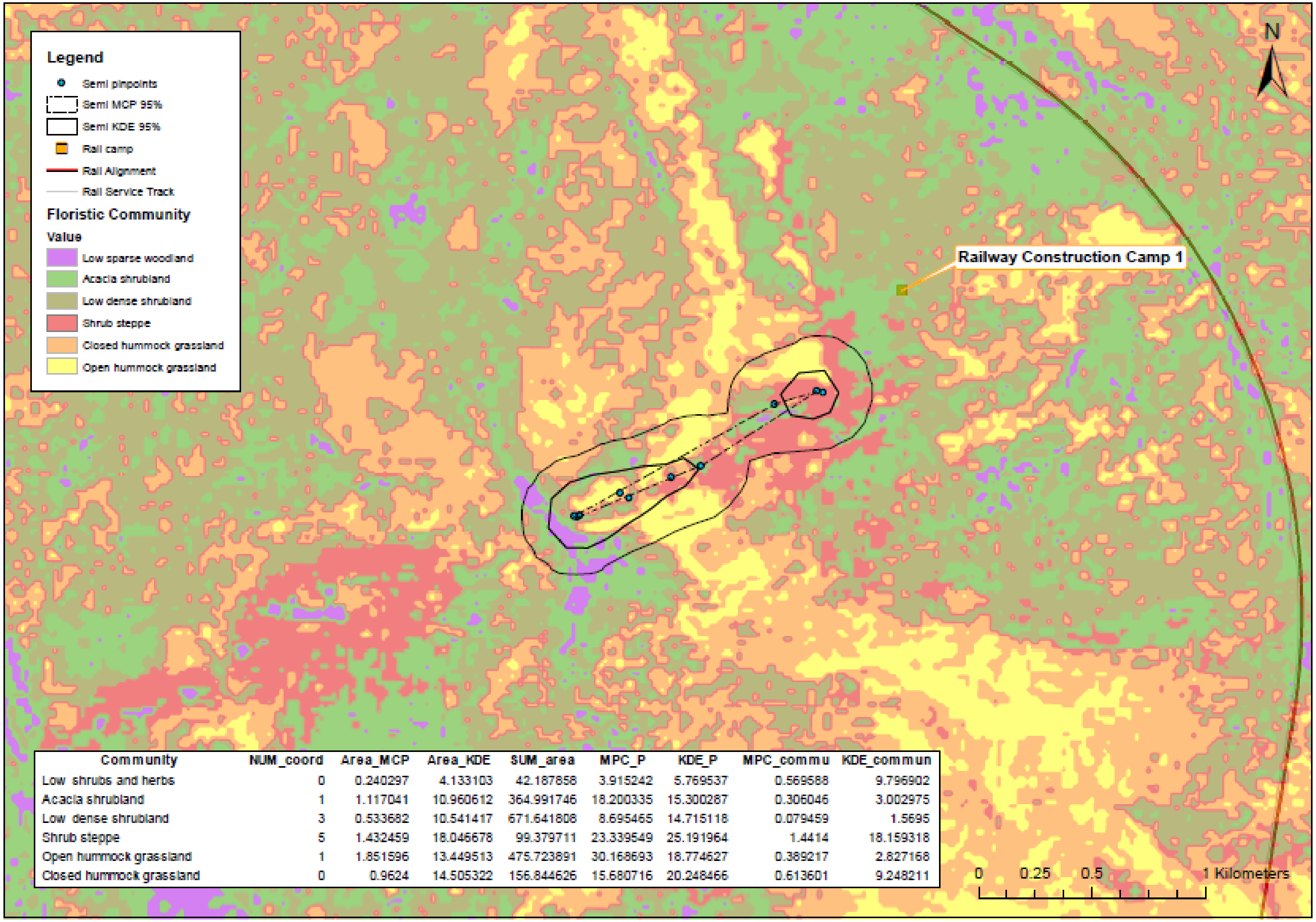
Appendix 4: Raw Camera Trap Data from Roy Hill Iron Ore

	Chainage	Camera No. (* = Roy Hill camera)	Date set	Date collected	Culvert type (diam.)	Easting	Northing	Size class	East or west
L02FC006	51600	8698 (RH3*)	30/05/2015	15/07/2015	600x1 brl	668649.7	7702247	1	east
L02FC006	51600	6800 (RH6*)	9/05/2015	15/07/2015	600x1 brl	668649.7	7702247	1	west
L03010	57372	361 (RH15)	10/05/2015	15/07/2015	1800x11 brl	673226.5	7698812	3	east
L03010	57372	ecoscape c5	9/05/2015	15/07/2015	1800x11 brl	673226.5	7698812	3	west
L09160	225689	1024 (RH06)	9/05/2015	14/07/2015	900x1 brl	731207.4	7554681	1	east
L09160	225689	8688 (RH1*)	9/05/2015	13/07/2015	900x1 brl	731207.4	7554681	1	west
L09161	225887	9795 (RH17)	7/05/2015	14/07/2015	2100x4 brl	731363.9	7554582	3	east
L09161	225887	5095 (blank)	7/05/2015	14/07/2015	2100x4 brl	731363.9	7554582	3	west
south side of cutting (cut 7) at quoll knoll. Facing on top of the railway	approx 225000	9787	8/05/2015	27/07/2015	over rail	730998	7554806	n/a	

Appendix 5: Descriptions of Geological Classifications from the Geological Survey of Western Australia

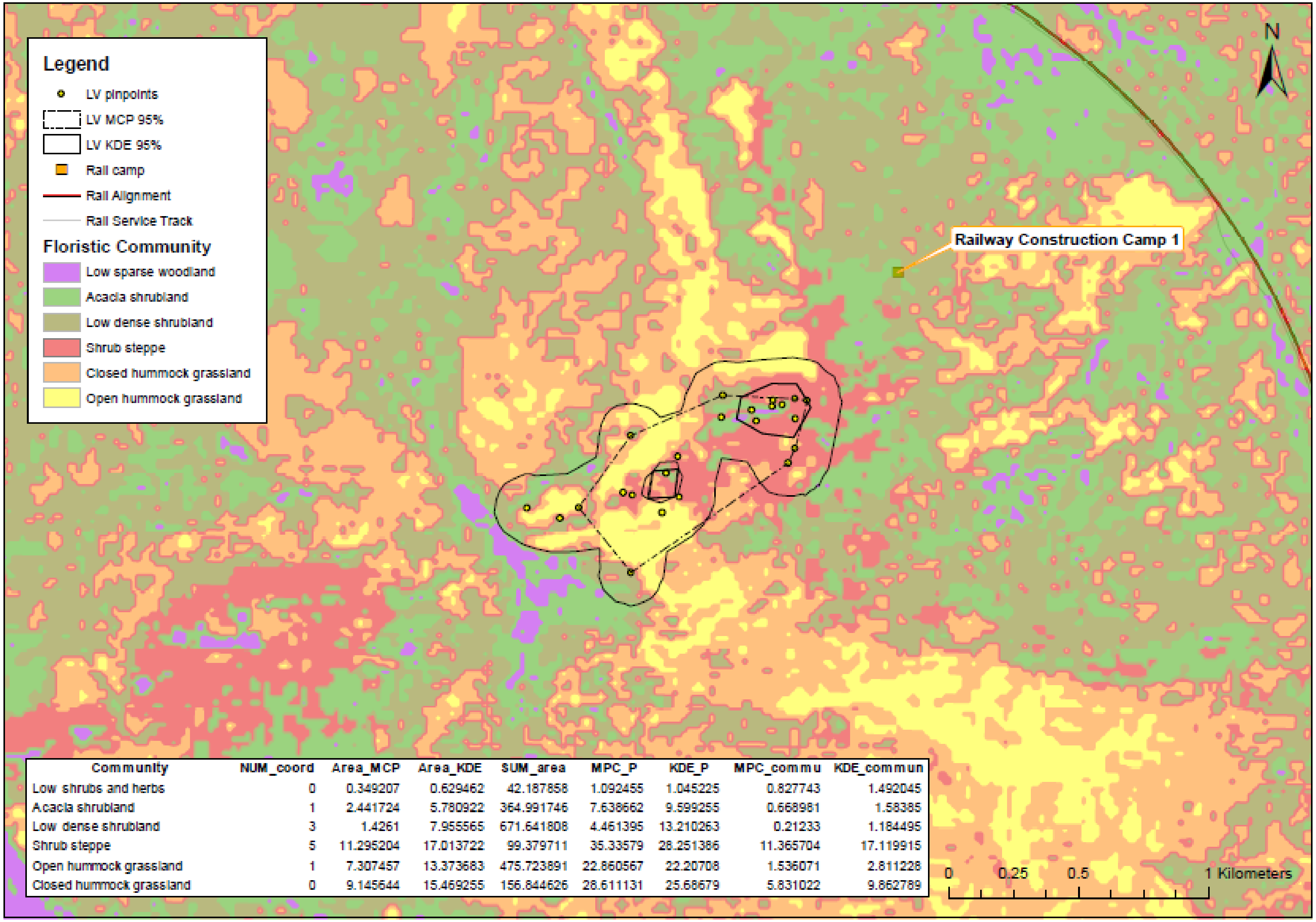
CODE	Description
R2-g-pg	Variably consolidated eluvial and colluvial sand, gravel, and silt overlying, and derived from granitic rocks; variably consolidated; dissected by present-day drainage
A-FO-sr	Pebbly sandstone and coarse-grained sandstone; minor pebble conglomerate; thickly-bedded
A-PI-mutk	Talc-carbonate and talc-chlorite-carbonate schist
Abus	Interleaved actinolite schist, talc-tremolite-chlorite schist, and quartz-sericite schist; locally mylonitized
ADm	MALLINA FORMATION: interbedded shale, siltstone, and medium- to fine-grained wacke; minor layers of chert; metamorphosed
ADmhl	Chlorite-rich, laminated shale and siltstone; metamorphosed
AGlc	Chert; metamorphosed
AGli	Banded iron-formation; locally includes banded quartz-magnetite-grunerite rock; metamorphosed
AgLmf	Biotite monzogranite, strongly foliated; seriate to K-feldspar porphyritic; related to AgLmp; metamorphosed
AgLmp	Biotite monzogranite, porphyritic (K-feldspar) to seriate; massive to weakly foliated; locally strong flow-alignment; metamorphosed
AgLpe	Pegmatite; metamorphosed
Aogs	Fine- to medium-grained plagioclase-hornblende-actinolite-epidote schist after gabbro; locally includes interleaved talc-serpentine-chlorite schist
Aogsf	Fine- to medium-grained plagioclase-hornblende-actinolite-epidote schist; includes abundant interleaved quartz-sericite-epidote schist
Aus	Serpentinite; serpentine-tremolite(-talc-chlorite) rock after peridotite; locally preserved, medium-grained olivine-cumulate texture
Aut	Talc-serpentine-chlorite schist; locally preserved olivine- and pyroxene-spinifex textures
Czaf	Pisolitic limonite deposits, developed along palaeodrainage lines; dissected by present-day drainage
Czc	Colluvium - sand, silt, and gravel on outwash fans; scree, and talus; variably consolidated; dissected
Czrk	Residual calcrete; massive, nodular, and cavernous limestone; mainly silicified
Qaa	Alluvium - undivided clay, silt, sand, and gravel in rivers and creeks
Qaa	Alluvium - sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains
Qao	Alluvial sand, silt, and clay on floodplains
Qaoc	Alluvial sand, silt, and clay; mixed floodplain deposits (Qao) characterized by numerous small claypans

Appendix 6: GIS Maps Displaying Individual Home Range Upon Floristic Classification



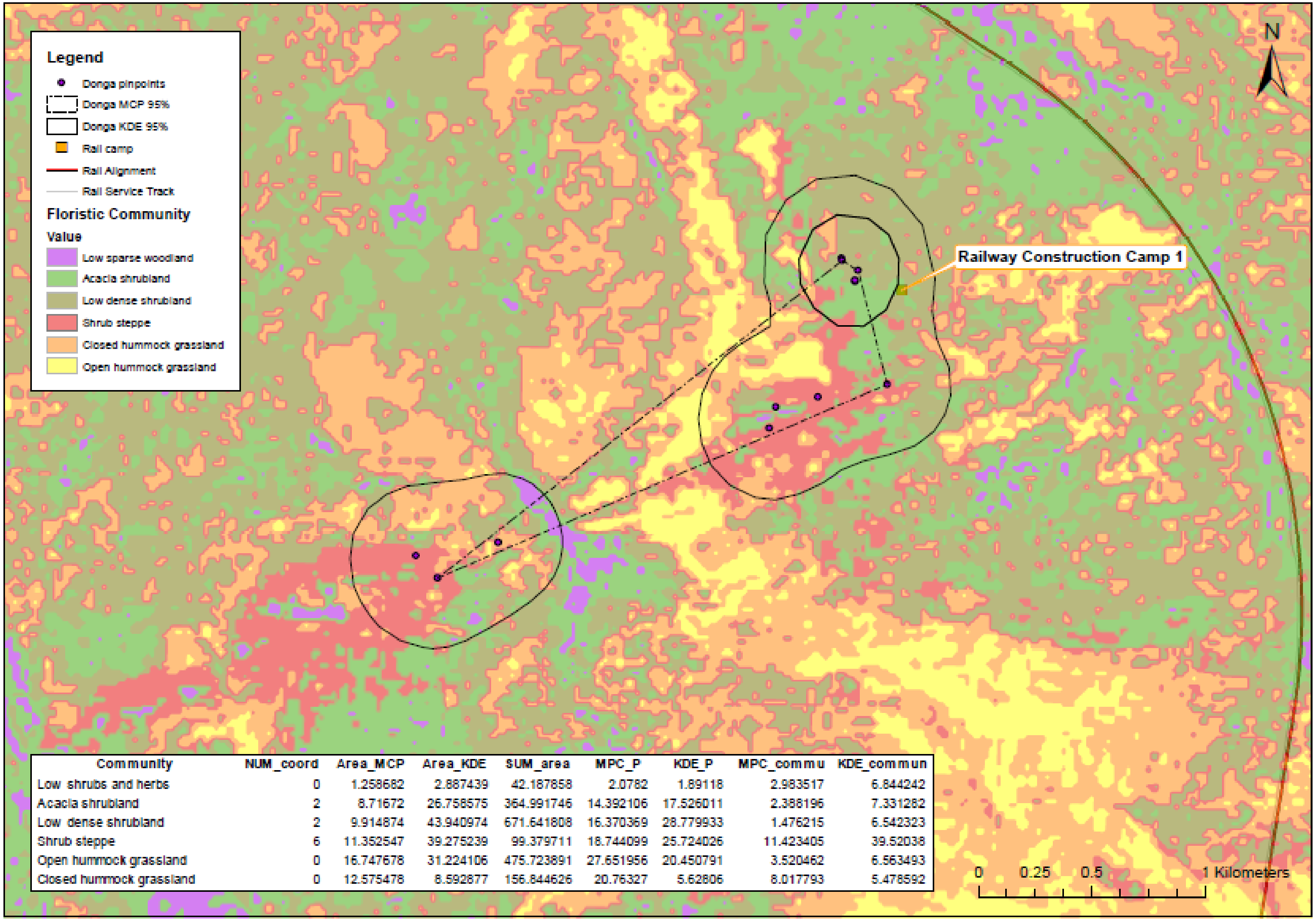
Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low shrubs and herbs	0	0.240297	4.133103	42.187858	3.915242	5.769537	0.569588	9.796902
Acacia shrubland	1	1.117041	10.960612	364.991746	18.200335	15.300287	0.306046	3.002975
Low dense shrubland	3	0.533682	10.541417	671.641808	8.695465	14.715118	0.079459	1.5695
Shrub steppe	5	1.432459	18.046678	99.379711	23.339549	25.191964	1.4414	18.159318
Open hummock grassland	1	1.851596	13.449513	475.723891	30.168693	18.774627	0.389217	2.827168
Closed hummock grassland	0	0.9624	14.505322	156.844626	15.680716	20.248466	0.613601	9.248211

Figure 26. Percentage of floristic array within Semi's MCP and KDE home range compared to the total amount of each available within the local area (ha).



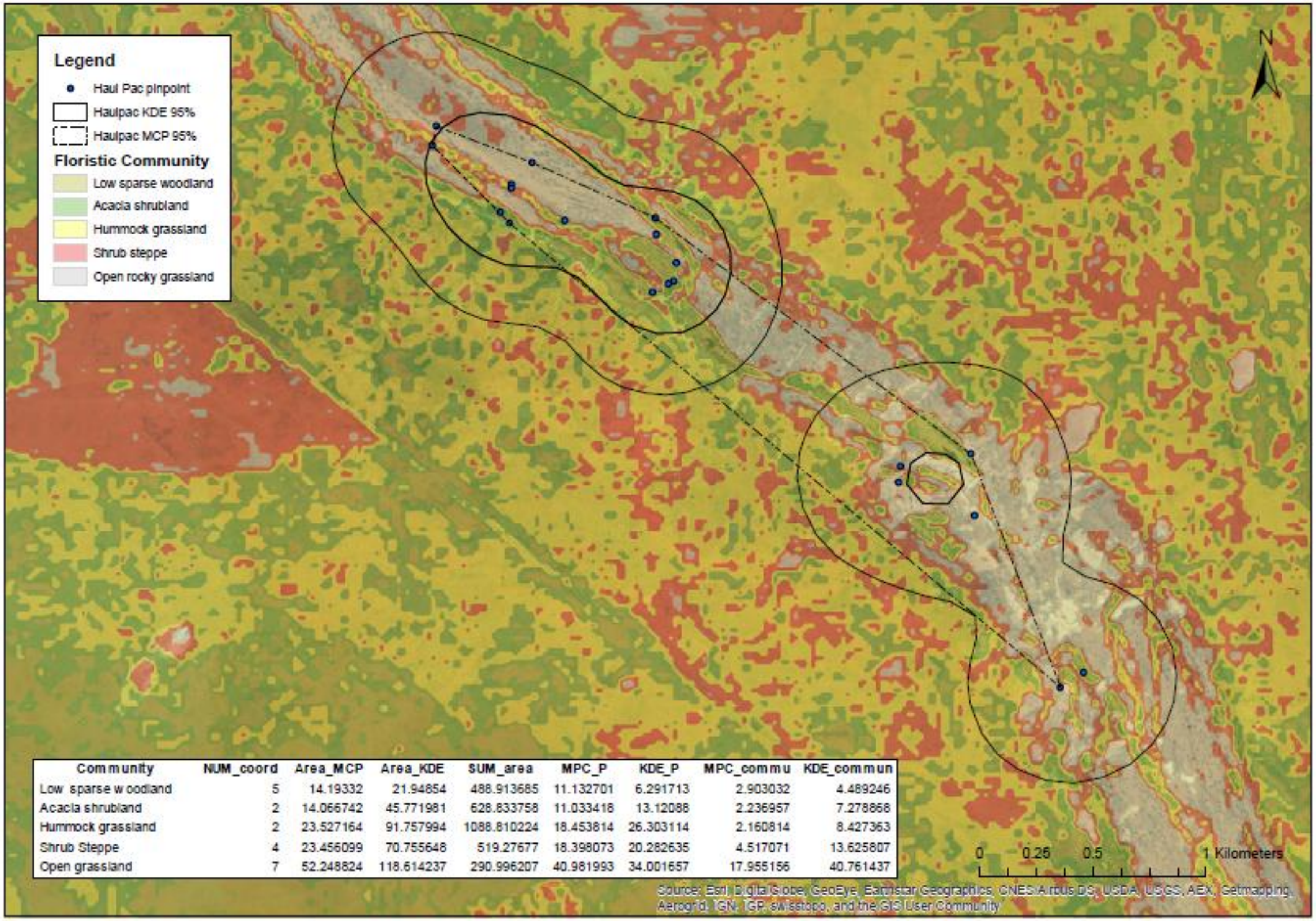
Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low shrubs and herbs	0	0.349207	0.629462	42.187858	1.092455	1.045225	0.827743	1.492045
Acacia shrubland	1	2.441724	5.780922	364.991746	7.638662	9.599255	0.668981	1.58385
Low dense shrubland	3	1.4261	7.955565	671.641808	4.461395	13.210263	0.21233	1.184495
Shrub steppe	5	11.295204	17.013722	99.379711	35.33579	28.251386	11.365704	17.119915
Open hummock grassland	1	7.307457	13.373683	475.723891	22.860567	22.20708	1.536071	2.811228
Closed hummock grassland	0	9.145644	15.469255	156.844626	28.611131	25.68679	5.831022	9.862789

Figure 27. Percentage of floristic array within LV's MCP and KDE home range compared to the total amount of each available within the local area (ha).



Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low shrubs and herbs	0	1.258682	2.887439	42.187858	2.0782	1.89118	2.983517	6.844242
Acacia shrubland	2	8.71672	26.758575	364.991746	14.392106	17.526011	2.388196	7.331282
Low dense shrubland	2	9.914874	43.940974	671.641808	16.370369	28.779933	1.476215	6.542323
Shrub steppe	6	11.352547	39.275239	99.379711	18.744099	25.724026	11.423405	39.52038
Open hummock grassland	0	16.747678	31.224106	475.723891	27.651956	20.450791	3.520462	6.563493
Closed hummock grassland	0	12.575478	8.592877	156.844626	20.76327	5.62806	8.017793	5.478592

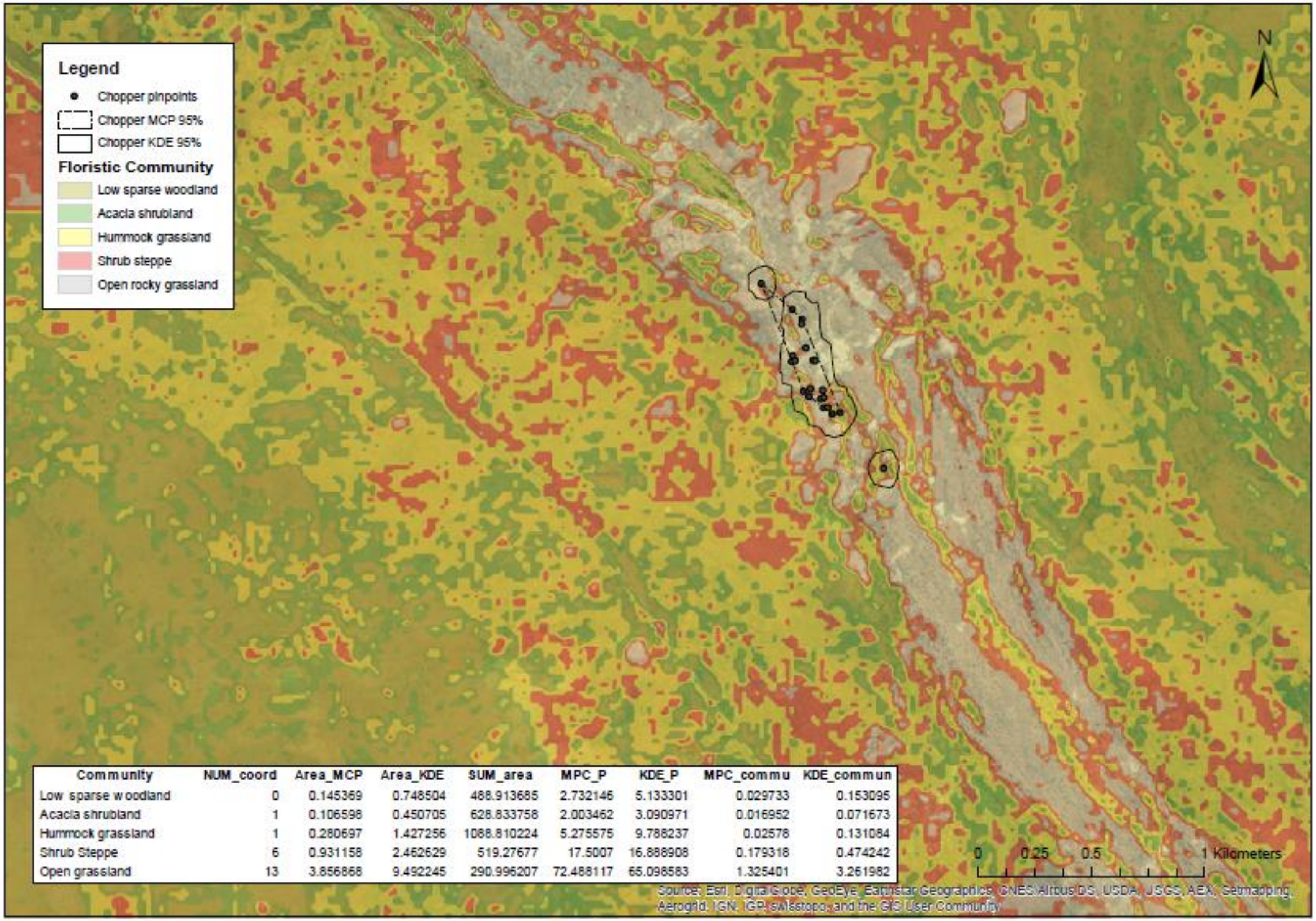
Figure 28. Percentage of floristic array within Donga’s MCP and KDE home range compared to the total amount of each available within the local area (ha).



Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low sparse w oodland	5	14.19332	21.94854	488.913685	11.132701	6.291713	2.903032	4.489246
Acacia shrubland	2	14.066742	45.771981	628.833758	11.033418	13.12088	2.236957	7.278868
Hummock grassland	2	23.527164	91.757994	1088.810224	18.453814	26.303114	2.160814	8.427363
Shrub Steppe	4	23.456099	70.755648	519.27677	18.398073	20.282635	4.517071	13.625807
Open grassland	7	52.248824	118.614237	290.996207	40.981993	34.001657	17.955156	40.761437

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

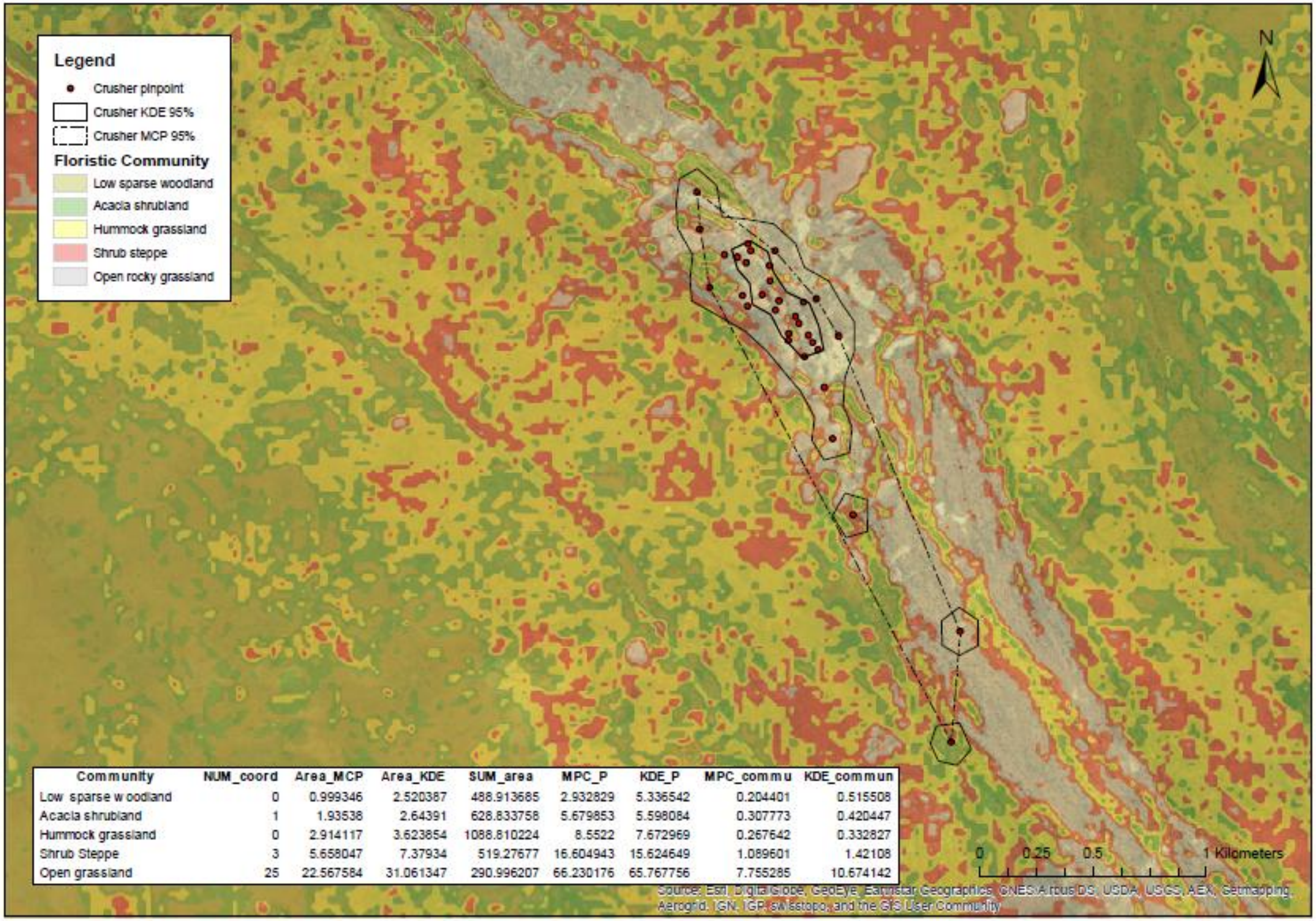
Figure 29. Percentage of floristic array within Haul Pac's MCP and KDE home range compared to the total amount of each available within the local area (ha).



Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low sparse woodland	0	0.145369	0.748504	488.913685	2.732146	5.133301	0.029733	0.153095
Acacia shrubland	1	0.106598	0.450705	628.833758	2.003462	3.090971	0.016952	0.071673
Hummock grassland	1	0.280697	1.427256	1088.810224	5.275575	9.788237	0.02578	0.131084
Shrub Steppe	6	0.931158	2.462629	519.27677	17.5007	16.888908	0.179318	0.474242
Open grassland	13	3.856868	9.492245	290.996207	72.488117	65.098583	1.325401	3.261982

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

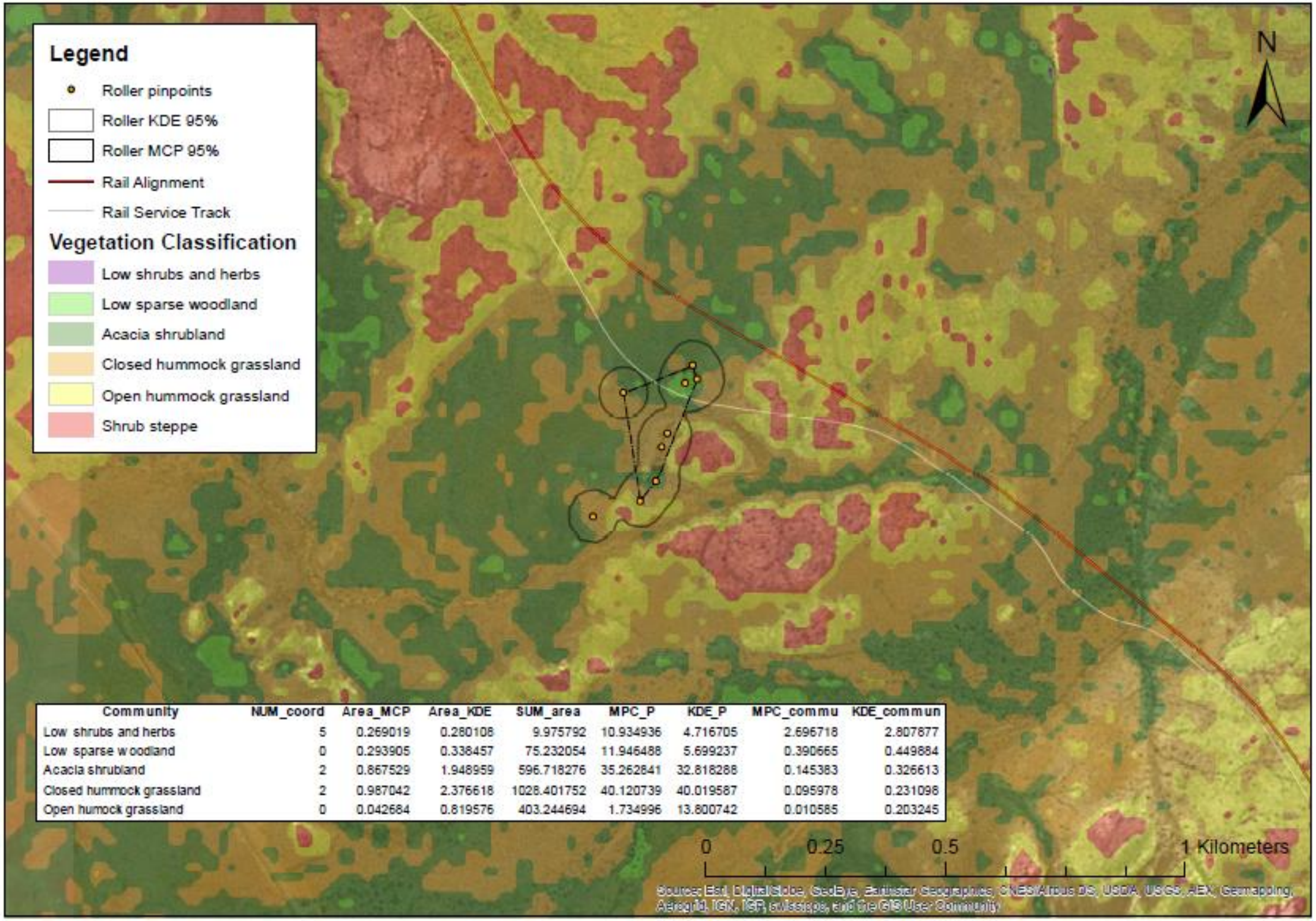
Figure 30. Percentage of floristic array within Chopper's MCP and KDE home range compared to the total amount of each available within the local area (ha).



Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low sparse w oodland	0	0.999346	2.520387	488.913685	2.932829	5.336542	0.204401	0.515508
Acacia shrubland	1	1.93538	2.64391	628.833758	5.679853	5.598084	0.307773	0.420447
Hummock grassland	0	2.914117	3.623854	1088.810224	8.5522	7.672969	0.267642	0.332827
Shrub Steppe	3	5.658047	7.37934	519.27677	16.604943	15.624649	1.089601	1.42108
Open grassland	25	22.567584	31.061347	290.996207	66.230176	65.767756	7.755285	10.674142

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 31. Percentage of floristic array within Crusher’s MCP and KDE home range compared to the total amount of each available within the local area (ha).



Community	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_commu	KDE_commun
Low shrubs and herbs	5	0.269019	0.280108	9.975792	10.934936	4.716705	2.696718	2.807877
Low sparse woodland	0	0.293905	0.338457	75.232054	11.946488	5.699237	0.390665	0.449884
Acacia shrubland	2	0.867529	1.948959	596.718276	35.262841	32.818288	0.145383	0.326613
Closed hummock grassland	2	0.987042	2.376618	1028.401752	40.120739	40.019587	0.095978	0.231098
Open humock grassland	0	0.042684	0.819576	403.244694	1.734996	13.800742	0.010585	0.203245

Figure 32. Percentage of floristic array within Roller’s MCP and KDE home range compared to the total amount of each available within the local area (ha).

Description of individual preference within Floristic Classification

GIS maps for each individual are displayed showing MCP 95% and KDE 95% overlaid upon floristic communities and geological series. Mapping has been used to determine the percentage of each floristic and geologic community within home range estimates. The total area of each floristic class within the MCP home range and the KDE home range was calculated (Area_MCP, Area_KDE). The sum area (ha) of each floristic class within a 10km² area of the trap sites was calculated at each site (MCP_P, KDE_P). This was extrapolated to determine the percentage of vegetation used, as determined by home range, within the overall local area (MCP_commu, KDE_commu).

Figure 26

All vegetative classes are present within both the MCP home range and KDE home range. However, coordinates are only observed within 4 of the 6 classes. The greatest number of coordinates recorded for Semi fall within shrub steppe. Within MCP home range hummock grassland occurs most often, making up 30% of the overall area. This is closely followed by shrub steppe which makes up a further 23% of the MCP area. A quarter of the KDE home range is made up of shrub steppe (25%) and this makes up 18% of what is available overall.

Figure 27

Coordinates fall within 4 of the 6 floristic categories. Shrub steppe is predominant within both MCP and KDE home range making up 36% and 25% respectively. Open and closed hummock grasslands are also dominant categories within home range. Within the KDE they represent 22% and 25% of the area within home range. Shrub steppe within KDE home range estimates for LV makes up 17% of what is available overall.

Figure 28

Within Donga’s MCP the floristic class most common is open hummock grassland. This is quite different within the area defined by KDE, with low dense shrubland making up 28% of the total area. This is closely followed by shrub steppe with 25% and open hummock grass land at 20%. Within the local landscape Donga utilises 39% of the available shrub steppe.

Figure 29

The greatest number of coordinates for this individual was recorded within low sparse woodland and open rocky grassland. Of the MCP area 40% is made up of open grassland and 18% of Hummock grassland. Of the KDE area open grassland and hummock grassland make up 34% and 26% of the home range. Haul Pac's KDE home range covers 40% of the total available open grassland in the local area.

Figure 30

Locations recorded for Chopper fall within 4 of the 6 floristic categories. 13 of these are within open rocky grassland. This makes up a large proportion of both MCP and KDE home range for Chopper, with 72% and 65% respectively. Choppers home range is so small that he has little impact on the total use of these categories in the overall area.

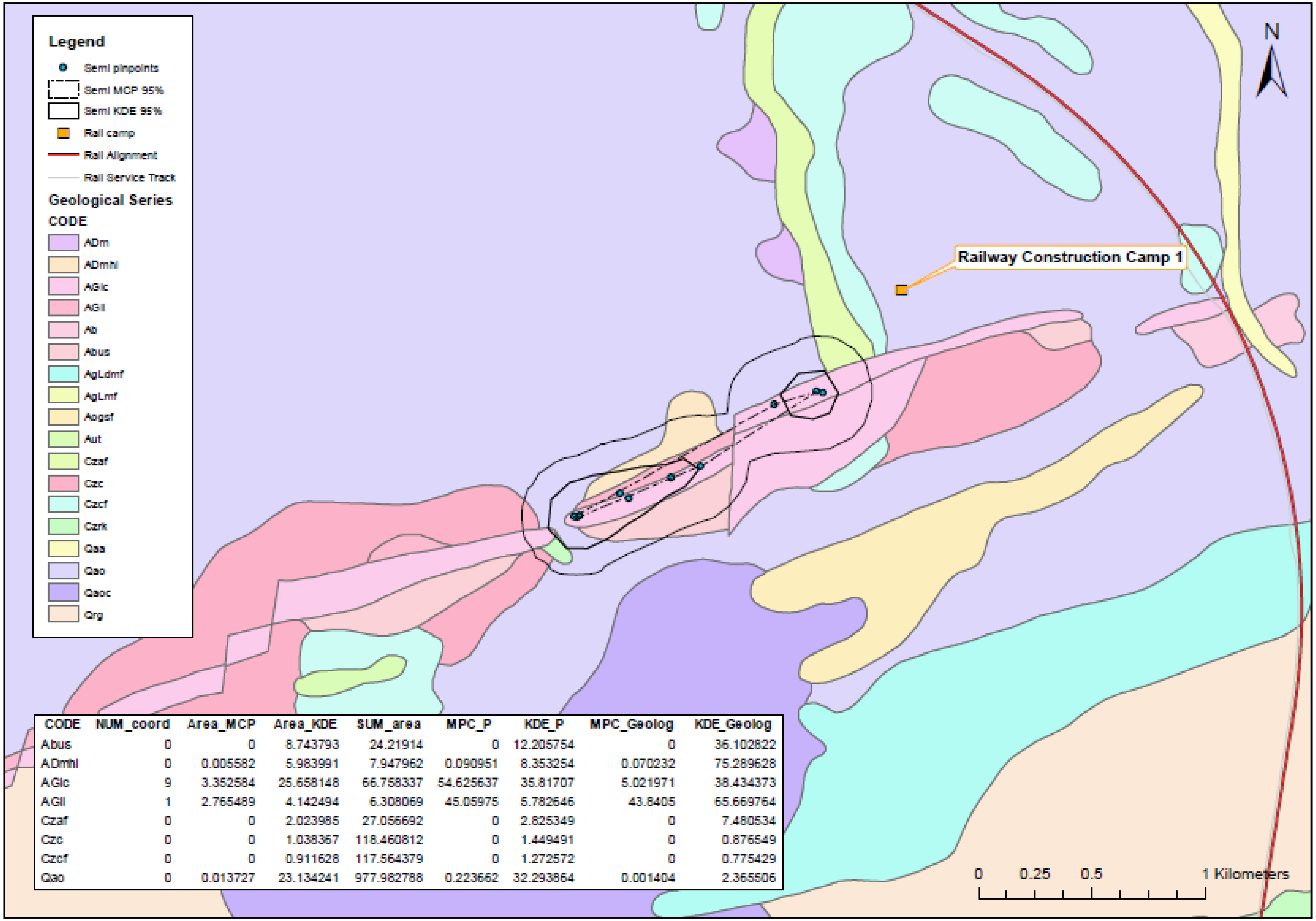
Figure 31

Crusher recorded coordinates within only three of possible 5 floristic categories. A total of 25 out of 29 of these fell within open rocky grassland. Within the MCP home range this made up 66% of the total area and just a little more, 67% of the KDE area. Although this category makes up a large percentage of Crushers home range it makes up only 11% of what is available in the local landscape.

Figure 32

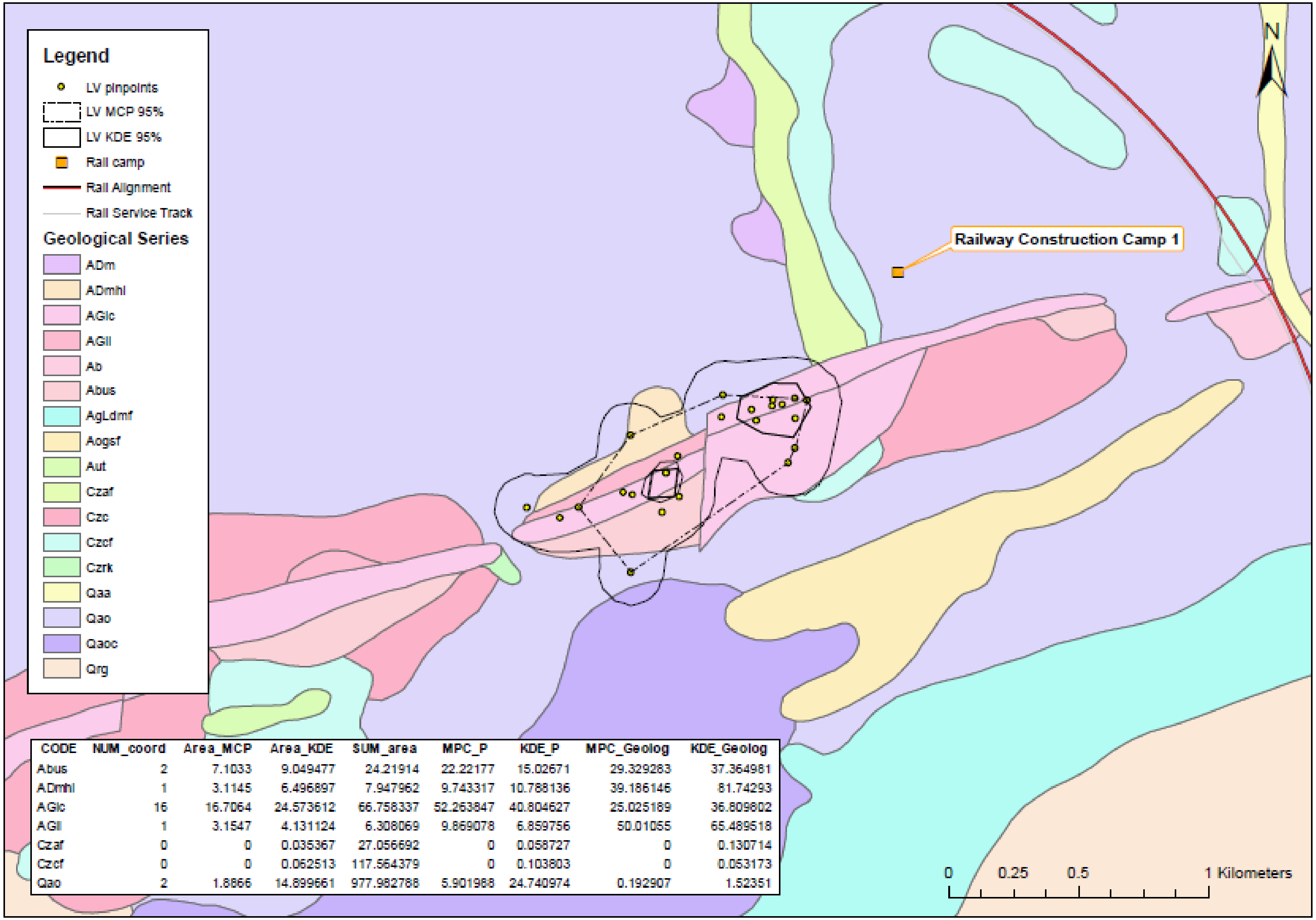
Coordinates recorded by Roller fall within 3 of the 5 floristic categories in the area of Quoll Knoll. Of these closed hummock grassland and Acacia shrubland make up a large proportion of the MCP home range. Similarly within KDE home range, closed hummock grassland makes up 40% of the total area and 32% is comprised of Acacia shrubland. This makes little to no impact on these categories in proportion to their availability within the local area.

Appendix 7: GIS Maps Displaying Individual Home Range upon Geological Series



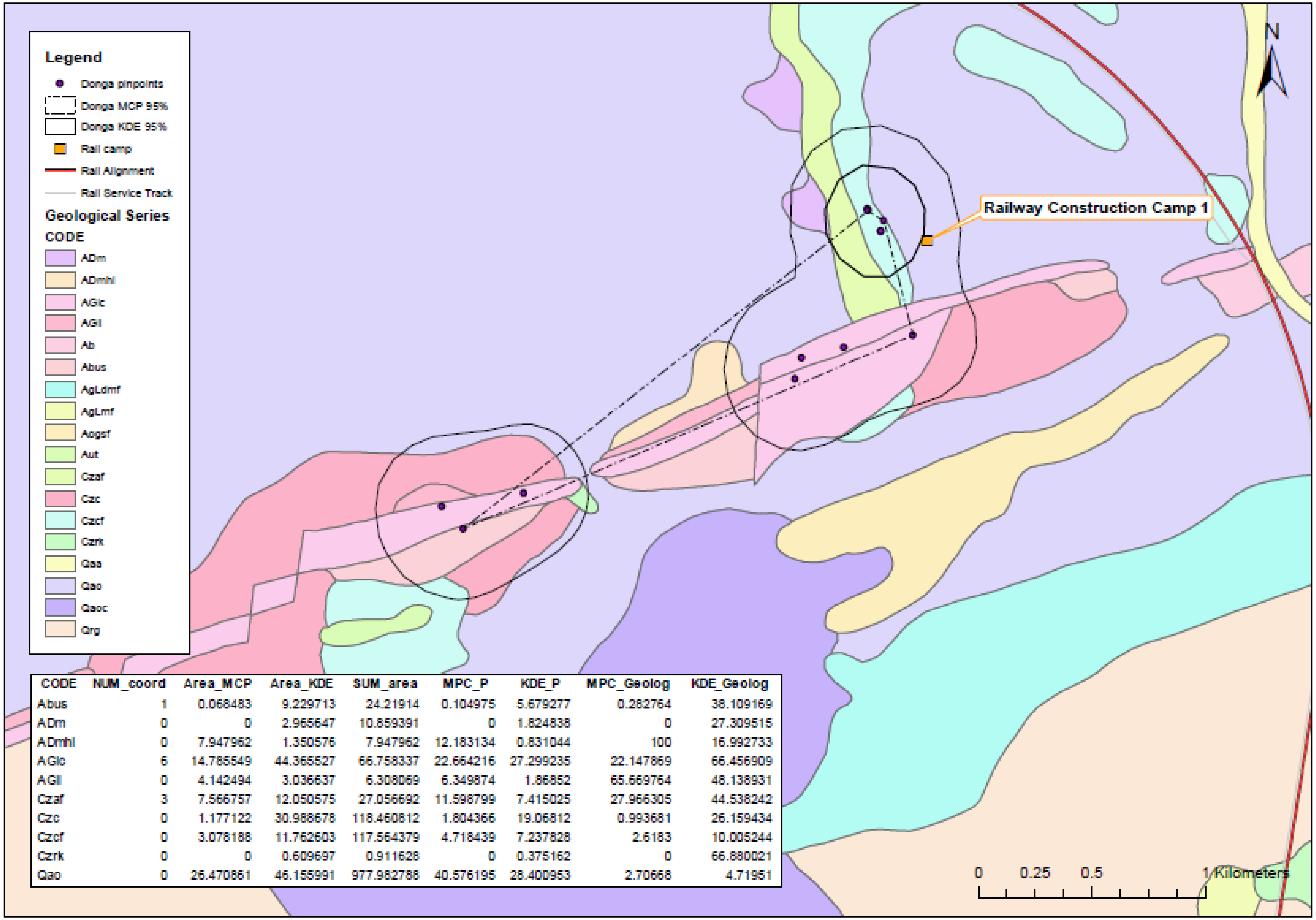
CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
Abus	0	0	8.743793	24.21914	0	12.205754	0	36.102822
ADmhl	0	0.005582	5.983991	7.947962	0.090951	8.353254	0.070232	75.289628
AGlc	9	3.352584	25.658148	66.758337	54.625637	35.81707	5.021971	38.434373
AGll	1	2.765489	4.142494	6.308069	45.05975	5.782646	43.8405	65.669764
Czaf	0	0	2.023985	27.056692	0	2.825349	0	7.480534
Czc	0	0	1.038367	118.460812	0	1.449491	0	0.876549
Czcf	0	0	0.911628	117.564379	0	1.272572	0	0.775429
Qao	0	0.013727	23.134241	977.982788	0.223662	32.293864	0.001404	2.365506

Figure 33. Percentage of each Geology Series within Semi’s MCP and KDE home range compared to the total amount of each within the local area (ha).



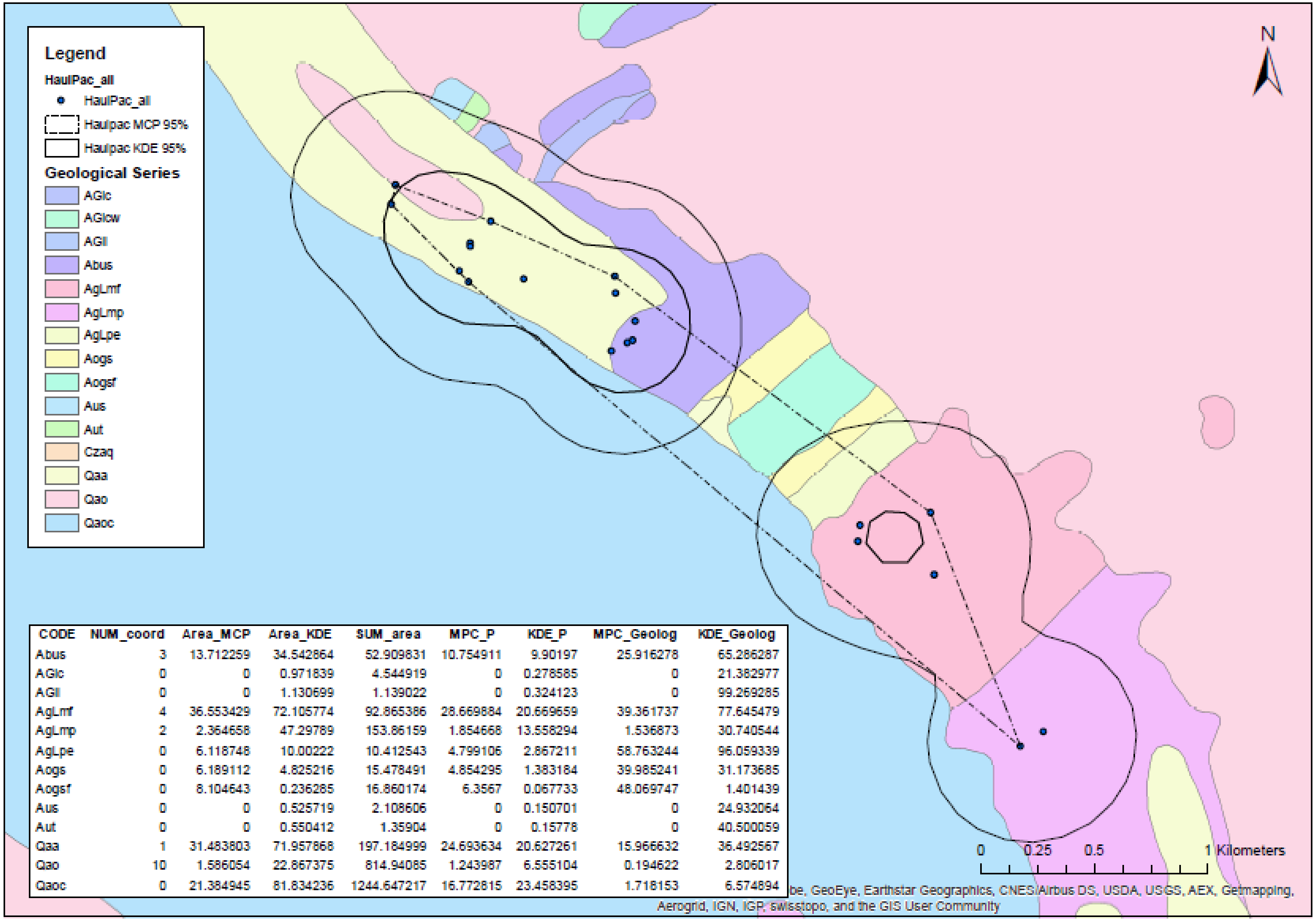
CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
Abus	2	7.1033	9.049477	24.21914	22.22177	15.02671	29.329283	37.364981
ADmhl	1	3.1145	6.496897	7.947962	9.743317	10.788136	39.186146	81.74293
AGlc	16	16.7064	24.573612	66.758337	52.263847	40.804627	25.025189	36.809802
AGll	1	3.1547	4.131124	6.308069	9.869078	6.859756	50.01055	65.489518
Czaf	0	0	0.035367	27.056692	0	0.058727	0	0.130714
Czcf	0	0	0.062513	117.564379	0	0.103803	0	0.053173
Qao	2	1.8866	14.899661	977.982788	5.901988	24.740974	0.192907	1.52351

Figure 34. Percentage of each Geology Series within LV’s MCP and KDE home range compared to the total amount of each within the local area (ha).



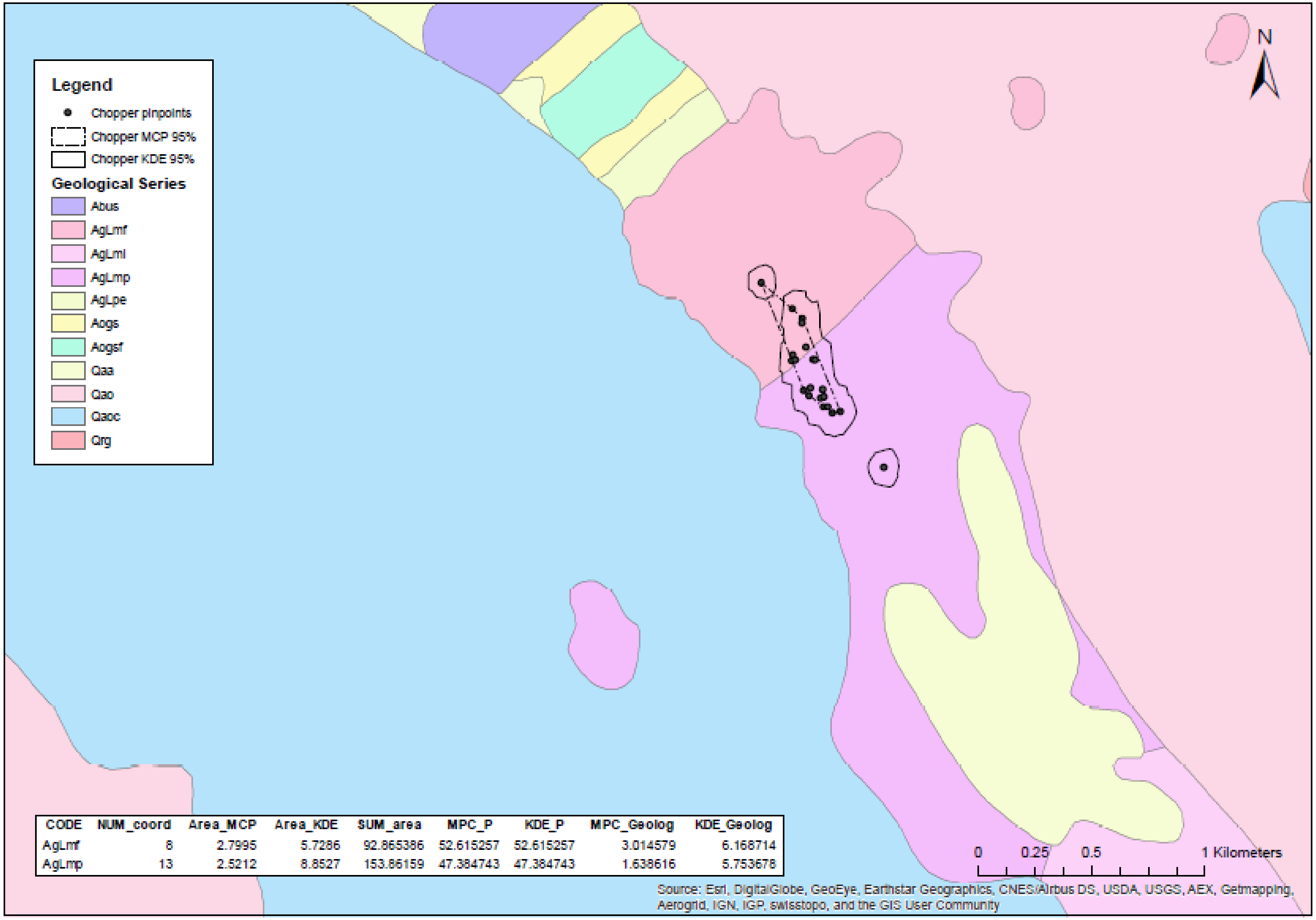
CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
Abus	1	0.068483	9.229713	24.21914	0.104975	5.679277	0.282764	38.109169
ADm	0	0	2.965647	10.859391	0	1.824838	0	27.309515
ADmhl	0	7.947962	1.350576	7.947962	12.183134	0.831044	100	16.992733
AGlc	6	14.785549	44.365527	66.758337	22.664216	27.299235	22.147869	66.456909
AGll	0	4.142494	3.036637	6.308069	6.349874	1.86852	65.669764	48.138931
Czaf	3	7.566757	12.050575	27.056692	11.598799	7.415025	27.966305	44.538242
Czc	0	1.177122	30.988678	118.460812	1.804366	19.06812	0.993681	26.159434
Czcf	0	3.078188	11.762603	117.564379	4.718439	7.237828	2.6183	10.005244
Czrk	0	0	0.609697	0.911628	0	0.375162	0	66.880021
Qao	0	26.470861	46.155991	977.982788	40.576195	28.400953	2.70668	4.71951

Figure 35. Percentage of Geological Series within Donga's MCP and KDE home range compared to the total amount of each available within the local area (ha).



CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
Abus	3	13.712259	34.542864	52.909831	10.754911	9.90197	25.916278	65.286287
AGlc	0	0	0.971839	4.544919	0	0.278585	0	21.382977
AGll	0	0	1.130699	1.139022	0	0.324123	0	99.269285
AgLmf	4	36.553429	72.105774	92.865386	28.669884	20.669659	39.361737	77.645479
AgLmp	2	2.364658	47.29789	153.86159	1.854668	13.558294	1.536873	30.740544
AgLpe	0	6.118748	10.00222	10.412543	4.799106	2.867211	58.763244	96.059339
Aogs	0	6.189112	4.825216	15.478491	4.854295	1.383184	39.985241	31.173685
Aogsf	0	8.104643	0.236285	16.860174	6.3567	0.067733	48.069747	1.401439
Aus	0	0	0.525719	2.108606	0	0.150701	0	24.932064
Aut	0	0	0.550412	1.35904	0	0.15778	0	40.500059
Qaa	1	31.483803	71.957868	197.184999	24.693634	20.627261	15.966632	36.492567
Qao	10	1.586054	22.867375	814.94085	1.243987	6.555104	0.194622	2.806017
Qaoc	0	21.384945	81.834236	1244.647217	16.772815	23.458395	1.718153	6.574894

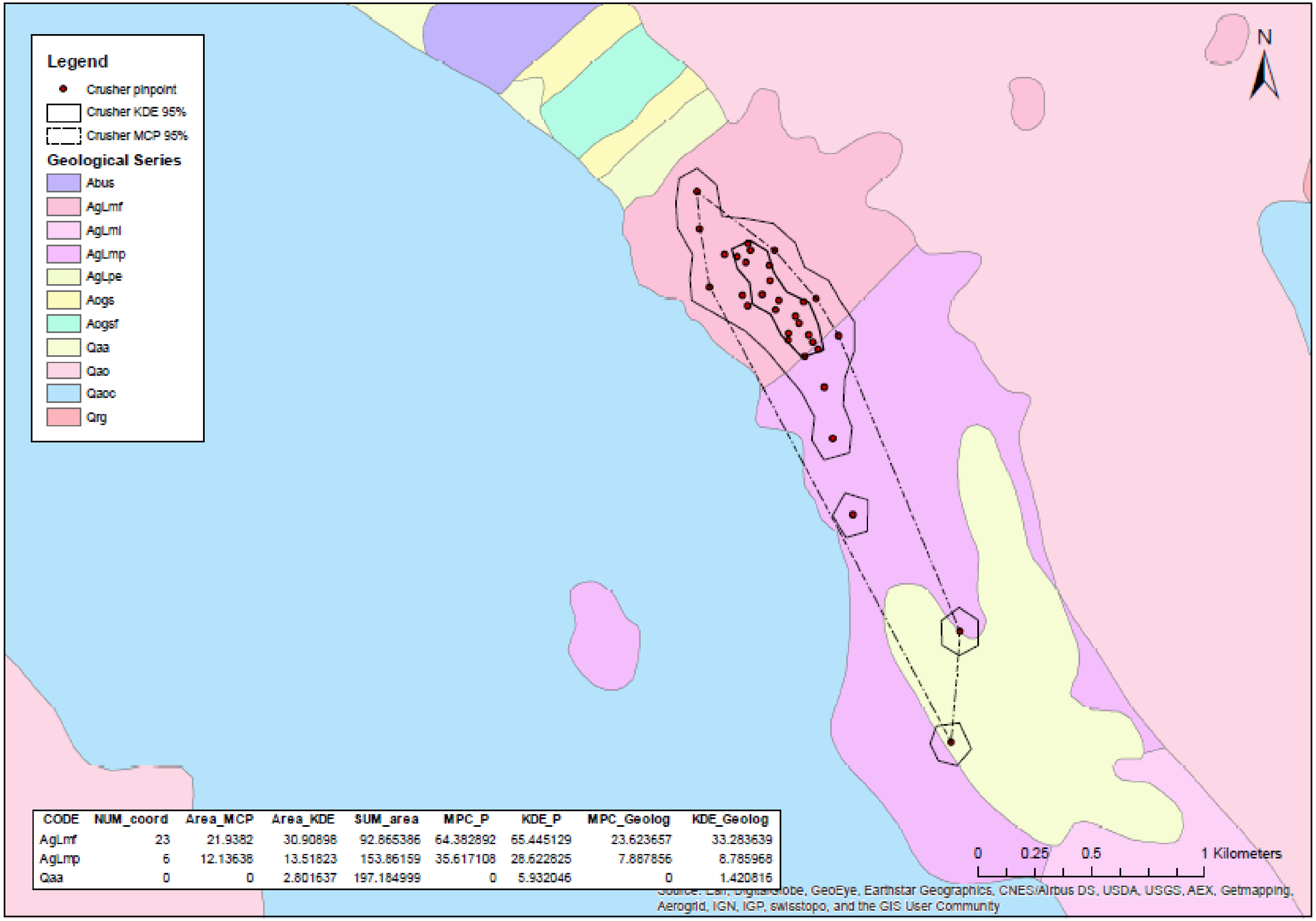
Figure 36. Percentage of Geological Series within Haul Pac’s MCP and KDE home range compared to the total amount of each available within the local area (ha).



CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
AgLmf	8	2.7995	5.7286	92.865386	52.615257	52.615257	3.014579	6.168714
AgLmp	13	2.5212	8.8527	153.86159	47.384743	47.384743	1.638616	5.753678

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

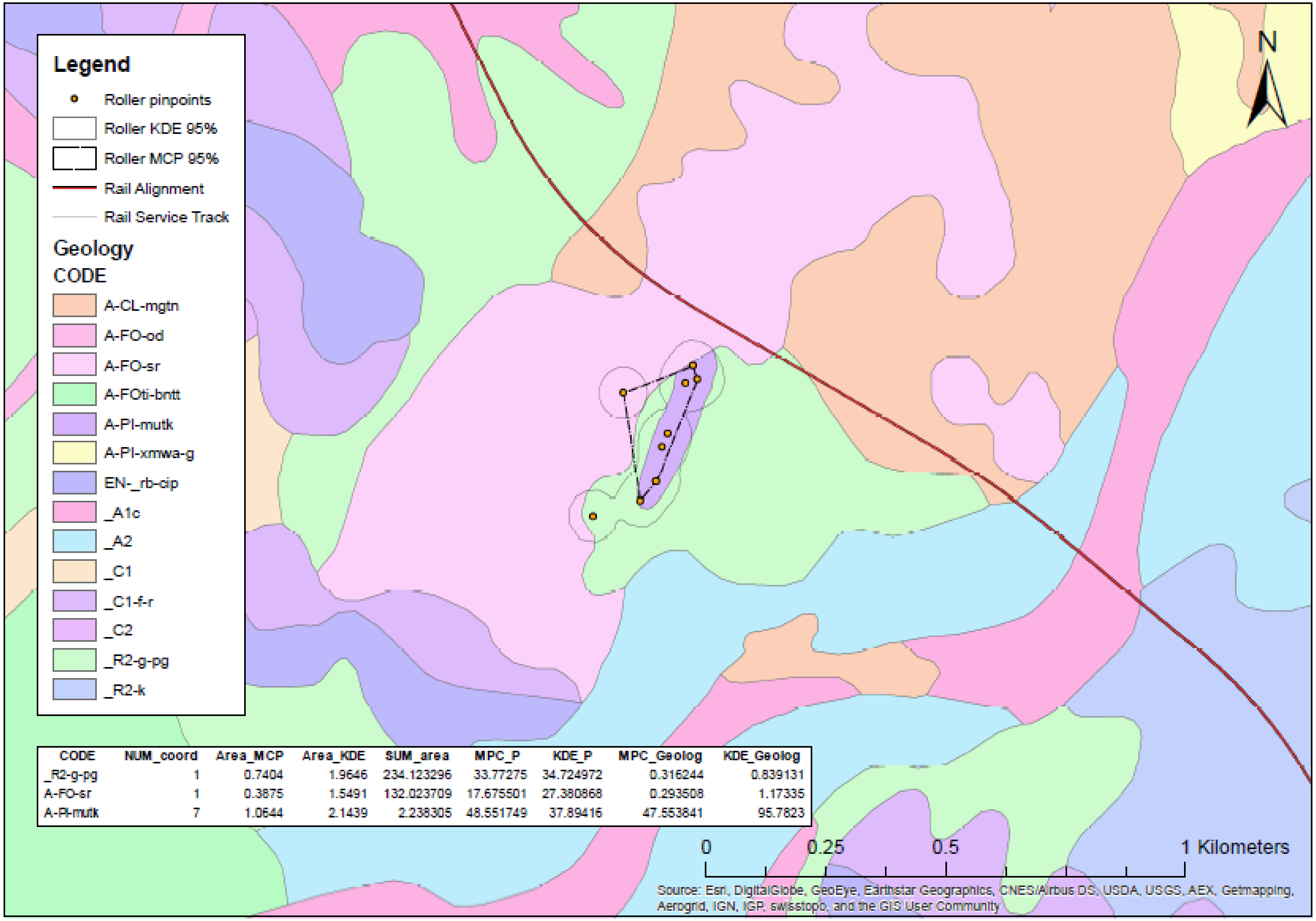
Figure 37. Percentage of Geological Series within Chopper's MCP and KDE home range compared to the total amount of each available within the local area (ha).



CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
AgLmf	23	21.9382	30.90898	92.865386	64.382892	65.445129	23.623657	33.283639
AgLmp	6	12.13638	13.51823	153.86159	35.617108	28.622825	7.887856	8.785968
Qaa	0	0	2.801637	197.184999	0	5.932046	0	1.420816

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 38. Percentage of Geological Series within Crusher's MCP and KDE home range compared to the total amount of each available within the local area (ha).



CODE	NUM_coord	Area_MCP	Area_KDE	SUM_area	MPC_P	KDE_P	MPC_Geolog	KDE_Geolog
_R2-g-pg	1	0.7404	1.9646	234.123296	33.77275	34.724972	0.316244	0.839131
A-FO-sr	1	0.3875	1.5491	132.023709	17.675501	27.380868	0.293508	1.17335
A-PI-mutk	7	1.0644	2.1439	2.238305	48.551749	37.89416	47.553841	95.7823

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 39. The percentage of Geological Series within Roller's MCP and KDE home range compared to the total amount of each available within the local area (ha).

Description of individual preference within Geological Series

Figure 33

Coordinates only fall within two categories for geology. MPC home range is predominantly comprised of these two categories. Overall 55% of the MCP area is made up of metamorphosed chert (AGlc) with 45% of metamorphosed banded quartz-magnetite-grunerite rock (AGli). MCP home range for semi covers 43% of the available area of this geological series and 65% when KDE is taken into account. Semi's KDE home range covers a total of 75% of the available metamorphosed chlorite-rich, laminated shale and siltstone (ADmhl) in the local area.

Figure 34

For LV the greatest number of coordinates falls within metamorphosed chert (AGlc). This makes up 52% and 40% of the overall MCP and KDE home range. Within the KDE alluvial sand, silt, and clay on floodplains (Qao) is important as it makes up 24% of LV's KDE home range. In the overall landscape Abus, ADmhl, AGlc and AGli are dominant within home range estimates as they make up 37%, 81%, 35% and 65% of the total available geology within the local area.

Figure 35

Coordinates fall within 3 out of 10 geological classifications at this site. Within the MCP home range the most important classification is alluvial sand, silt, and clay on floodplains (Qao) making up 26% of the area. Within the KDE AGlc, Czc and Qao are all present at 44%, 30% and 46% respectively. Alluvial sand, silt, and clay on floodplains (Qao) makes up the greatest percentage of both MCP and KDE. Within the locally available geology Banded iron-formations (AGli) make up the greatest area of MCP at 66%. Within the KDE both banded iron-formations (AGli) and calcrete and cavernous limestone (Czrk) are used at a high rate of 66% of the total available.

Figure 36

The greatest number of coordinates recorded for Haul Pac was located within the series Alluvium (Qaa). This makes up a total of 24% of the area within MCP home range. Biotite monzogranite (AgLmf) makes up a greater proportion of overall MCP at 28%. Within the KDE three categories are important and make up approximately 20% each of the KDE home range. Due to the size and coverage of his home range it is spread over the greatest variety of geological substraites. This included 99% of AGli, 96% of AgLmp, 77% of AgLmf and 40% of Aut.

Figure 37

Choppers home range falls within only 2 geologic categories. These categories are both composed of Biotite monzogranite and make up 52% and 47% of both MCP and KDE areas. These two categories are strongly related to one another. Again there is little impact on the percentage of use of both categories in the overall landscape.

Figure 38

There are just three categories of geology within Crushers home range. Most coordinates fall within AgLmf and this category makes up 64% of MCP home range area. Within MCP AgLmp makes up the remaining 35%. KDE is similar but also incorporates 5% of Qaa. Overall the area of AgLmf within KDE home range is important as it makes up 33% of this substrate overall.

Figure 39

The geology at Quoll Knoll is very different to the associations at either of the other sites. 7 out of the 9 coordinates fall within talc-carbonate and talc-chlorite-carbonate schist (A-PI-mutk). This makes up 48% of the area within Rollers MCP home range and 37% of the KDE home. This is important overall as there is only a further 5% of this substrate available for use within the local area.

Appendix 8: Raw Habitat Site Data for Northern Quolls

Datasheet Site Name Indee Station Plot Number 15T9 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 52.173' E118° 34.349'

Structural formation (Circle)	*[✓ woodland]*	*shrubland*	*savannah*	*steppe*	*succulent steppe*
Dominant spp.	*Trees*	*Shrubs*	*Herbs and sedges*		*[✓ Grasses]*
Ground cover	*% leaf litter*	20%	*%bare ground*	80%	
Height of Vegetation	50cm				
Evidence of logs/nesting trees	*[✓ Yes]*	*No*			

Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*[✓ Fine silt]*	6	*Fine gravel*
		B	*[✓ Brown]*	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	*None; rock only*

Morphological type	C	*Crest*	F	*Flat*
	U	*Upper slope*	V	*Open depression (vale)*
	M	*Mid slope*	D	*[✓ Closed depression]*
	L	*Lower slope*	H	*Hillock*
	S	*Simple slope*	R	*Ridge*

ROCK OUTCROP TYPE (e.g. granite) Slate

Abundance	0	*No bedrock exposed*	
	1	*Very slightly rocky*	*<2%*
	2	*Slightly rocky*	*2-10%*
	3	*Rocky*	*10-20%*
	4	*Very rocky*	*20-50%*
	5	*[✓ Rockland]*	*>50%*

FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*[✓ No coarse fragments]*	0	***Rock size***	3	*Gravelly*	>60 mm
		1	*Very slightly; very few*	<2%		4	*Cobbly; or cobbles*	60-200 mm
		2	*Slightly; few*	2%-10%		5	*Stony; stones*	200-600 mm
		3	*No qualifier; common*	10%-20%		6	*[✓ Bouldery; or boulders]*	600 mm-2 m
		4	*Moderately; many*	20%-50%		7	*Large boulders*	>2 m
		5	*Very; abundant*	50%-90%				
		6	*Extremely; very abundant*	>90%				

Datasheet Site Name Indee Station Plot Number 1ST3 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 53.048' E118° 35.216'

Structural formation (Circle)	*woodland*	[✓ *shrubland*]	*savannah*	*steppe*	*succulent steppe*
Dominant spp.	*Trees*	*Shrubs*	*Herbs and sedges*		*Grasses*
Ground cover	*% leaf litter*	*0%*	*%bare ground*	*100%*	
Height of Vegetation	*0cm*				
Evidence of logs/nesting trees	[✓ *Yes*]	*No*			

Soil	***Colour***	R	[✓ *Red*]	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	*Brown*	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	[✓ *Fine sand*]	8	*None; rock only*

Morphological type	C	*Crest*	F	*Flat*
	U	*Upper slope*	V	*Open depression (vale)*
	M	*Mid slope*	D	[✓ *Closed depression*]
	L	*Lower slope*	H	*Hillock*
	S	*Simple slope*	R	*Ridge*

ROCK OUTCROP TYPE (e.g. granite) Granite

Abundance	0	*No bedrock exposed*	
	1	*Very slightly rocky*	*<2%*
	2	*Slightly rocky*	*2-10%*
	3	*Rocky*	*10-20%*
	4	*Very rocky*	*20-50%*
	5	[✓ *Rockland*]	*>50%*

FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*	0	***Rock size***	3	*Gravelly*	>60 mm
		1	[✓ *Very slightly; very few*]	<2%		4	*Cobbly; or cobbles*	60-200 mm
		2	*Slightly; few*	2%-10%		5	*Stony; stones*	200-600 mm
		3	*No qualifier; common*	10%-20%		6	*Bouldery; or boulders*	600 mm-2 m
		4	*Moderately; many*	20%-50%		7	[✓ *Large boulders*]	>2 m
		5	*Very; abundant*	50%-90%				
		6	*Extremely; very abundant*	>90%				

Datasheet Site Name Indee Station Plot Number 1ST6 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 52.765' E118° 35.208'

Structural formation (Circle)	woodland	[✓ shrubland]	savannah	steppe	succulent steppe
Dominant spp.	Trees	Shrubs	Herbs and sedges		[✓ Grasses]
Ground cover	% leaf litter	10%	%bare ground	90%	
Height of Vegetation	50cm				
Evidence of logs/nesting trees	[✓ Yes]	No			

Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*[✓ Orange]*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	*Brown*	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	*[✓ None; rock only]*

Morphological type	C	*Crest*	F	*Flat*
	U	*[✓ Upper slope]*	V	*Open depression (vale)*
	M	*Mid slope*	D	*Closed depression*
	L	*Lower slope*	H	*Hillock*
	S	*Simple slope*	R	*Ridge*

ROCK OUTCROP TYPE (e.g. granite) Granite

Abundance	0	*No bedrock exposed*	
	1	*Very slightly rocky*	*<2%*
	2	*Slightly rocky*	*2-10%*
	3	*Rocky*	*10-20%*
	4	*Very rocky*	*20-50%*
	5	*[✓ Rockland]*	*>50%*

FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*	0	***Rock size***	3	*Gravelly*	>60 mm
		1	*[✓ Very slightly; very few]*	<2%		4	*Cobbly; or cobbles*	60-200 mm
		2	*Slightly; few*	2%-10%		5	*Stony; stones*	200-600 mm
		3	*No qualifier; common*	10%-20%		6	*Bouldery; or boulders*	600 mm-2 m
		4	*Moderately; many*	20%-50%		7	*[✓ Large boulders]*	>2 m
		5	*Very; abundant*	50%-90%				
		6	*Extremely; very abundant*	>90%				

Datasheet Site Name Indee Station Plot Number 1ST8 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 52.724' E118° 35.028'

Structural formation (Circle)	*woodland*	[✓ *shrubland*]	*savannah*	*steppe*	*succulent steppe*					
Dominant spp.	*Trees*	*Shrubs*	*Herbs and sedges*		[✓ *Grasses*]					
Ground cover	*% leaf litter*	*10%*	*%bare ground*	*30%*						
Height of Vegetation	*30-150cm*									
Evidence of logs/nesting trees	[✓ *Yes*]	*No*								
Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	[✓ *Brown*]	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	[✓ *None; rock only*]
Morphological type	C	*Crest*	F	*Flat*						
	U	*Upper slope*	V	*Open depression (vale)*						
	M	*Mid slope*	D	[✓ *Closed depression*]						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Granite									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	[✓ *Rockland*]		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	[✓ *Very slightly; very few*]		<2%		4	*Cobbly; or cobbles*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	*Stony; stones*	200-600 mm	
		3	*No qualifier; common*		10%-20%		6	*Bouldery; or boulders*	600 mm-2 m	
		4	*Moderately; many*		20%-50%		7	[✓ *Large boulders*]	>2 m	
		5	*Very; abundant*		50%-90%					
		6	*Extremely; very abundant*		>90%					

Datasheet Site Name Back Rock Plot Number BR11 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 48.451' E118° 38.667'

Structural formation (Circle)	*woodland*	*shrubland*	*savannah*	[✓ *steppe*]	*succulent steppe*					
Dominant spp.	*Trees*	*Shrubs*	[✓ *Herbs and sedges*]		*Grasses*					
Ground cover	*% leaf litter*	*10%*	*%bare ground*	*80%*						
Height of Vegetation	*50cm*									
Evidence of logs/nesting trees	*Yes*	[✓ *No*]								
Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	[✓ *Fine silt*]	6	*Fine gravel*
		B	[✓ *Brown*]	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	*None; rock only*
Morphological type	C	*Crest*	F	*Flat*						
	U	[✓ *Upper slope*]	V	*Open depression (vale)*						
	M	*Mid slope*	D	*Closed depression*						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Granite									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	[✓ *Rockland*]		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	*Very slightly; very few*		<2%		4	*Cobbly; or cobbles*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	[✓ *Stony; stones*]	200-600 mm	
		3	[✓ *No qualifier; common*]		10%-20%		6	*Bouldery; or boulders*	600 mm-2 m	
		4	*Moderately; many*		20%-50%		7	*Large boulders*	>2 m	
		5	*Very; abundant*		50%-90%					
		6	*Extremely; very abundant*		>90%					

Datasheet Site Name Back Rock Plot Number BR3 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 48.387' E118° 38.842'

Structural formation (Circle)	*woodland*	*shrubland*	*savannah*	[✓ *steppe*]	*succulent steppe*
Dominant spp.	*Trees*	*Shrubs*	*Herbs and sedges*		[✓ *Grasses*]
Ground cover	*% leaf litter*	*0%*	*%bare ground*	*30%*	
Height of Vegetation	*1m*				
Evidence of logs/nesting trees	*Yes*	[✓ *No*]			

Soil	***Colour***	R	[✓ *Red*]	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	*Brown*	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	[✓ *None; rock only*]

Morphological type	C	*Crest*	F	*Flat*
	U	[✓ *Upper slope*]	V	*Open depression (vale)*
	M	*Mid slope*	D	*Closed depression*
	L	*Lower slope*	H	*Hillock*
	S	*Simple slope*	R	*Ridge*

ROCK OUTCROP TYPE (e.g. granite) Granite

Abundance	0	*No bedrock exposed*	
	1	*Very slightly rocky*	*<2%*
	2	*Slightly rocky*	*2-10%*
	3	*Rocky*	*10-20%*
	4	*Very rocky*	*20-50%*
	5	[✓ *Rockland*]	*>50%*

FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*	0	***Rock size***	3	*Gravelly*	>60 mm
		1	*Very slightly; very few*	<2%		4	*Cobbly; or cobbles*	60-200 mm
		2	*Slightly; few*	2%-10%		5	*Stony; stones*	200-600 mm
		3	*No qualifier; common*	10%-20%		6	*Bouldery; or boulders*	600 mm-2 m
		4	*Moderately; many*	20%-50%		7	[✓ *Large boulders*]	>2 m
		5	[✓ *Very; abundant*]	50%-90%				
		6	*Extremely; very abundant*	>90%				

Datasheet Site Name Back Rock Plot Number LV recapture Date 17/07/2015

GPS Datum WGS 1984 Position S20° 48.615' E118° 38.472'

Structural formation (Circle)	*woodland*	*shrubland*	*savannah*	[✓ *steppe*]	*succulent steppe*					
Dominant spp.	*Trees*	*Shrubs*	*Herbs and sedges*		[✓ *Grasses*]					
Ground cover	*% leaf litter*	*10%*	*%bare ground*	*50%*						
Height of Vegetation	*1-1.5m*									
Evidence of logs/nesting trees	*Yes*	[✓ *No*]								
Soil	***Colour***	R	[✓ *Red*]	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	*Brown*	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	[✓ *None; rock only*]
Morphological type	C	*Crest*	F	*Flat*						
	U	[✓ *Upper slope*]	V	*Open depression (vale)*						
	M	*Mid slope*	D	*Closed depression*						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Quartz/Iron									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	[✓ *Rockland*]		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	*Very slightly; very few*		<2%		4	*Cobbly; or cobbles*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	*Stony; stones*	200-600 mm	
		3	[✓ *No qualifier; common*]		10%-20%		6	*Bouldery; or boulders*	600 mm-2 m	
		4	*Moderately; many*		20%-50%		7	[✓ *Large boulders*]	>2 m	
		5	*Very; abundant*		50%-90%					
		6	*Extremely; very abundant*		>90%					

Datasheet Site Name Back Rock Plot Number BR1 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 48.390' E118° 38.858'

Structural formation (Circle)	woodland	shrubland	savannah	[✓ steppe]	succulent steppe					
Dominant spp.	Trees	[✓ Shrubs]	Herbs and sedges		[✓ Grasses]					
Ground cover	% leaf litter	0%	%bare ground	40%						
Height of Vegetation	40-100cm									
Evidence of logs/nesting trees	Yes	[✓ No]								
Soil	**Colour**	R	[✓ Red]	Y	Yellow	**Type**	1	Clay	5	Coarse sand
		O	Orange	G	Grey		2	Fine silt	6	Fine gravel
		B	Brown	D	Dark		3	Coarse silt	7	[✓ Coarse gravel]
							4	Fine sand	8	None; rock only
Morphological type	C	Crest	F	Flat						
	U	Upper slope	V	Open depression (vale)						
	M	[✓ Mid slope]	D	Closed depression						
	L	Lower slope	H	Hillock						
	S	Simple slope	R	Ridge						
ROCK OUTCROP TYPE (e.g. granite)	Quartz Ridge									
Abundance	0	No bedrock exposed								
	1	Very slightly rocky		<2%						
	2	Slightly rocky		2-10%						
	3	Rocky		10-20%						
	4	Very rocky		20-50%						
	5	[✓ Rockland]		>50%						
FRAGMENTS ON THE SURFACE	**Rock abundance**	0	No coarse fragments		0	**Rock size**	3	Gravelly	>60 mm	
		1	Very slightly; very few		<2%		4	Cobbly; or cobbles	60-200 mm	
		2	Slightly; few		2%-10%		5	[✓ Stony; stones]	200-600 mm	
		3	No qualifier; common		10%-20%		6	Bouldery; or boulders	600 mm-2 m	
		4	Moderately; many		20%-50%		7	Large boulders	>2 m	
		5	[✓ Very; abundant]		50%-90%					
		6	Extremely; very abundant		>90%					

Datasheet Site Name Back Rock Plot Number BR2 Date 17/07/2015
GPS Datum WGS 1984 Position S20° 48.402' E118° 38.846'

Structural formation (Circle)	woodland	shrubland	savannah	[✓ steppe]	succulent steppe					
Dominant spp.	Trees	[✓ Shrubs]	Herbs and sedges		[✓ Grasses]					
Ground cover	% leaf litter	0%	%bare ground	100%						
Height of Vegetation	0									
Evidence of logs/nesting trees	Yes	[✓ No]								
Soil	***Colour***	R	Red	Y	Yellow	***Type***	1	Clay	5	Coarse sand
		O	[✓ Orange]	G	Grey		2	Fine silt	6	Fine gravel
		B	Brown	D	Dark		3	Coarse silt	7	Coarse gravel
							4	Fine sand	8	[✓ None; rock only]
Morphological type	C	[✓ Crest]	F	Flat						
	U	Upper slope	V	Open depression (vale)						
	M	Mid slope	D	Closed depression						
	L	Lower slope	H	Hillock						
	S	Simple slope	R	Ridge						
ROCK OUTCROP TYPE (e.g. granite)	Quartz									
Abundance	0	No bedrock exposed								
	1	Very slightly rocky		<2%						
	2	Slightly rocky		2-10%						
	3	Rocky		10-20%						
	4	Very rocky		20-50%						
	5	[✓ Rockland]		>50%						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	No coarse fragments		0	***Rock size***	3	Gravelly	>60 mm	
		1	Very slightly; very few		<2%		4	Cobbly; or cobbles	60-200 mm	
		2	Slightly; few		2%-10%		5	Stony; stones	200-600 mm	
		3	[✓ No qualifier; common]		10%-20%		6	Bouldery; or boulders	600 mm-2 m	
		4	Moderately; many		20%-50%		7	[✓ Large boulders]	>2 m	
		5	Very; abundant		50%-90%					
		6	Extremely; very abundant		>90%					

Datasheet Site Name Little Knoll Plot Number LN4 Date 14/07/2015
GPS Datum WGS 1984 Position S22° 05.871' E119° 14.193'

Structural formation (Circle)	*woodland*	*shrubland*	*savannah*	[✓ *steppe*]	*succulent steppe*
Dominant spp.	*Trees*	*Shrubs*	[✓ *Herbs and sedges*]		*Grasses*
Ground cover	*% leaf litter*	*5%*	*%bare ground*	*80%*	
Height of Vegetation	*30-200cm*				
Evidence of logs/nesting trees	*Yes*	[✓ *No*]			

Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	[✓ *Fine silt*]	6	*Fine gravel*
		B	[✓ *Brown*]	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	*None; rock only*

Morphological type	C	*Crest*	F	*Flat*
	U	[✓ *Upper slope*]	V	*Open depression (vale)*
	M	*Mid slope*	D	*Closed depression*
	L	*Lower slope*	H	*Hillock*
	S	*Simple slope*	R	*Ridge*

ROCK OUTCROP TYPE (e.g. granite)	Granite		
Abundance	0	*No bedrock exposed*	
	1	*Very slightly rocky*	*<2%*
	2	*Slightly rocky*	*2-10%*
	3	*Rocky*	*10-20%*
	4	[✓ *Very rocky*]	*20-50%*
	5	*Rockland*	*>50%*

FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*	0	***Rock size***	3	*Gravelly*	>60 mm
		1	*Very slightly; very few*	<2%		4	*Cobbly; or cobbles*	60-200 mm
		2	*Slightly; few*	2%-10%		5	*Stony; stones*	200-600 mm
		3	*No qualifier; common*	10%-20%		6	[✓ *Bouldery; or boulders*]	600 mm-2 m
		4	[✓ *Moderately; many*]	20%-50%		7	*Large boulders*	>2 m
		5	*Very; abundant*	50%-90%				
		6	*Extremely; very abundant*	>90%				

Datasheet Site Name Little Knoll Plot Number LN4NEW Date 14/07/2015
GPS Datum WGS 1984 Position S22° 05.857' E119° 14.191'

Structural formation (Circle)	woodland	shrubland	savannah	[✓ steppe]	succulent steppe
Dominant spp.	Trees	Shrubs	Herbs and sedges		[✓ Grasses]
Ground cover	% leaf litter	5%	%bare ground	90%	
Height of Vegetation	30-200cm				
Evidence of logs/nesting trees	Yes	[✓ No]			

Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	[✓ *Brown*]	D	*Dark*		3	*Coarse silt*	7	[✓ *Coarse gravel*]
							4	*Fine sand*	8	*None; rock only*

Morphological type	C	*Crest*	F	*Flat*
	U	*Upper slope*	V	*Open depression (vale)*
	M	[✓ *Mid slope*]	D	*Closed depression*
	L	*Lower slope*	H	*Hillock*
	S	*Simple slope*	R	*Ridge*

ROCK OUTCROP TYPE (e.g. granite)	Granite		
Abundance	0	*No bedrock exposed*	
	1	*Very slightly rocky*	*<2%*
	2	*Slightly rocky*	*2-10%*
	3	*Rocky*	*10-20%*
	4	*Very rocky*	*20-50%*
	5	[✓ *Rockland*]	*>50%*

FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*	0	***Rock size***	3	*Gravelly*	>60 mm
		1	*Very slightly; very few*	<2%		4	*Cobbly; or cobbles*	60-200 mm
		2	*Slightly; few*	2%-10%		5	[✓ *Stony; stones*]	200-600 mm
		3	*No qualifier; common*	10%-20%		6	*Bouldery; or boulders*	600 mm-2 m
		4	[✓ *Moderately; many*]	20%-50%		7	*Large boulders*	>2 m
		5	*Very; abundant*	50%-90%				
		6	*Extremely; very abundant*	>90%				

Datasheet Site Name Mesa 228 Plot Number N12 Date 13/07/2015
GPS Datum WGS 1984 Position S22° 06.876' E119° 14.739'

Structural formation (Circle)	*woodland*	*shrubland*	*savannah*	[✓ *steppe*]	*succulent steppe*					
Dominant spp.	*Trees*	[✓ *Shrubs*]	*Herbs and sedges*		[✓ *Grasses*]					
Ground cover	*% leaf litter*	*0%*	*%bare ground*	*95%*						
Height of Vegetation	*20-30cm*									
Evidence of logs/nesting trees	*Yes*	[✓ *No*]								
Soil	***Colour***	R	[✓ *Red*]	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	*Brown*	D	*Dark*		3	*Coarse silt*	7	[✓ *Coarse gravel*]
							4	*Fine sand*	8	*None, rock only*
Morphological type	C	[✓ *Crest*]	F	*Flat*						
	U	*Upper slope*	V	*Open depression (vale)*						
	M	*Mid slope*	D	*Closed depression*						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Silicate/Iron									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	[✓ *Rockland*]		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	*Very slightly; very few*		<2%		4	*Cobbly; or cobbles*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	*Stony; stones*	200-600 mm	
		3	*No qualifier; common*		10%-20%		6	[✓ *Bouldery; or boulders*]	600 mm-2 m	
		4	*Moderately; many*		20%-50%		7	*Large boulders*	>2 m	
		5	[✓ *Very; abundant*]		50%-90%					
		6	*Extremely; very abundant*		>90%					

Datasheet Site Name Quoll Knoll Plot Number QN2 Date 14/07/2015
GPS Datum WGS 1984 Position S22° 05.779' E119° 14.220'

Structural formation (Circle)	*woodland*	*[✓ shrubland]*	*savannah*	*steppe*	*succulent steppe*					
Dominant spp.	*Trees*	*Shrubs*	*[✓ Herbs and sedges]*		*Grasses*					
Ground cover	*% leaf litter*	*0%*	*%bare ground*	*80%*						
Height of Vegetation	*30cm*									
Evidence of logs/nesting trees	*Yes*	*[✓ No]*								
Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	*[✓ Brown]*	D	*Dark*		3	*Coarse silt*	7	*[✓ Coarse gravel]*
							4	*Fine sand*	8	*None; rock only*
Morphological type	C	*[✓ Crest]*	F	*Flat*						
	U	*[✓ Upper slope]*	V	*Open depression (vale)*						
	M	*Mid slope*	D	*Closed depression*						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Granite									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	*[✓ Rockland]*		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	*Very slightly; very few*		<2%		4	*[✓ Cobbly; or cobbles]*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	*Stony; stones*	200-600 mm	
		3	*No qualifier; common*		10%-20%		6	*Bouldery; or boulders*	600 mm-2 m	
		4	*[✓ Moderately; many]*		20%-50%		7	*Large boulders*	>2 m	
		5	*Very; abundant*		50%-90%					
		6	*Extremely; very abundant*		>90%					

Datasheet Site Name Quoll Knoll Plot Number QN4 Date 14/07/2015
GPS Datum WGS 1984 Position S22° 05.799' E119° 14.211'

Structural formation (Circle)	*woodland*	[✓ *shrubland*]	*savannah*	*steppe*	*succulent steppe*					
Dominant spp.	*Trees*	*Shrubs*	[✓ *Herbs and sedges*]		*Grasses*					
Ground cover	*% leaf litter*	*5%*	*%bare ground*	*90%*						
Height of Vegetation	*30cm*									
Evidence of logs/nesting trees	*Yes*	[✓ *No*]								
Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	[✓ *Brown*]	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	*Fine sand*	8	[✓ *None; rock only*]
Morphological type	C	[✓ *Crest*]	F	*Flat*						
	U	[✓ *Upper slope*]	V	*Open depression (vale)*						
	M	*Mid slope*	D	*Closed depression*						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Granite									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	[✓ *Rockland*]		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	*Very slightly; very few*		<2%		4	*Cobbly; or cobbles*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	*Stony; stones*	200-600 mm	
		3	*No qualifier; common*		10%-20%		6	*Bouldery; or boulders*	600 mm-2 m	
		4	*Moderately; many*		20%-50%		7	[✓ *Large boulders*]	>2 m	
		5	[✓ *Very; abundant*]		50%-90%					
		6	[✓ *Extremely; very abundant*]		>90%					

Datasheet Site Name Quoll Knoll Plot Number QN6 Date 14/07/2015
GPS Datum WGS 1984 Position S22° 05.804' E119° 14.260'

Structural formation (Circle)	*woodland*	[✓ *shrubland*]	*savannah*	*steppe*	*succulent steppe*					
Dominant spp.	*Trees*	*Shrubs*	[✓ *Herbs and sedges*]		*Grasses*					
Ground cover	*% leaf litter*	*5%*	*%bare ground*	*80%*						
Height of Vegetation	*30cm*									
Evidence of logs/nesting trees	[✓ *Yes*]	*No*								
Soil	***Colour***	R	*Red*	Y	*Yellow*	***Type***	1	*Clay*	5	*Coarse sand*
		O	*Orange*	G	*Grey*		2	*Fine silt*	6	*Fine gravel*
		B	[✓ *Brown*]	D	*Dark*		3	*Coarse silt*	7	*Coarse gravel*
							4	[✓ *Fine sand*]	8	*None; rock only*
Morphological type	C	*Crest*	F	*Flat*						
	U	[✓ *Upper slope*]	V	*Open depression (vale)*						
	M	*Mid slope*	D	*Closed depression*						
	L	*Lower slope*	H	*Hillock*						
	S	*Simple slope*	R	*Ridge*						
ROCK OUTCROP TYPE (e.g. granite)	Granite									
Abundance	0	*No bedrock exposed*								
	1	*Very slightly rocky*		*<2%*						
	2	*Slightly rocky*		*2-10%*						
	3	*Rocky*		*10-20%*						
	4	*Very rocky*		*20-50%*						
	5	[✓ *Rockland*]		*>50%*						
FRAGMENTS ON THE SURFACE	***Rock abundance***	0	*No coarse fragments*		0	***Rock size***	3	*Gravelly*	>60 mm	
		1	*Very slightly; very few*		<2%		4	*Cobbly; or cobbles*	60-200 mm	
		2	*Slightly; few*		2%-10%		5	[✓ *Stony; stones*]	200-600 mm	
		3	*No qualifier; common*		10%-20%		6	[✓ *Bouldery; or boulders*]	600 mm-2 m	
		4	*Moderately; many*		20%-50%		7	*Large boulders*	>2 m	
		5	[✓ *Very; abundant*]		50%-90%					
		6	*Extremely; very abundant*		>90%					


IST3


IST6


IST8


IST9

BR2

BR3

BR11

LV recapture

RC1

N12

LN4

LN4 new

QN2

QN4

BR11

QN6

Appendix 9: Raw Radio-tracking data for Northern Quolls

Collar ID	PIT ID	Site	Location	Surrounding Area	Potential Enterance
10	953384	Indee Station, Turner River	S20° 52.627' E118° 35.115'		
10	953384	Indee Station, Turner River	S20° 52.641' E118° 35.111'		

Collar ID	PIT ID	Site	Location	Surrounding Area	Potential Enterance
9	3024287	Indee Station, Turner River			
6	955922	Indee Station, Turner River	S20° 52.765' E118° 35.208'		

Collar ID	**PIT ID**	**Site**	**Location**	**Surrounding Area**	**Potential Enterance**
9	3024287	Indee Station, Turner River	S20° 52.173' E118° 34.349'		
8	44748	Indee Station, Turner River	S20° 52.724' E118° 35.028'		

Collar ID	PIT ID	Site	Location	Surrounding Area	Potential Enterance
1	361953828	Back rock at Rail Camp 1	S20° 48.615' E118° 38.472'		
4	163700079	Quoll Knoll	S22° 05.788' E119° 14.223'		

Collar ID	**PIT ID**	**Site**	**Location**	**Surrounding Area**	**Potential Enterance**
4	163700079	Quoll Knoll	S22° 05.785' E119° 14.224'