

Appendix 19

Mount Emerald Wind Farm – EIS – *Dasyurus hallucatus* Habitat Utilisation Study

Prepared by RPS



Mount Emerald Wind Farm – EIS

Dasyurus hallucatus Habitat Utilisation Study

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I.0 Introduction

I.1 Background

The proposed Mount Emerald Wind Farm (MEWF) project consists of construction and operation of a wind farm located approximately 20km SSW of Mareeba on the Atherton Tablelands including of approximately 63 wind turbines, associated access tracks and an electricity substation that will feed into the main electricity grid (the Chalumbin – Woree transmission line). The general characteristics of wind turbines being considered include the following:

- Upwind pointing horizontal axis wind turbine;
- Three-bladed design with blade lengths between 50m and 54m (100m to 108m diameter);
- Turbine capacity of approximately 3.0mw;
- Cylindrical steel towers providing a hub height of 78m to 80m;
- Blade length of approximately 50m; and
- Total height to blade tip between 130m and 134m.

This project is intended to supply approximately 500,000 megawatt hours which should supply sufficient renewable energy to power the equivalent annual needs of approximately 75,000 North Queensland homes over a 20 year period. The site has been selected primarily as it displays an excellent wind resource, there are few residences in close proximity to the site, and the site is traversed by existing Powerlink transmission line infrastructure (providing ease of connection).

I.2 Site Description

The wind farm project site, hereafter referred to as the “site” or “project area” is a single rural property, formerly described as Lot 7 on Plan SP235244, and covering an area of approximately 2422 ha (**Figure 1**).

The site is situated at the northern most end of the Herberton Range, which forms part of the Great Dividing Range. The site varies in altitude from 540 m ASL at the northern-most point along Kippen Drive to 1089 m ASL in the south-eastern most section (closest to Mt Emerald). The north-western section of the site is dominated by Walsh’s Bluff (907 m ASL) (**Figure 1**).

The site is dominated by a series of three, approximately parallel high rhyolite ridges running in a south-east to north-west direction. There is a large area (~500 ha) of relatively flat country located in the western section. The site is dissected by a series of steep rocky ephemeral drainage lines and gorges, including the headwaters of a tributary of Granite Creek (**Figure 1**).

The site is intersected by a 5-10 m wide, 6.7 km long access track for Powerlink’s Chalumbin to Woree 275 kV transmission line that roughly traverses the property. Two other vehicle tracks, 750 m and 2.95 km in length respectively, connect the two test wind towers with the main power line access track (**Figure 1**).

The site is not currently grazed by domestic stock and aside from the cleared areas of access tracks and test wind monitoring tower pads, consists entirely of remnant vegetation. The site is located on the boundary of the Einasleigh Uplands and the Wet Tropics Bioregions, both of which are characterized by high levels of bioregional endemic flora and fauna species.

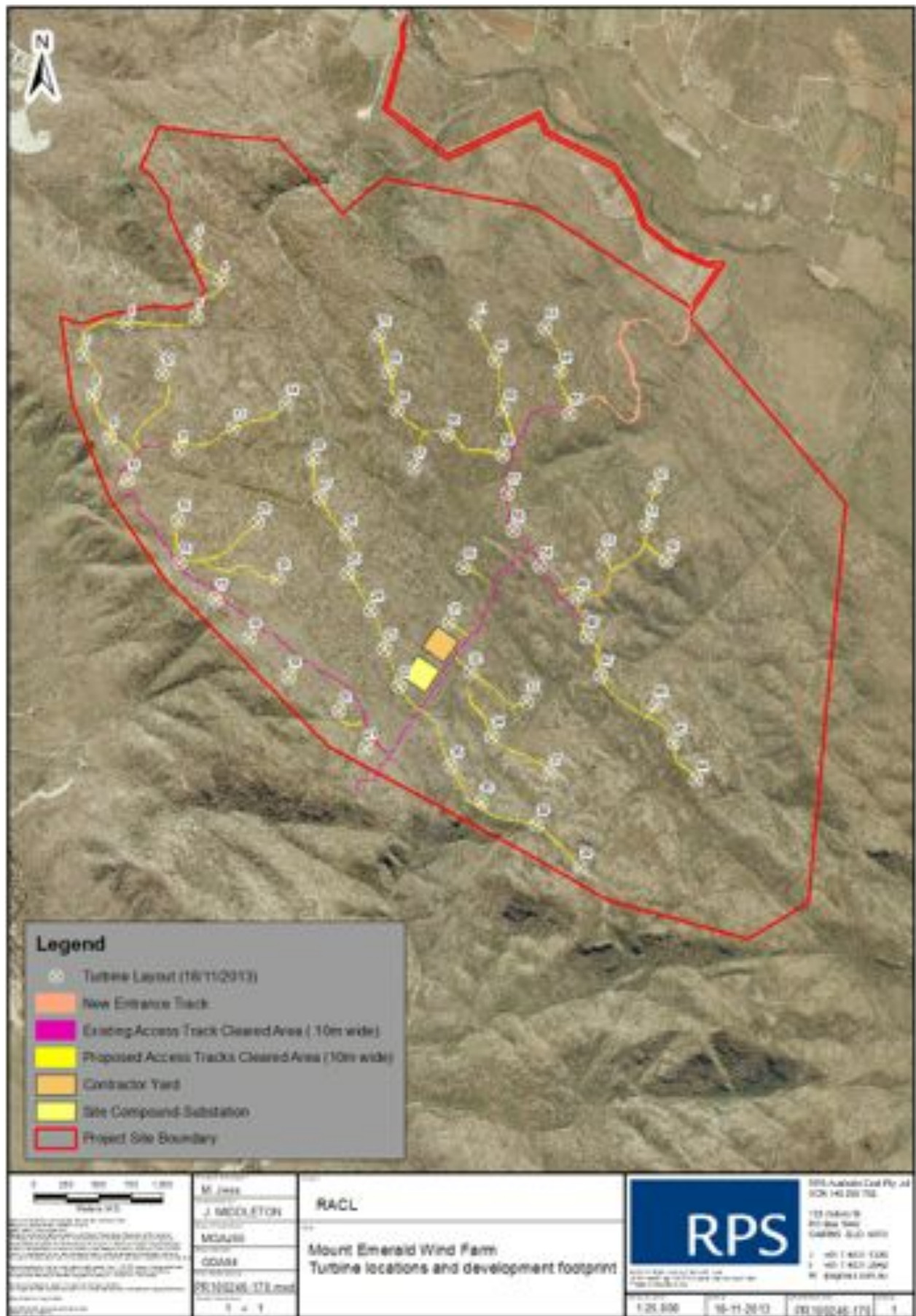


Figure 1 Development Footprint

1.2.2 Previous Surveys

Northern Quolls (*Dasyurus hallucatus*) are listed as a critically endangered under the EPBC Act. The species was first confirmed on the proposed Mt Emerald Wind Farm site in May 2011 (when a single scat was discovered in the vicinity of proposed Turbine 35 (previously Turbine 30) (RPS 2011). Following this detection, an intensive, large-scale camera trapping survey was conducted across the project site in June 2011, targeting ridge habitats, where the majority of turbines are proposed to be located, and creek lines (non-impact areas). The objective of the survey was to assess the broad habitat preferences of the species and to trial the use of camera traps to estimate population size through the identification of individuals by their unique spot patterns. The results of this survey indicated that the project site supported a substantial population, although it was not possible at the time to quantify the number of individuals from spot-pattern recognition due to limited resources. The camera trapping survey indicated that *D. hallucatus* were widely distributed across both ridge and creek line habitats at the time of the survey.

1.2.3 Study Scope

The objective of this study was to examine the spatial and temporal fine-scale habitat utilisation of *D. hallucatus* on the project site to assist with assessing the likely impact of the project on the local population. This information would also be used to develop effective and feasible management strategies to avoid and/or reduce impacts of the project on the local population, particularly during breeding periods that overlap with the construction phase.

Oakwood's (1997) study of the ecology of Northern Quolls in lowland tropical savannah at Kakadu National Park, Northern Territory showed that females display marked seasonal variation in den site habitat selection, with a preference for rocky areas during the non-breeding season and open forest habitats during the breeding season. Females were found to den in rocky areas more frequently than males and those females whose home ranges contained a greater proportion of rocky habitat were likely to live longer and therefore experience greater lifetime reproductive success (Oakwood, 1997).

The small body weight of *D. hallucatus* (300-1000 g) precluded the use of satellite or GPS telemetry to examine fine-scale habitat utilisation at the time of the study design (October 2011), and therefore the only option to collect fine scale habitat utilisation data over a long-period (at least 7-9 months) was VHF radio telemetry. However, the rugged topography of the site and the requirement to collect accurate position locations over a long period meant that traditional methods of obtaining position fixes of active animals using manual triangulation were considered to be unfeasible. It was decided to examine the effectiveness of an automated radio-telemetry system (ARTS) (Kays *et al.*, 2011; Ward *et al.*, 2013) which had been demonstrated to be effective on a wide range of species in tropical conditions.

The survey methods used in the study are described in the following section.

2.0 Methods

2.1 Live-trapping

A trapping survey was completed between the 5th February 2013 and the 23rd August 2013 and is summarised below in **Table 1**.

Table 1 Summary of Trapping Effort

Live-trap Types	Trap Lines	No. Traps	Start Date	End Date	Duration (days)	Trap Nights
Elliots	A, B, C lines	116	5/02/2013	11/02/2013	6	696
Wire Cages	A & C lines	28	13/05/2013	17/05/2013	4	112
Wire Cages	G	50	11/06/2013	15/06/2013	4	200
Elliots	D	30	20/03/2013	22/03/2013	3	90
Elliots	E	30	21/03/2013	22/03/2013	2	60
Elliots	F	30	27/03/2013	28/03/2013	2	60
Wire Cages	K	47	16/07/2013	18/07/2013	3	141
		56	23/07/2013	24/07/2013	2	112
		56	19/08/2013	23/08/2013	4	224
					TOTAL	1,695

2.1.2 Targeted Juvenile Trapping (February – April 2012)

Live-trapping to specifically target juvenile quolls was conducted within the signal coverage area of the southern Automated Radio-Telemetry System (ARTS) site using type-A Elliot collapsible box-style treadle traps (Elliott Scientific, Upwey, Victoria).

Three trap lines were established, along a creek line (C-line: 30 traps), a vehicle track (B-line: 50 traps) and following the base of the western escarpment respectively (A-line: 25 traps) (**Figure 2**). Traps were spaced at ~20 m intervals and the locations marked and labelled with reflective tape to assist with location during the evening. All trap locations were recorded with a hand-held GPS.

Trapping was conducted for seven continuous nights between the 5th and 11th February 2013. Each day, traps were opened and baited with three chicken necks in the late afternoon (1600-1700) and checked three times per night at 3-4 hourly intervals (i.e. 2000-2200, 0000-0200, and 0300-0500). Traps were closed following the final early morning check prior to sunrise and rebaited the following afternoon. Traps were inserted within plastic bags during rainy conditions and dry leaves and grass provided for bedding material.

Each captured animal was fitted a radio-collar (juveniles with 1.5 g Holohill and adults >300 g with 15 g Sirtrack collars), photographed to assist with identification, and the following data was collected:

- Sex;
- Body weight;
- Head-body length;
- Pes (foot) length; and
- Tail length.

Up until June 2013, digital photographs were taken of the dorsal surface of each captured animal whilst it was held in a calico handling bag to assist with subsequent identification. From June to August 2013, each

captured animal was placed within a 80 cm x 30 cm x 30 cm white plastic container and photographed to ensure that the images more closely resembled those captured with vertical mounted camera traps to enable survivorship to be calculated from future camera trapping based monitoring.

On the 7th February 2013, it was discovered that the Holohill elastic thread radio-collars (described in **Section 2.2.1**) had an intrinsic design flaw that caused the elastic thread to ratchet progressively tighter around the animal's neck resulting in deep abrasion injuries to the skin. Each collared juvenile was then recaptured and the the collars removed. Collars were then modified (expand the bore of the tube in the epoxy casing through which the elastic was threaded through and covering the elastic thread with heat shrink tubing so that it could not tighten) for future collaring to prevent further injuries to animals. Targeted den site trapping was continued until such time all collared juvenile animals were recaptured or the day time den site was no longer able to be located.

A single collared male (NQ-T4-1) was no longer able to be located by radio-tracking after the 14th March 2013 and an aerial search with a helicopter was undertaken. Additional trap lines were established in the vicinity of the remaining collared animals' day time den sites in an attempt to recapture the animal and remove the faulty Holohill collar (**Figure 2**);

- D-line, consisting of 30 Elliot traps spaced at 20 m intervals was set on the 20th March 2013 and trapping was conducted for three consecutive nights.
- E-line, consisting of 30 Elliot traps spaced at 20 m intervals was established on the 21st March 2013 and trapping was conducted for two consecutive nights.
- F-line, consisting of 30 Elliots spaced at 20 m intervals was established on the 27th March 2013 and trapping was conducted for two consecutive nights.

In addition to the targeted Elliot trapping, a total of five Reconyx HC550 visible flash camera traps were set in the vicinity of the last known day time den site location between the 22nd March and 16th May 2013 to determine whether the individual was still active in the area. The cameras were set in a vertical orientation, attached to a tree at ~90 cm above the ground with an angle bracket and baited with chicken necks placed within a bait holder affixed to the ground directly beneath the camera. Following the detection of animal NQ-T4-1 on the camera traps on the 16th May 2013, targeted trapping using wire cage traps was conducted along G-line as described below.

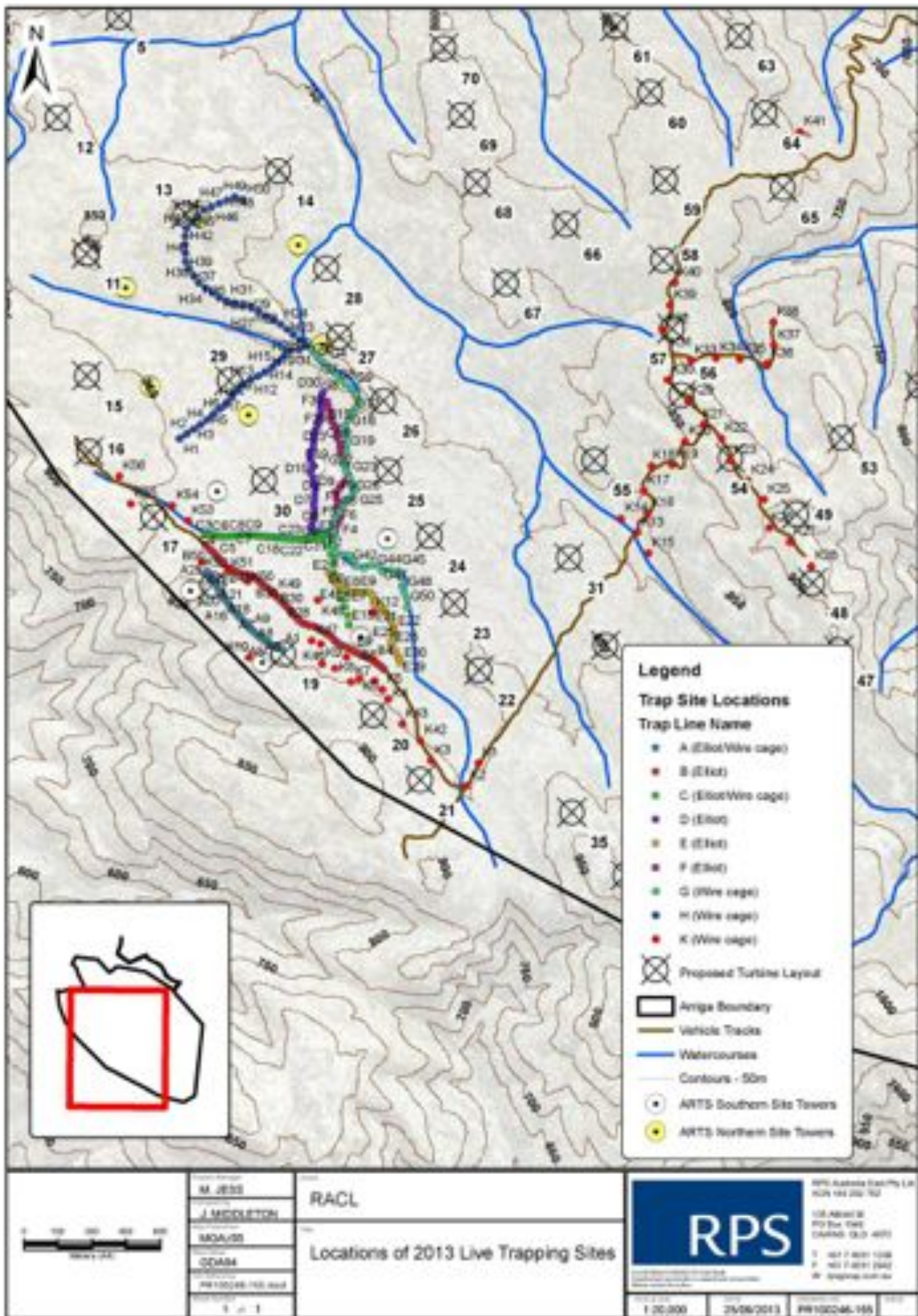


Figure 2 2013 Live Trapping Sites

2.1.3 Targeted Sub-adult/ Adult Trapping (May to August 2013)

Two lines of collapsible wire cage traps (15 cm x 15 cm x 45 cm, Mascott Wire Works, Homebush West, NSW) were established along the previous A and C-lines and consisted of 12 and 16 traps respectively, spaced at ~40 m intervals (2). Trapping was conducted for four consecutive nights from the 13th to the 17th May. A line of 50 collapsible wire cage traps was established along the major creek line transecting the eastern edge of the southern ARU site and heading N to the SW corner of the northern ARU site (G-line - 2). Traps were spaced at approximately 40 m intervals. Trapping was conducted for three consecutive nights from the 20th-22nd May 2013. A line of 50 wire cage traps, spaced at 40 m intervals was established within the northern ARTS site (H-line, 2). Traps were set for four consecutive nights from the 11th-15th June 2013 (**Figure 2**).

All cage traps along the A, C, G and H-lines were baited in the late afternoon with half a chicken frame and checked twice a night, between 2200-0000 hrs and 0400-0600 when the traps were closed until the following afternoon. All cages were covered in an inner layer of cut grass to provide bedding material and a water-proof outer layer of polyethylene film. All cage trap locations were marked and labelled with reflective tape to assist with locating them at night and their positions recorded with a hand-held GPS unit.

A total of 47 wire cage traps, spaced at approximately 100 m intervals were established immediately adjacent to vehicle tracks with the primary purpose of capturing animals for collaring both within the ARTS sites and along major ridges (K-line, 2). Trapping was conducted at the K-line trap for three consecutive nights between the 16th to the 18th July 2013. An additional nine traps were added to the K-line (total of 56 traps) and trapping was conducted for two consecutive nights between the 23rd and 24th July 2013 and for four consecutive nights between the 19th and 23rd August 2013 (**Figure 2**). Traps along the K-line were first baited during day-light hours, checked between 0530 and 1000 hr the following morning and rebaited if necessary (e.g. if bait had been eaten, removed or was too ant-infested). Traps were covered in a thick inner layer of cut grass for bedding and a water/windproof outer layer of polyethylene film. All cage trap locations were marked and labelled with reflective tape to assist with locating them at night and their positions recorded with a hand-held GPS unit.

2.2 Radio-tracking

2.2.1 Radio-collar Specifications

Few researchers have previously attempted to radio-track juvenile Northern Quolls, especially males due to their rapid growth rate (Teigan Cremon, PhD Candidate, USC, *pers. com.*). A total of twenty light weight (10 x 0.5 g & 10 x 1.5 g) Holohill VHF radio-collars with whip aerials were obtained for use on juvenile quolls. The transmitters were encased in epoxy, pulsed at 30 pulses/minute and the battery life was estimated to be 28 days for the 0.8 g units and 49 days for the 1.5 g units. The collar itself consisted of elastic thread (1.5 mm diameter on the 1.5 g units and 0.5 mm diameter on the 0.8 g units) secured by a knot through a tube attached to the epoxy case. The elastic thread collar was selected over leather or PVC collar materials in order to allow expansion. The 0.8 and 1.5 g packages were matched to juvenile individuals to ensure that they weighted no more than 3% of their body weight.

A total of 50 SIRTRACK VHF suede radio-collars with whip aerials (9 g) were obtained for use on adult quolls with body weights exceeding 300g. The transmitters were encased in epoxy, pulsed at 30 pulses per minute and battery life was estimated to be 234 days. The Sirtrack collars were matched to individuals to ensure that they weighted no more than 5% of their body weight i.e. minimum body weight of 300 g. The actual material consisted of soft suede cut to size and secured with a nylon nut and bolt, which once tightened, was then covered in head shrink to reduce skin abrasion. After periods of rainfall or heavy dew, the suede material of some of the Sirtrack collars on recaptured animals was found to have stretched and required readjustment. The detection range of the Sirtrack and Holohill radio-collar transmitter signals was

stated by the manufacturers to be approximately 1000 m. The pulse width and pulse interval of all of the radio-transmitters was independently measured by using an oscilloscope (Austek, Cairns).

Following the recapture of the juveniles injured by the Holohill collar, it was decided to immediately cease collaring until May 2013 (to continue collaring with the Sirtrack permanent suede collars) when animals had approached their adult body weight and their neck circumference growth had slowed or ceased.

2.2.2 Radio-tracking with the Automated Radio Telemetry System (ARTS)

The use of traditional radio-tracking methods (i.e. triangulation using hand-held yagis and radio-receivers) to quantify night-time movements and fine-scale habitat usage of a sufficient sample size of Northern Quolls was not feasible for a number of reasons, but in particular due to the sites extensively rugged terrain (83% of slopes over 15°) and human health and safety.

An alternative tracking method was devised, in consultation with Scott Burnett (USC), to use an automated radio telemetry system (ARTS) similar to that used by Crofoot *et al.* (2010), Kays *et al.* (2011) and Ward *et al.* (2013). ARTS systems use multiple directional antennas for each receiver and rely on differences in signal strength to detect movement and to estimate an animal's location (Ward *et al.*, 2013). These studies identified that when an animal was within the range of three or more antenna array towers, its location could be estimated through triangulation. According to White (1985), the optimal spatial arrangement for six radio-detection towers is for them to be arranged equidistantly around a circle with a diameter equal to the detection range of the radio-transmitters, assumed to be approximately 1000 m (**Figure 5** and **Figure 5**).

Locations where at least one *D. hallucatus* were determined by camera trapping in July-August 2011 were identified (**Figure 3**). View-shed analysis using Global Mapper ver. 14.0.3 (Blue Marble Geographics) was used to examine various positions of the optimal ARTS tower set-up with the tower height set at 6 m and using a 5 m digital elevation model of the study site within the areas of high *D. hallucatus* abundance. The areas of overlapping tower coverage were calculated and visualised with ARGIS 10.1 (ESRI, 2012). Locations were chosen so as to maximise the total detection area covered by three or more antenna array towers.

The final locations of the two selected ARTS sites are shown in **Figure 4** and **Figure 5**. Both ARTS sites included ridge habitats where turbines are proposed to be located and creek lines as both habitats have been shown to be important for *D. hallucatus* at different times of the year in tropical savannah (Oakwood, 1997). The total area where triangulated fixes were possible (visible by three or more towers) within the northern and southern ARTS sites was approximately 115 ha and 149 ha respectively, based on a 900 m detection range for each tower (**Figure 5** and **Figure 5**).

Due to the remote and rugged nature of the site, the lack of vehicle tracks in the vicinity of the selected areas and the size and weight of the tower and antenna equipment, a helicopter was used to sling in the equipment to the nearest suitable landing area. The towers were erected in December 2012. Each radio-receiver array tower comprised a four m tall galvanised metal pipe (50 mm diameter) attached to a one m long T-bar with an attachment to fit a three m long jenny-bar to assist with the raising and lowering the tower (**Plate 1**). The T-bar was secured to the ground with U-brackets screwed into rock. When erect, the tower was stabilised by four guy wires (four m wire rope) attached to the tower at four m above the ground and affixed to the ground using star-pickets or rock bolts.

Each tower supported six horizontally oriented yagi antennas (Sparrow Systems) arranged with their azimuth directions separated by 60° to give 360° coverage (**Plate 1**). A Bantam automated receiving unit (ARU) (Sparrow Systems) was connected to the antenna array on top of the tower by coaxial cables. The ARUs were located within a water-proof enclosure located at the base of the tower and shaded from direct sun

using air-cell aluminised bubble-wrap roof insulation as the unit's ability to lock onto the radio-signal is highly sensitive to temperature (Jim Cochran, pers. comm.).

Each Bantam ARU was programmed to tune to the radio frequency of each transmitter and record the signal strengths (in dB) from each of the 36 yagi antennas at intervals of 15 minutes. The search interval is programmed using custom software (provided by the manufacturer) as a text file on a standard secure digital (SD) card. An ARU can store two gigabytes of data on its SD card. Data was collected from each ARU unit on average every 14-20 days by replacing the SD card and downloading data onto a ruggedized tablet. Power for each ARU was provided by a 12- volt deep cycle marine battery powered by a 30W solar panel. At each initialisation, the internal clocks of each ARU unit had to be synchronised to ensure that all units tuned to the correct frequency at the same time. A detailed description of the method used to estimate signal bearings from data obtained from an ARU and a six antenna array is provided in Kays *et al.* (2011).

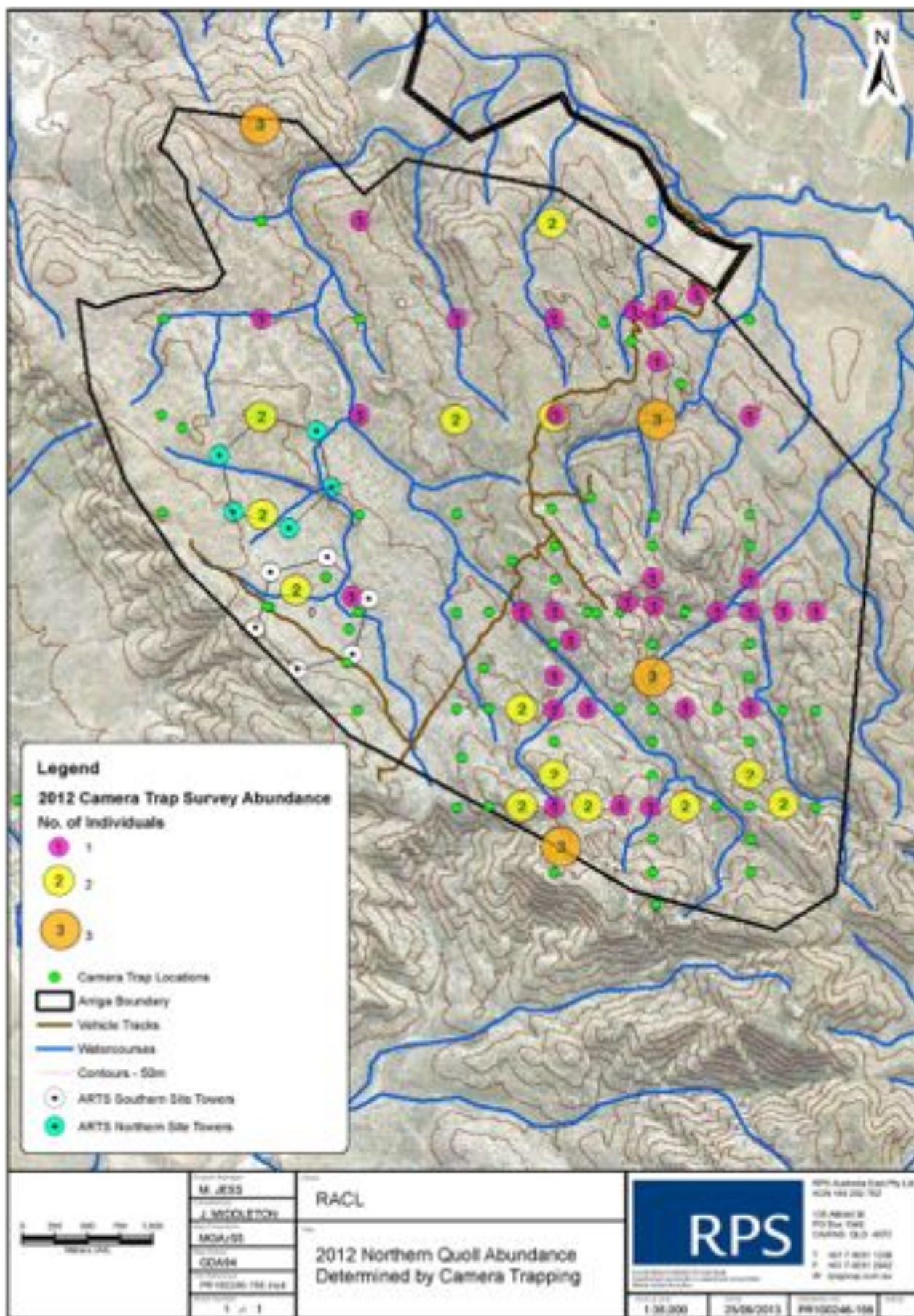


Figure 3 *D. hallucatus* Abundance from 2012 Camera Trapping Study and 2013 ARTS site locations

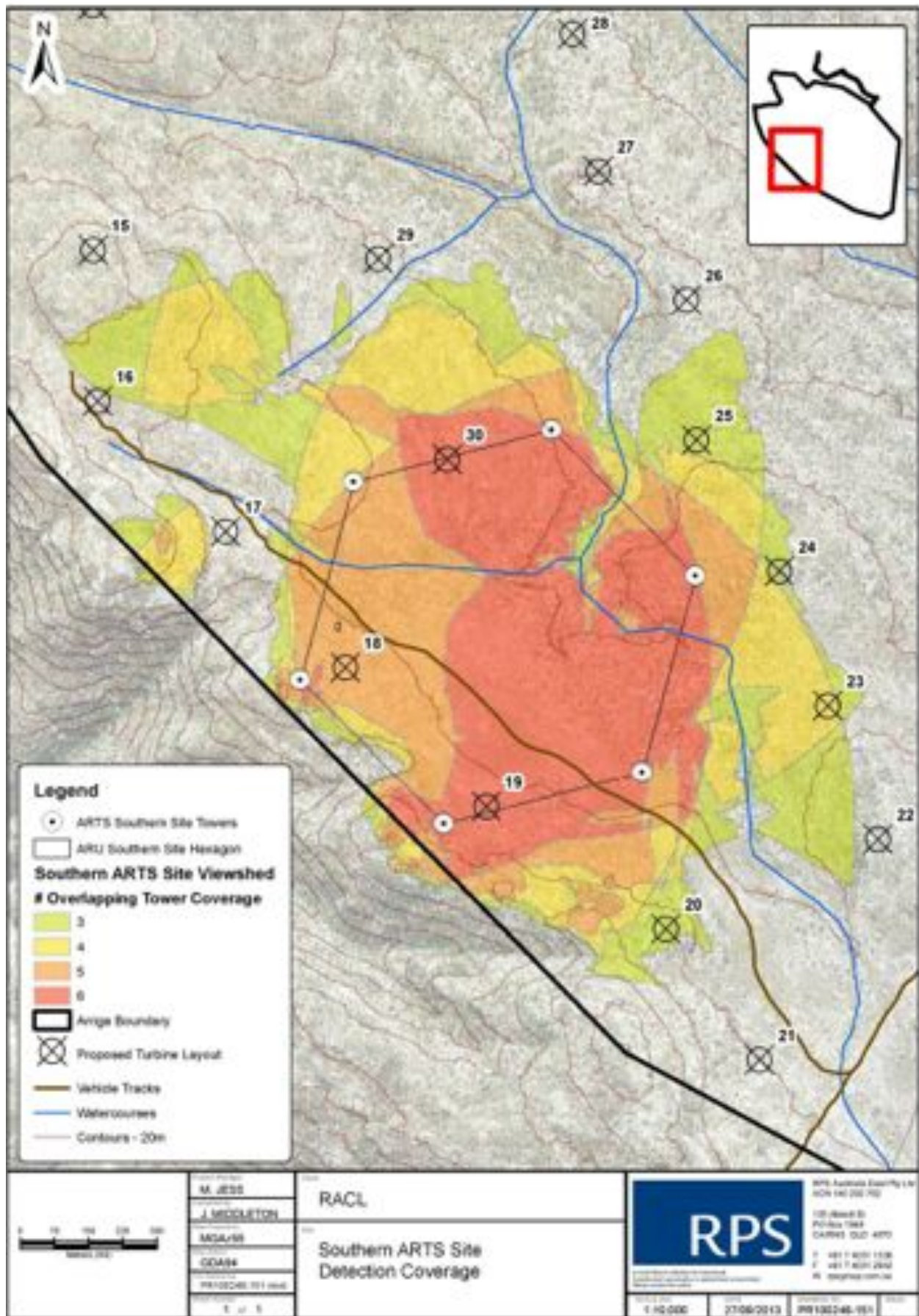


Figure 4 Southern ARTS Detection Coverage Area

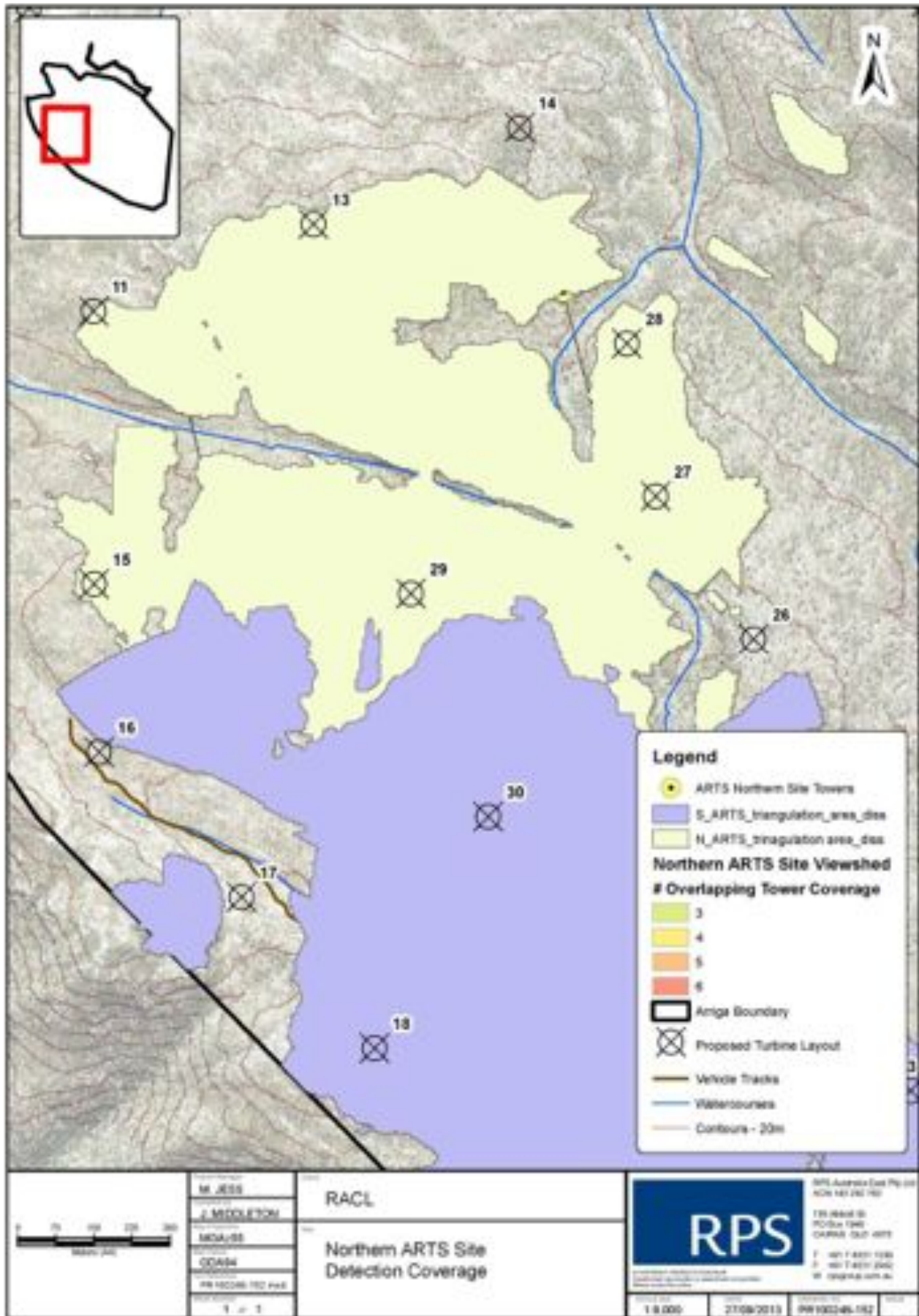


Figure 5 Northern ARTS Site Radio Coverage Area



Plate 1 ARTS Tower Prior to Erection

It was initially proposed to relocate the yagi arrays and ARU units between the southern and northern ARTS sites approximately every two weeks to maximise the spatial coverage. However, it became apparent after the initial set-up of the antenna arrays and ARU at the southern ARTS site in January 2013, that it would be more cost efficient to purchase another 36 yagi antennas for the northern ARTS site and simply transfer the

ARU units between the sites rather than having to lower the towers, dismantle the yagis, transport them up to 1 km on foot over uneven rocky terrain to the new sites, lowering the new towers, reassemble and attach the yagis and coaxial cables, raise the towers and tension the guy wires and remeasure the new antenna bearings twice every two weeks (estimated cost \$26,000/month). The periods the ARU units were deployed at each of the two ARTS sites is shown in **Table 2**.

The bearing direction of the #1 and #4 yagi antennas was determined by attaching a 2 kg plumb bob to 5 m long cords affixed to the main elements of the two yagis, then sighting between the two vertical lines made by the cords with a Suunto KB-77 hand-bearing compass.

Table 2 ARTS Sites Survey Periods

ARTS Site	Deployment Dates
Northern Site	26/6/13 TO 15/7/2013
Southern Site	30/1/13 TO 8/2/13; 24/4/13 TO 28/5/13; 17/7/13 TO 8/8/13

The *BantamView* software that was provided with the purchase of ARU units did not have a user's manual (the original programmer failed to complete a manual and then the funding for the development of the software was discontinued) nor was any software support available from the manufacturer (Jim Cochran, Sparrow Systems) to assist with the extraction of locations from the ARU signal strength data using this software. Therefore, the signal strength data from the ARU units recorded on the southern ARTS site was sent to Michael Ward (University of Illinois) who has been engaged by Sparrow Systems since July 2013 to develop ARU data analysis software using *R* (freeware statistical software <http://www.r-project.org/>). Michael Ward has extensive experience with the use of the Bantam ARU units for automated radio-tracking of snakes and birds (see Ward *et al.*, 2013).

A test transmitter beacon (150.2700 KHz) was attached to a tree with a cable tie at a height of ~ 2 m above the ground at c. 326853 8100367 on the 16/7/13 to assist estimating the spatial error of the location fixes obtained by the ARU units.

2.2.3 Day-time Den Site Radio-tracking

To assist with validating the position locations of collared animals obtained using the automated radio-telemetry system, and to quantify den site characteristics, all day time den sites were manually located with the use of a Titley Electronics Australis K2600 receiver and a hand-held collapsible yagi antennae during the following periods: 6-15/2/13; 18-22/2/13; 25-28/2/13; 1/3/2013; 6/3/2013; 12/3/13 to 14/3/13; 18- 20/3/13; 14-16/5/2013; 21/5/13; 17-19/6/13; 27/6/13; 16/7/2013; 22-24/7/13; 8/8/13; 22-23/8/13; 28/8/13; 30/8/13; 2/9/13; 4/9/13; 6/9/13; 9/9/13.

Triangulation methods were frequently used to determine the general location of resting animals during day-light hours. Once the approximate general location was established by triangulation, the exact location of the day time den sites was determined by walking-in and isolating their collar signal to a specific structure (e.g. hollow log, rock pile etc). Where possible, each den site was investigated with a burrow-scope or directly with the aid of a torch to determine whether the collar was still attached to a living animal (**Plate 2**).

Although it was demonstrated that some radio-signals could be detected on foot from distances of up to 1.8 – 2 km when positioned on high ridges, the detection range for the majority of the collars was much more constrained, especially if the animals were denning in rugged rocky gullies, underneath the ground or within rock piles. Many of the collared animals were not able to be detected within several days of their first capture

Each den site was marked and labelled (collar frequency, date and time) with pink fluorescent survey tape, photographs taken of the den site and the surrounding area (one photo at each cardinal point) and a

description of the location and type of den site recorded (e.g. in dead standing *Eucalyptus reducta* with a d.b.h of 30 cm, ~ three m above the ground; under rock slab uplifted by *Callitris intratropica*). Den sites were classified into four general microhabitats:

- Beneath ground (e.g. burnt out root hollow);
- Hollow log on ground;
- Hollow standing tree (live or dead); and
- Rock fissure (e.g. beneath rock slab/boulder pile, within rock crevasse etc)

Determination of the approximate locations of active collared animals that were unable to be located on foot was also attempted from the air using a helicopter on the 20th March, 17th June and 21st August 2013. Although it was difficult to obtain accurate locations, the general vicinity could be determined and followed-up with ground-based searching.



Plate 2 Adult male *D. hallucatus* NQ-T5-7 in day time den located under a large horizontal rock slab on 23rd August 2013.

3.0 Results

3.1 Live-trapping

A total of 26 individual *D. hallucatus* were captured between the 6th February and the 21st August 2013. Of these 26 individuals, five were females.

All males that were captured had descended testes. On the basis of body weight and general condition, it is likely that all of the captured males were less than one year old.

A female (NQ-T1-6) weighing 620 g was captured on the 10th February 2013 and it is likely this individual was greater than 1 year in age as it possessed an enlarged stained pouch. All of the remaining females that were captured between February and August 2013 were likely to have been less than a year old (based on their body weight and pouch condition). A female (NQ-T5-1) weighing 575 g was captured on the 16th July 2013 and possessed a stained pouch and slightly enlarged nipples indicated it was approaching breeding condition. When NQ-T5-1 was recaptured on the 23rd August 2013, six hairless young (~10 mm head-body length) were present in the pouch (**Plate 3**).

None of the males that were trapped between July 2013 and August 2013, after the first female that appeared to be in breeding condition was captured, showed any obvious signs of reduced condition (e.g. sores, thinning or loss of hair etc) characteristic of the males towards the end of the breeding season.

3.2 Day-time Denning Sites

A total of 146 day time locations of collared Northern Quolls were located on foot during the study period (February to August 2013). It was assumed that these locations represented day time den sites; however it was only possible to confirm the presence of the living animal in a few cases. An additional three day-time fixes for three animals were obtained only from a helicopter on the 17th June 2013, however the spatial accuracy of these fixes was not able to be confirmed as they were located in remote rugged section in the northwest of the site and were not able to be checked on foot.

The duration between successive fixes varied considerably between individuals as not all individuals could be located on every radio-tracking attempt

The location of day time dens was undertaken most frequently during February 2012 because the Holohill collars that were deployed had a limited battery life (27-49 days depending on the unit size) and also, after it was discovered the collars were causing injuries to the animals, the locations had to be determined every day until such time as the animal was recaptured or the signal was not able to be found.

Limited ground-based manual radio-tracking was undertaken between the 21st March and the 13th May 2013 as only two individuals (female NQ-T1-6 and male NQ-T1-4) remained collared and neither was able to be located on foot despite intensive searching throughout the site.

Despite Sirtrack indicating that the radio-collar only had a range of up to 1000 m, it was possible to detect the signal of a test beacon (150.2700 Hz) up to two km from some elevation vantage points.

The location of the day time den sites for all of the collared juvenile males (5), adult males (14) and adult females (4) and as determined by manual radio-tracking are shown in **Figure 6**; **Figure 7** & **Figure 8** respectively.

The average and median number of day time den site locations obtained for all collared animals was five and four sites respectively (**Table 3**).

The periods over which den sites were located for all of the collared animals are shown in **Table 3**. The mean and median duration of the period over which all collared animals den sites were located was 30 days and 28 days respectively (n=19 animals).

Table 3 Day-time Den Site Summary Table

Quoll ID	Sex/ Estimated Age	Date First Collared	Date First Den Site Obtained	Date Last Den Site Obtained	Duration Between 1 st & Last Fixes (days)	Number of Fixes Obtained	Number of Unique Den Sites Located
NQ-T1-1	M/juvenile	6/2/13	6/2/13	18/3/13	42	16	10
NQ-T1-2	M/juvenile	6/2/13	8/2/13	27/2/13	19	13	3
NQ-T1-3	M/juvenile	6/2/13	7/2/13	11/2/13	4	6	3
NQ-T1-4	M/juvenile	6/2/13	7/02/13	14/3/13	37	21	13
NQ-T1-5	M/juvenile	8/2/13	8/2/3	19/3/13	41	16	9
NQ-T1-6	F/2 nd year adult	8/2/13	8/2/13	17/6/13	129	22	14
NQ-T2-1	F/1 st year adult	13/5/13	14/5/13	19/6/13	35	6	5
NQ-T2-2	M/1 st year adult	21/5/13	17/6/13	27/6/13	10	3	2
NQ-T3-1	M/1 st year adult	11/6/13	17/6/13	17/6/13	0	1	1
NQ-T3-2	M/1 st year adult	12/6/13	17/6/13	19/6/13	2	2	2
NQ-T3-3	M/1 st year adult	12/6/13	12/6/13	23/8/13	71	6	5
NQ-T3-5	M/1 st year adult	12/6/13	14/6/13	27/6/13	13	4	2
NQ-T4-2	F/1 st year adult	11/7/13	16/7/13	8/8/13	22	4	2
NQ-T5-1	F/1 st year adult	16/7/13	23/7/13	20/9/13	57	12	8
NQ-T5-2	M/1 st year adult	16/7/13	21/8/13	21/8/13	0	1	1
NQ-T5-7	M/1 st year adult	18/7/13	20/8/13	20/9/13	30	7	6
NQ-T6-1	M/1 st year adult	23/7/13	23/08/2013	23/08/13	0	1	1
NQ-T6-2	M/1 st year adult	23/7/13	20/08/2013	20/09/13	30	5	4
NQ-T7-1	M/1 st year adult	21/8/13	22/08/2013	20/09/13	28	7	4

Of the 153 day time den sites locations recorded by radio-tracking, 131 had microhabitat information recorded. The majority of den sites were located within rock fissures (64), followed by tree hollows (44), hollow fallen logs (14) and beneath the ground (2), although each individual showed significant variation in the selection of den microhabitats (**Table 4**).

Table 4 Den Site Microhabitat Types For Each Collared Individual

Quoll ID	Sex/Estimated Age	Microhabitat Type				Total
		Hole Under ground	Hollow Log	Hollow Tree	Rock Fissure	
NQ-T1-1	M/juv	1	4	2	9	16
NQ-T1-2	M/juv	0	1	9	3	13
NQ-T1-3	M/juv	0	0	3	3	6
NQ-T1-4	M/juv	0	0	7	12	19
NQ-T1-5	M/juv	0	0	0	10	10
NQ-T1-6	F/2nd year adult	1	3	10	5	19
NQ-T2-1	F/1 st year adult	0	0	1	2	3
NQ-T2-2	M/1 st year adult	0	0	2	0	2
NQ-T3-1	M/1 st year adult*	0	0	0	0	0
NQ-T3-2	M/1 st year adult	0	1	0	0	1
NQ-T3-3	M/1 st year adult	0	0	0	1	1
NQ-T3-5	M/1 st year adult	0	2	0	0	2
NQ-T4-2	F/1 st year adult	0	0	0	3	3
NQ-T5-1	F/1 st year adult	0	0	8	2	10
NQ-T5-2	M/1 st year adult	0	0	0	0	0
NQ-T5-7	M/1 st year adult	0	1	0	5	6
NQ-T6-1	M/1 st year adult	0	1	0	0	1
NQ-T6-2	M/1 st year adult	0	1	1	3	5
NQ-T7-1	M/1 st year adult	0	0	1	6	7
Grand Total		2	14	44	64	124

Note: * denotes no description was recorded for this individual's one den site.

3.2.2 Tracked Females

Radio-tracking revealed that the mean Euclidian distance between consecutive den sites (i.e. those used on successive days only) for the three individuals, NQ-T1-6, NQ-T2-1 and NQ-T5-1, between 8th February and the 24th July 2013 was 306 m (range = 0 m to 532 m, n=15). None of the den sites locations for female NQ-T4-2 were obtained on consecutive days.

The majority of den sites for females were located with hollow trees and rock fissures (refer **Table 4**).

NQ-T1-6 (2nd-year adult)

The second-year adult female, TQ-1-6, was first captured on 8th February 2013 and fitted with a Holohill 1.5 g which was then replaced with a permanent Sirtrack suede collar on the 10th February 2013.

Den sites were located for this female every 1-2 days between 8th February 1st March 2013 and then every 2-6 days up until the 14th March 2013. The final approximate den site location was determined from a helicopter on the 20th March 2013 (**Figure 6**) and no subsequent locations were obtained despite frequent (at least weekly) surveys.

The adult female denned in a variety of different microhabitats including in standing and fallen tree hollows, in rock piles and under rock slabs (**Figure 6**). During the period between the 8th to the 15th February when den sites were located every day, the mean Euclidian distance (i.e. the ordinary distance between two points

that one would measure with a ruler), as opposed to the actual physical distance over the undulating landscape surface) that was moved between successive dens was 229 m (range = 0 m to 532 m, n=7) (**Figure 6**). A total of 14 unique den site locations were obtained for this individual by foot-based tracking. A single den site located 5 m above the ground in a large standing Eucalyptus tree at c. 3269801E 8101148N was used on seven separate occasions (**Table 3; Figure 6**). Only one other den site located in a hollow log on the ground at c. 327153E 8101485N was used twice. The remainder of the den sites for this individual that were located on foot were all used only once (**Figure 6**). During the period between the 18th and the 22nd February 2013 when den sites were located every day, the mean Euclidian distance that was moved between dens was 393 m (range = 373 m to 446 m, n = 4). The mean Euclidian distance moved between all den sites that were located on sequential days was 339 m (range = 0 m to 532 m, n = 12). The final located den site (17th June 2013 from helicopter) was approximately 3.4 km from the initial point of capture (**Figure 6**).

NQ-T2-I

This 1st-year female was first captured on the 13th May 2013 and was recaptured on seven other occasions between the 13/5/13 and the 21/5/13; often twice in a single evening. A total of five unique day time den sites were located on foot for this female between the 14th May 2013 and the 17th June 2013 (**Table 3; Figure 6**). The severed head of this female with the collar still attached and active was located on the 19/6/13 at c. 327248E 8100024N. The Euclidian distance between the two den site located on consecutive days was ~167 m for this individual.

NQ-T4-2

This 1st year female was first captured on the 12th July 2013. Only two den sites were located for this individual, both within ~100 m of each other. This individual was tracked to a den site located underneath a fractured rock slab at the base of a *Callitris intratropica* tree near the top of a ridge at c. 326518E 8 099 793N on four occasions before on the 16th August 2013, the collar was retrieved having apparently fallen off (**Table 3; Figure 6**).

NQ-T5-I

This 1st year female was first captured on the 16th July 2013 at c. 328476E 8101047N and was tracked from the 23rd July 2013 until the 20th September 2013. On the 23rd August 2013, the individual was recaptured and found to have a total of 6 hairless pouch young (**Plate 3**). A total of nine day time den sites were located on foot for this individual (**Table 3; Figure 6**). One den site located in a live hollow standing eucalyptus was used on three separate occasions, and two dens located within dead standing hollow trees were used twice each (**Figure 6**). The Euclidian distance between the two den site located on consecutive days was ~109 m.



Plate 3 Female *D. hallucatus* (NQ-T5-1) with 6 pouch young captured on 23/8/13

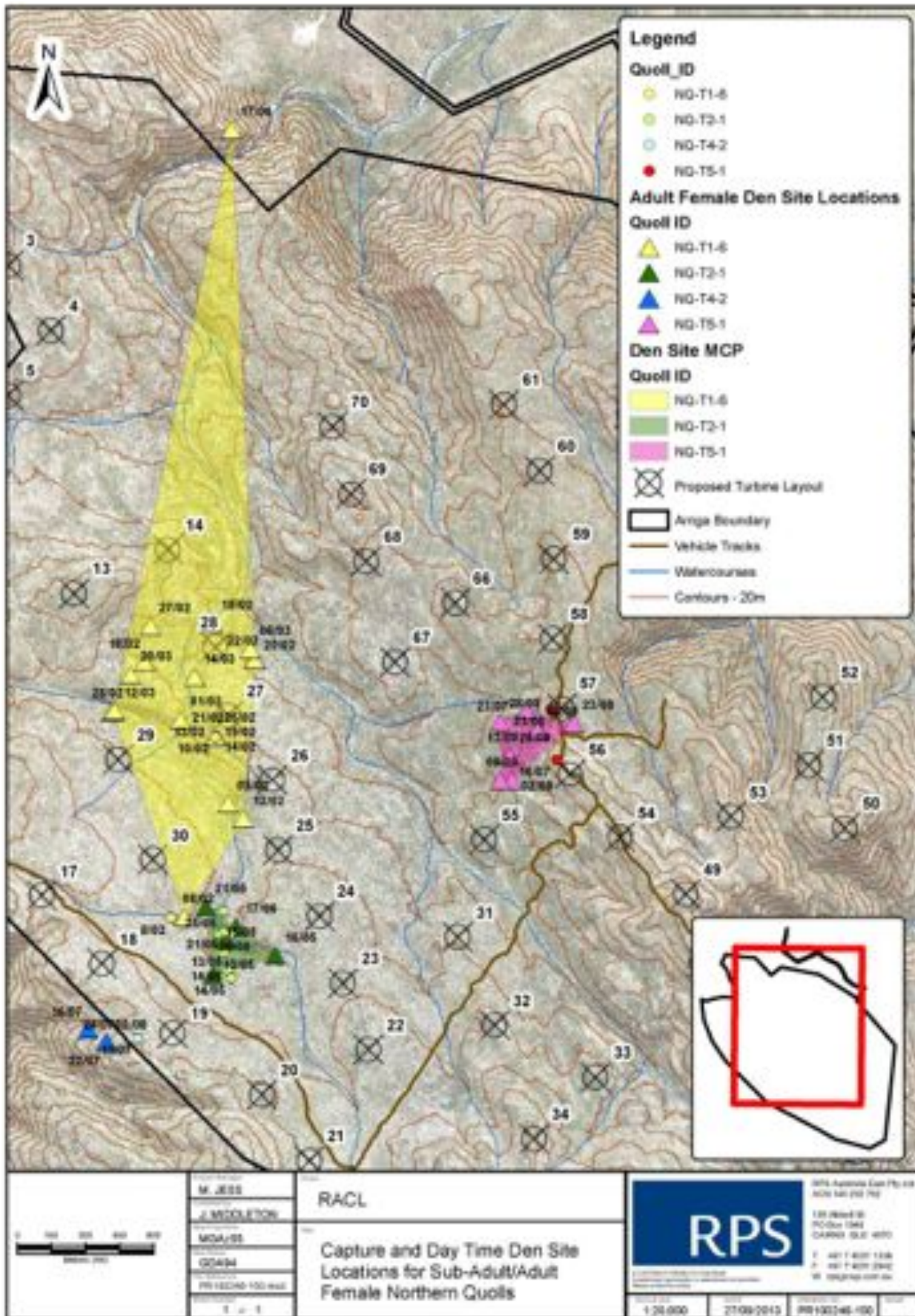


Figure 6 Capture and Day Time Den Site Locations for Sub-Adult/Adult Female Quolls.
MCP = minimum convex polygons

3.2.3 Tracked Juvenile Males

A total of five males were captured on the A, B & C Elliot-trap lines (**Figure 7**) and all were fitted with Holohill elastic thread collars between 6th and 14th February 2013. All five males were considered to be juveniles based on their body weights which were all below 400 g. All collared juvenile males were tracked to their day time dens until such time as they were recaptured and the collars removed or they were not longer able to be located.

NQ-TI-1

A total of 10 unique den site locations were recorded for this individual between the 6th February 2013 and the 18th March 2013, when it was recaptured at c. 327339E 8099976N and the collar removed. During the period the collar was fitted, the animal was tracked for four consecutive days between the 19th and the 22nd February and again between the 25-28th February. The mean Euclidian distance moved between the 19-22nd february was 329 m (range = 257 m to 364 m, n=3). The mean Euclidian distance moved between the 25-28th February was 78 m (range=52 m to 134 m, n=3).

NQ-TI-2

Only a total of four unique den site locations were obtained for this animal between the 8th and 27th February 2013 when the detached collar was located within a standing hollow tree at c. 326972 8099606N, the same location it had been since the 18th of February (**Figure 7**). It is not certain when exactly the collar was detached inside the den site.

NQ-TI-3

Only a total of four unique den sites were obtained for this animal between the 7th and 11th February, when the animal was recaptured in the vicinity of the den site located at c. 326994E 8100338N (**Figure 7**). The mean Euclidian distance between successive den sites for this individual during this period was 171 m (range = 23 m to 260 m, n=4).

NQ-TI-4

A total of 20 unique den sites were located for this individual between the 7th February and the 14th March (**Figure 7**). The mean Euclidian distance moved during this time was ~263 m (range = ~2 m to ~662 m). The maximum Euclidian distance moved between den sites on successive days was ~662 m.

NQ-TI-5

A total of 13 unique den sites were located for this individual between the 8th February and the 19th March 2013 (**Figure 7**). The mean Euclidian distance moved between these dates was ~147 m (range = 0 m to ~513 m). The maximum Euclidian distance moved between den sites on successive days was ~513 m.

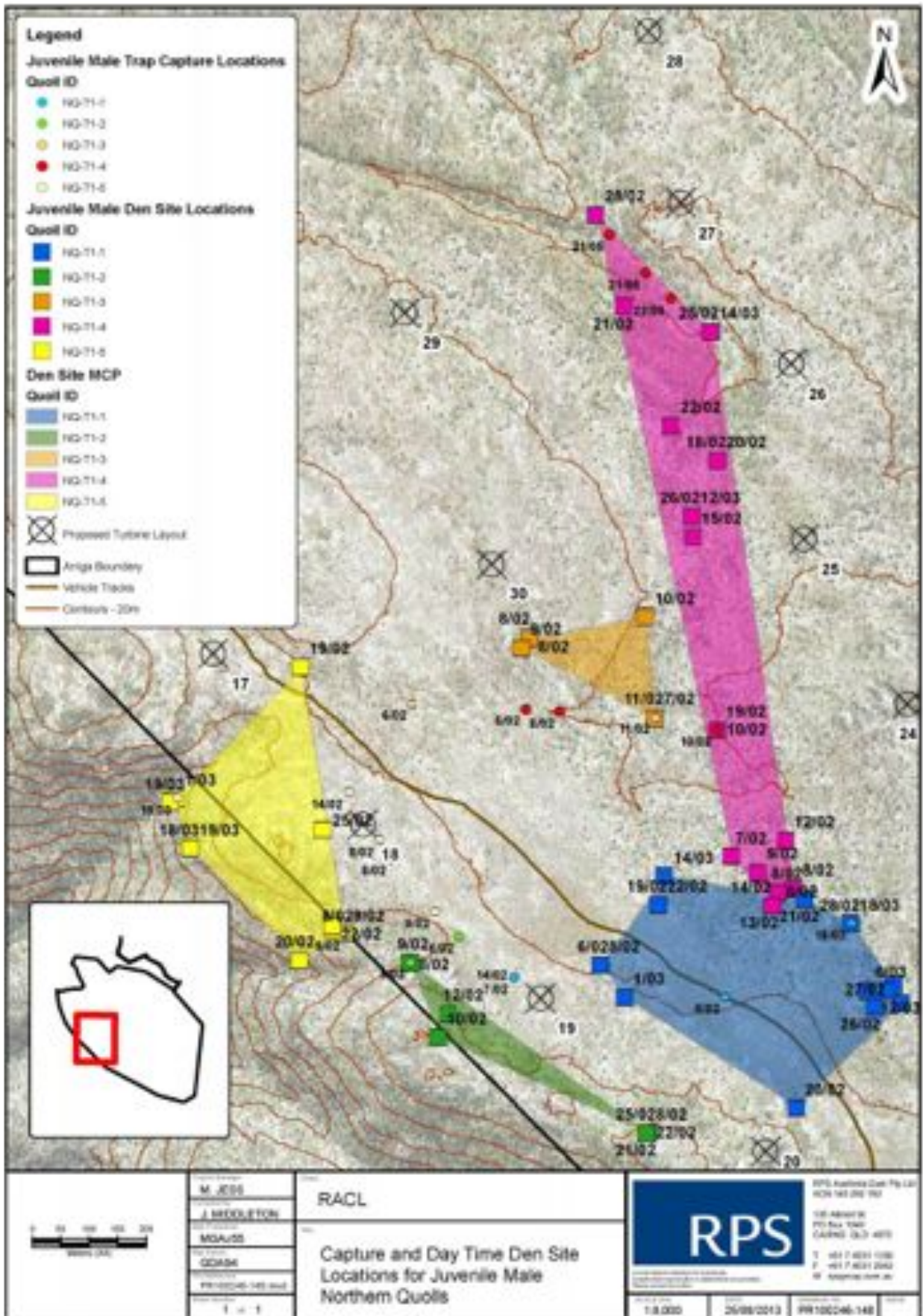


Figure 7 Capture and Day Time Den Site Locations for Juvenile Male Northern Quolls.
MCP = minimum convex polygons

3.2.4 Tracked Adult Males

No den sites were located on consecutive days for any of the collared adult male *D. hallucatus*.

NQ-T2-2

A total of two unique den site locations were recorded for this 1st year adult male between the 17th and 27th June 2013, although the animal was only tracked on three occasions (**Table 3; Figure 8**). Two of the fixes were recorded at the same den site (3–4 m above the ground within a hollow *Eucalyptus cloesiana*) eight days apart which may indicate that the collar had become detached. The two den sites were located approximately 753 m and 780 m from the location where the animal was captured on the 21st May 2013 (**Figure 8**). Both den sites for this animal were located in close proximity to creek lines (**Figure 8**). No further signal detections were recorded for this collared individual despite extensive searching on foot and by helicopter.

NQ-T3-1

Only a single den site located on the mid-slopes of a deep wide gully, approximately 1.2 km NNE of the initial capture point was recorded for this 1st year adult male (**Table 3; Figure 8**). The location was only approximate as it was detected from the air in a helicopter and time and resources did not permit the precise location to be confirmed on foot. No further signal detections were recorded for this collared individual despite extensive searching on foot and by helicopter.

NQ-T3-2

Only two unique den site locations were recorded for this 1st year male over a two day period between the 17th and 19th June, approximately 970 m and 2 km from the location where it was captured and collared on the 13th June 2013 (**Figure 8**). Both den sites for this animal were located in close proximity to creek lines (**Figure 8**). No further signal detections were recorded for this collared individual despite extensive searching on foot and by helicopter.

NQ-T3-3

A total of six unique den site locations were recorded for this 1st year male between the 12th June 2013 and the 23rd August 2013 (**Figure 8**). All of the den sites for this animal were located in close proximity (<50 m) to gullies, some of which contained rock pools with free water up until late July (**Table 3; Figure 8**).

NQ-T3-5

Only two unique den sites were recorded for this 1st year male between the 17th and 27th June 2013 (**Table 3; Figure 8**).

NQ-T5-2

Only a single den site was recorded for this 1st year male on the 21st August 2013 ~ 300m to the SW of the initial location where it was trapped on the 16th July 2013 (**Table 3; Figure 8**).

NQ-T5-7

A total of six unique den site locations were recorded for this male between the 20th August 2013 and the 20th September 2013 (**Table 3; Figure 8**). The animal was recorded on two occasions, four days apart, at the same den site located under a rock slab.

NQ-T6-1

Only a single den site was located for this male on the 23rd August 2013, approximately one month and 460 m S of the capture location (**Table 3; Figure 8**).

NQ-T6-2

A total of four unique locations were recorded for this male between the 20th August 2013 and the 20th September 2013, with a single den site being used twice (**Table 3; Figure 8**). All den sites for this male which was trapped along the power line access road near the SW boundary of the site on the 23rd July 2013 (**Figure 8**). All of the den sites for this species were located in the rugged south-eastern section of the site (**Table 3; Figure 8**).

NQ-T7-1

A total of six unique den sites were recorded for this male between the 22nd August and 20th September 2013, with a single site used on two successive days in close proximity to the proposed turbine site # 49 (**Table 3; Figure 8**).

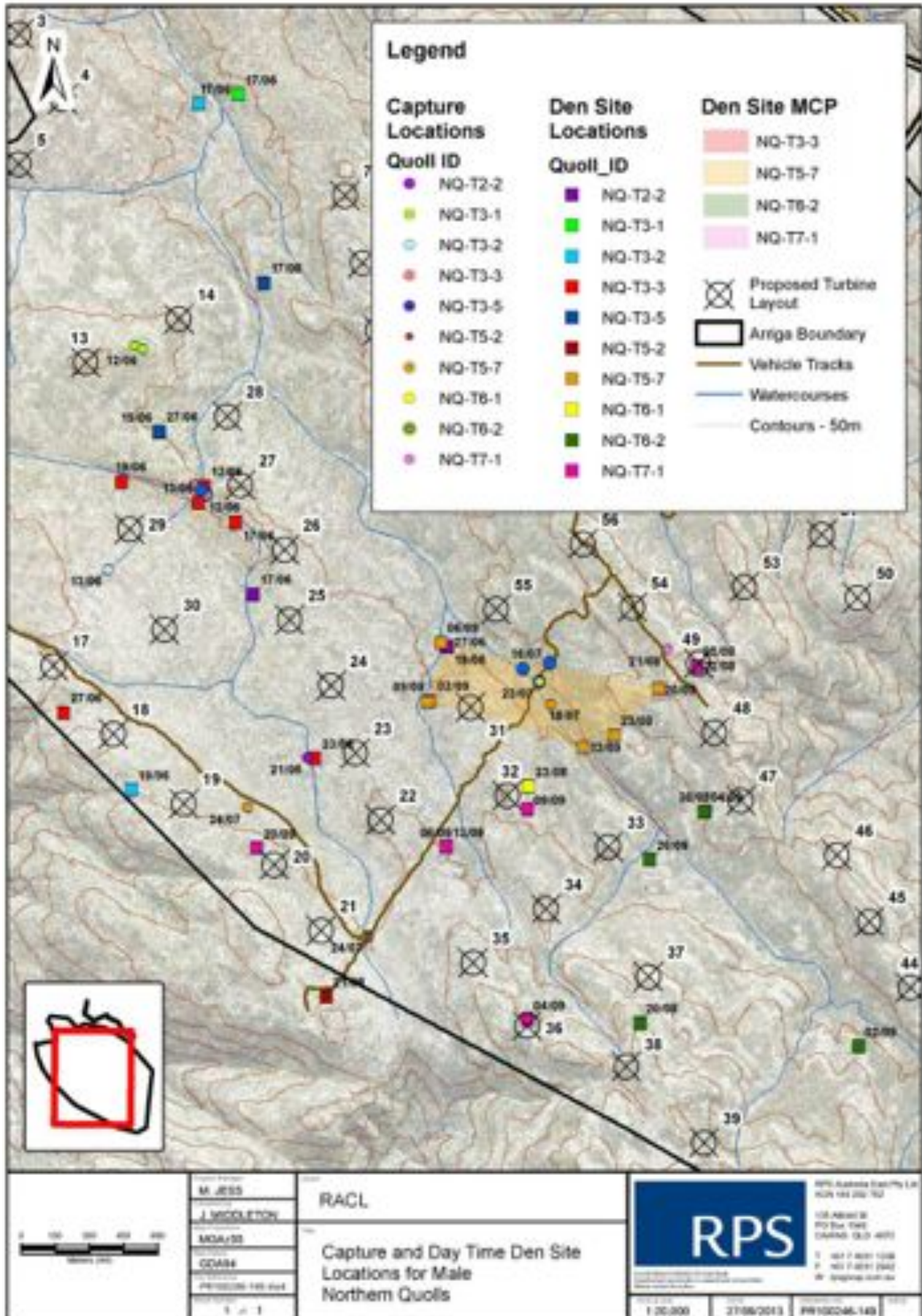


Figure 8 Capture and Day Time Den Sites for Male Northern Quolls. *MCP = minimum convex polygons*

3.3 Movement Data Obtained with Automated Radio-Telemetry System

At the Southern ARTS site a subset of all of the fix locations obtained for animal NQ-T2-1 (150.950) were extracted from the raw ARTS data by Michael Ward (University of Illinois) for the period 24th April to the 28th May 2013 and are shown in **Figure 9**. The estimated locations are clearly not accurate as the fix locations are all well outside the likely detection area of the southern ARTS site towers i.e. > 2 km (**Figure 9**). Further ARU data for the period 17th July to the 8th August 2013 from the southern ARTS site was provided to Michael Ward for analysis. A test transmitter beacon (150.2700 Hz) was operating during this entire sampling period. The estimated location fixes provided by Michael Ward for the test beacon together with the actual location as recorded with a hand-held GPS are shown in **Figure 10**. It is evident that there is a significant spatial error in the estimated locations of the beacon (mean difference of the distance between the estimated and the actual location = 231.79 m, range = 14 m to 1005.9 m) (**Figure 10**).

No useful data was able to be collected at the northern ARTS site at all during the period of deployment due to hardware failure and too many programming errors by the manufacturer (**Table 2**). At the time of the deployment of the ARU units, non functioning software complete with an instruction manual was provided by the manufacturer to extract the location bearings from the signal strength data.

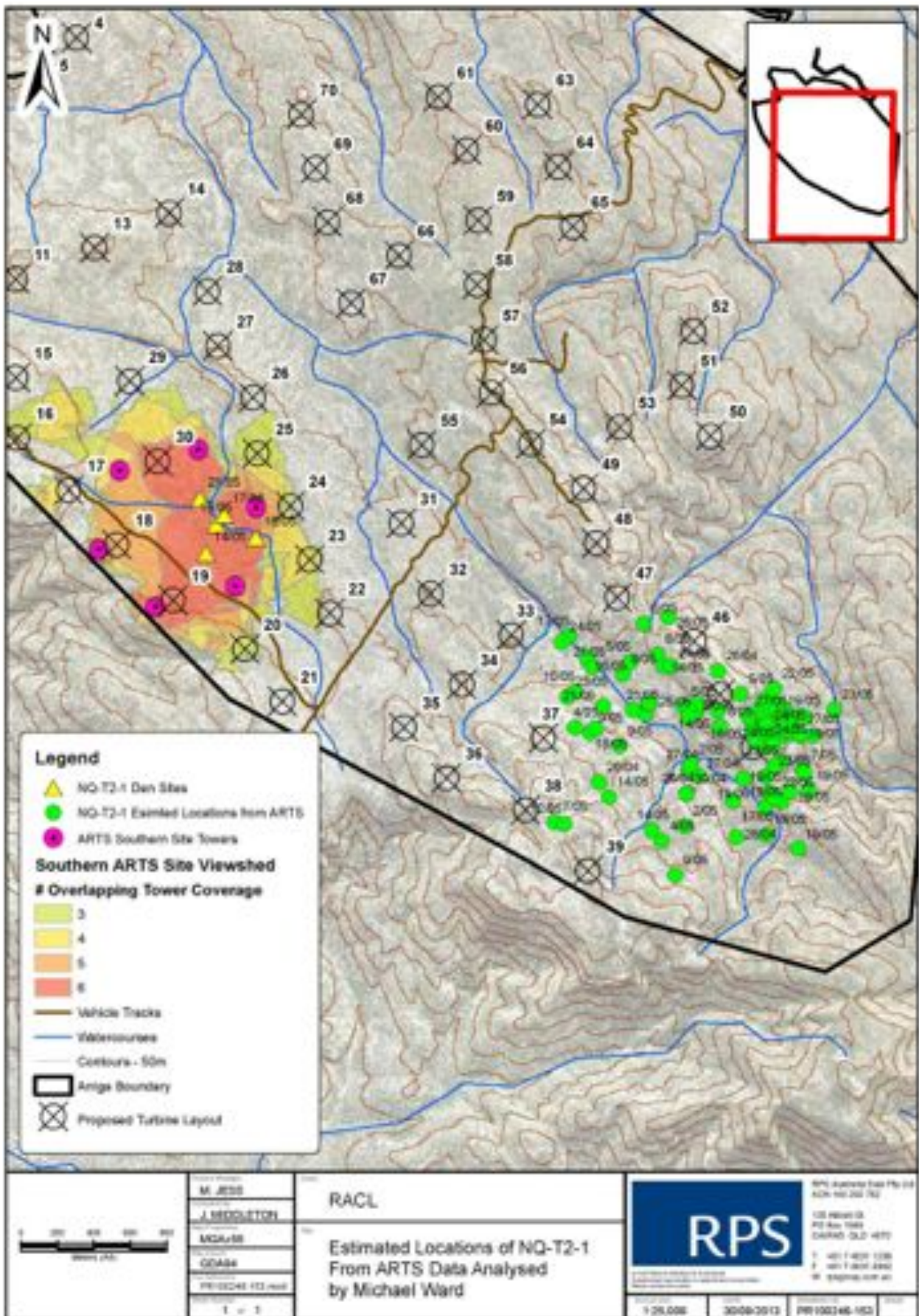


Figure 9 Estimated Locations of NQ-T2-1 derived from the Automated Radio-telemetry System (ARTS)

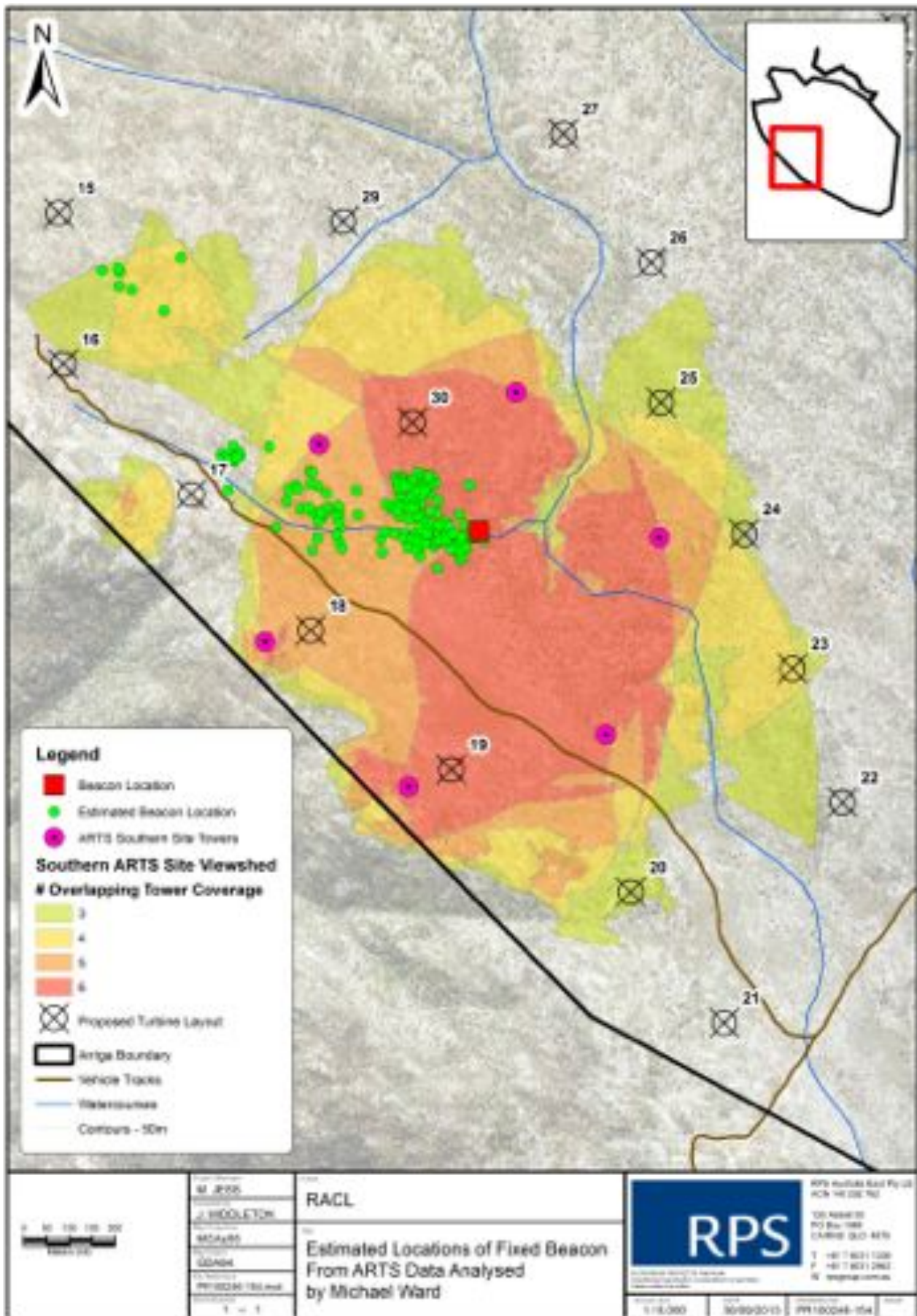


Figure 10 Fixed Beacon Estimated Locations derived from the Automated Radio-telemetry System (ARTS)

3.4 Collar Deployment /Animal Welfare Issues

Holohill collars attached with fine elastic thread proved to be an unacceptably risk to the well-being of the collared juvenile Northern Quolls due to a design flaw that resulted in the thread progressively ratcheting tighter through the attachment tube.

The following alterations were made to the collars to ensure that they could not tighten:

- the bore of the attachment tube was enlarged; and
- the entire elastic thread was circling the animals neck was covered in heat shrink so that even if the thread was pulled tight, the diameter of the collar could not shrink.

However, even with the changes to the Holohill collars, some individuals managed to insert an arm underneath the collar which resulted in severe abrasion injuries in the arm pit and opposing side of the upper neck.

Following the recapture of a juvenile male with a severe neck abrasion in February 2013, every effort was made to recapture all of the collared animals by targeted trapping in the immediate vicinity of the day time den sites determined by manual radio-tracking. All collared animals except for a single male (NQ-T1-4) were recaptured within 10 days of their first capture and the collars removed. All wounds were treated by application of copious antiseptic iodine. NQ-T1-4 was recaptured on the 21st May 2013 approximately 766 m from its first capture location and the Holohill collar was removed and the wound treated. Upon its recapture the following night, the wound was found to have healed well having formed a scab and was no longer weeping. The Holohill collar on this animal appears to have malfunctioned as no signal was able to be detected within the estimated battery life period of 49 days despite intensive searching for a signal on foot in the vicinity of the capture location, from surrounding high vantage points and from the air in a helicopter.

Only one individual (adult male NQ-T3-5) that was fitted with a Sirtrack suede collar exhibited any injuries that appeared to be related to poorly fitting collars. This individual was first collared on the 12th June and was recaptured on the 12th July and again on the 17th July 2013, when a weeping abrasion on the neck under the collar directly beneath the nylon securing nut was detected. The collar was removed and the injury treated with aqueous iodine. The animal was recaptured again on the 18th July 2013 and the abrasion injury was dry and had formed a scab. Following this incident, the nylon nut and bolt that secured the suede collar was completely covered with heat shrink on all subsequent deployments.

A total of three Sirtrack suede radio-collars were found detached from the animals within den sites or on the ground surface (**Figure 11**). It was not known whether the animals managed to squeeze out of the collars due to expansion of the suede when moistened by rain or heavy dew, or whether the animals were predated upon and the collars remained after the animals were consumed. No signs of teeth marks or puncture marks were observed on the detached collars.

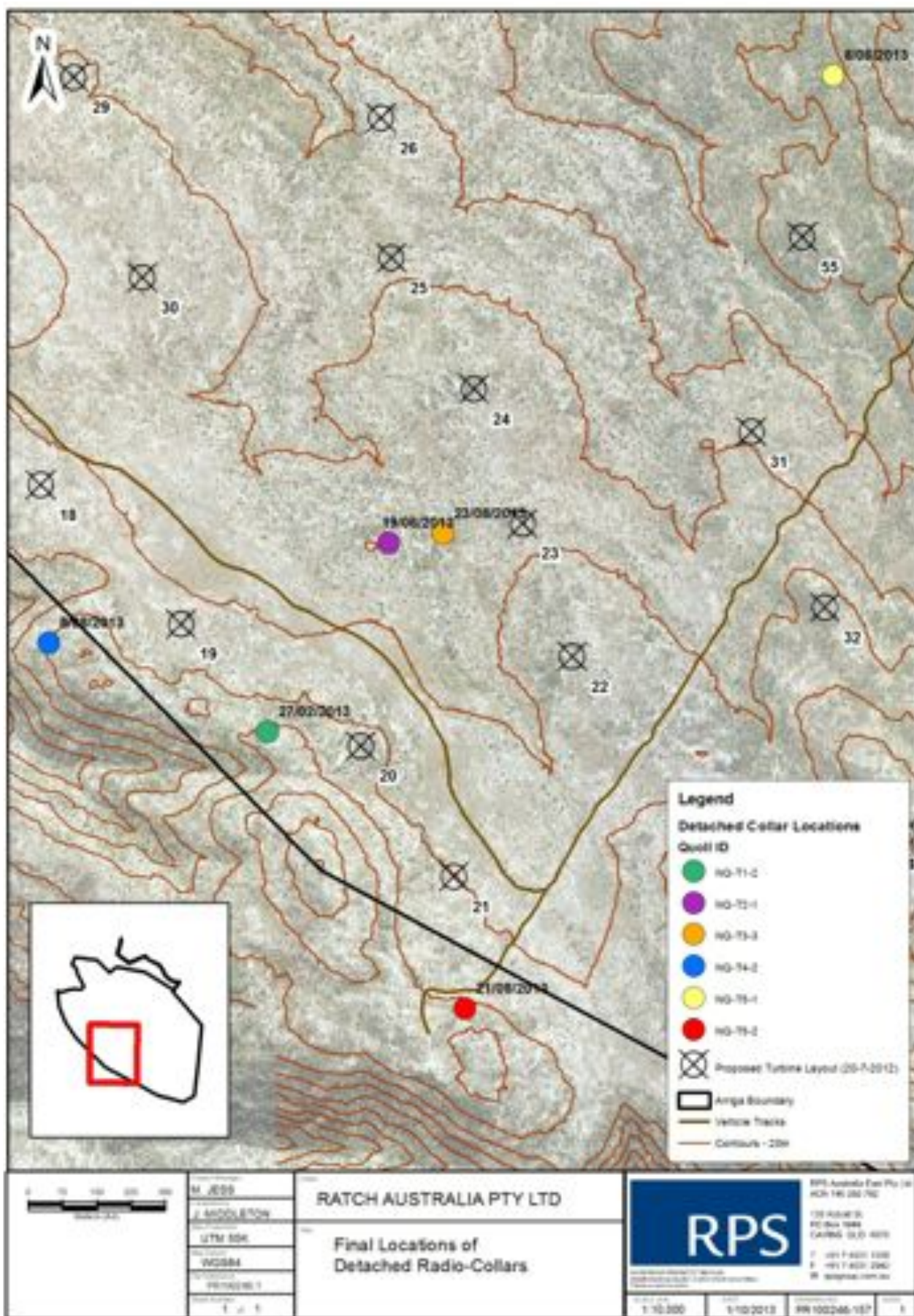


Figure 11 Final Locations of Detached Radio-Collars

3.5 *D. hallucatus* Mortality

At least one individual female *D. hallucatus* (NQ-T2-1) was confirmed to have died whilst fitted with a collar. The animal's head with collar still attached, scattered hair and the remains of the stomach were located on the 19/6/13 at c. 327248E 8100024N (refer **Figure 11**). It is likely the animal was predated shortly prior to the discovery as the eye surface was still bright

A collar that was fitted to a male, NQ-T5-2 on the 16/7/13 was located in a large stick nest (belonging to either raptor or a corvid) located on uppermost section of a high voltage transmission line at c. 327416E 8099000N (**Figure 11**) which indicates that the animal was most likely predated or scavenged after death, or that the detached collar was picked up and incorporated as nesting material by the bird that made the nest.

4.0 Discussion

The objective of this study was to examine the spatial and temporal fine-scale habitat utilisation of *D. hallucatus* on the project site to assist with assessing the likely impact of the project on the local population.

Obtaining frequent, accurate radio-telemetry locations for *D. hallucatus* on the proposed Mt Emerald Wind Farm site presented many challenges. *D. hallucatus* have a large home range relative to other predatory mammals of the same body size (*pers com* Dr Scott Burnett) and were capable of moving large distances overnight. The steep terrain, loose rocky substrate and dense grass layer that characterised much of the site made it difficult and time consuming to locate den sites of animals on foot. It was often not possible to detect signals from many of the collared animals, particularly males, possibly due to the signals being attenuated or reflected when animals were denning within burrows or deep within rock piles, especially in steep gullies, or simply that the animals may have moved out of detection range (~1-2 km line of sight). Oakwood (1997) found that male *D. hallucatus* frequently moved out of range and were hence unable to be located at each daily attempt.

4.1 Den Site Use

Relatively little information on the seasonal variation in den site utilisation was able to be obtained for any for any age and sex classes of *D. hallucatus* on the project site. Most of the den sites of the collared animals were located in within rocky outcrops suggesting that this is an important microhabitat on the site. Very little information was able to be gathered on maternal den site preferences by females due to the small number of females able to be collared for a long-period. As of September 2013, only a single adult female with pouch young was fitted with a radio-collar and only a total of nine dens were located within a period of 27 days. Although it would not be valid to make any general inferences about overall female maternal habitat usage on the such limited data, all of the den site locations for this female were located along a ridge line in close proximity to proposed turbine locations.

Oakwood (1997) tracked thirty-two *D. hallucatus* (13 females and 19 males) to 302 dens on 658 occasions within an 8km² area in tropical savanna of Kakadu National Park, Northern Territory over a 365 day period (345 days in the dry season and 11 days in the wet season). Each female was found to use between 20-55 dens each (mean = 35). (Oakwood (1997). Both male and females showed a preference for denning in different microhabitat with 98 dens located in hollows in live trees, 84 in rock crevices, 64 in logs, 25 in termite mounds, 21 in dead trees and 10 in burrows. During March-July, males and females differed significantly in their frequency of use of different den types. Although both sexes used live tree hollows most frequently, females used rock crevices more often than males, while males used logs more often than females (Oakwood, 1997). Oakwood (1997) found that female *D. hallucatus* showed a preference for denning in the rocky hills more often than in the gently sloping open forest and woodland habitats present on her study site.

Both males and females on the project site typically used different dens on consecutive days. Oakwood (1997) found that during the period when adult male *D. hallucatus* were present, both sexes tended to shift dens every night. A possible explanation for such frequent den shifting by *D. hallucatus* is to avoid ambush predators such as pythons (Oakwood, 1997).

4.2 Movements

Despite the investment of considerable time and resources into live-trapping, collaring and radio-tracking (manual and automated), of both juvenile and adult *D. hallucatus* over a period of approximately eight months, the objective of the study to examine seasonal variation in the fine-scale habitat utilisation of *D. hallucatus* on the project site using automated radio-telemetry was not able to be achieved successfully.

It is apparent that further work is required in order to obtain accurate location fixes using ARTS. The estimated location fixes provided to date for those individuals that were present within the range of the southern ARTS site antenna arrays are highly likely to be characterised by a large degree of spatial error as indicated by the large variation between the estimated and actual locations of the fixed test beacon. Wind-induced positional changes in the orientation of the whip aerial of the fixed test beacon are likely to have contributed the large spatial position errors for the estimated position of the test beacon. Ward *et al.* (2013) found that postural changes (e.g. coiled or uncoiling) by snakes fitted with radio-transmitters relative to the ARTS antennas resulted in changes in signal strength without any changes in location. Field testing that involved altering the position and posture of both live and model snakes fitted with transmitters was required in order to be able to determine thresholds in signal strength and bearing that indicated actual changes in location (Ward *et al.* 2013). RPS Group was not informed by Sparrow Systems of the need to ensure that the test beacon whip aerial was fixed in either a horizontal or vertical position until after the final sampling period (17th July to the 8th August 2013). Given that *D. hallucatus* are scansorial (adapted for climbing), the orientation of radio-collars will vary substantially (e.g. vertical when traversing flat ground, horizontal when climbing up vertical surfaces such as trees and rock faces) and therefore, it would be necessary to conduct field testing similar to that described by Ward *et al.* (2013) to account for this source of spatial error in estimated locations.

The areas on the site that were suitable for the establishment of an Automated Radio-telemetry System comprising six 4m tall towers were relatively small relative to the entire site due to severe constraints from topography and by the distribution and abundance of Northern Quolls (as determined by camera trapping in 2012). It was not feasible to establish the ARTS sites in topographically complex areas, which typically had highest quoll abundance, due to the limited detection view shed and resulting limited size of the area where triangulated fixes are possible to be obtained. In addition, the view shed calculations were computationally complex and time-intensive which limited the number of potential sites that could be assessed. The two ARTS sites that were selected were located within a relatively flat section of the proposed MEWF project site. Although the view shed of both sites contained examples of ridge and creek habitats, they are not representative of much of the southern, eastern and western sections of the site. However, this limitation was unavoidable at the time as no other alternative technological solution to obtain fine-scale habitat utilisation data was available. The only *D. hallucatus* movement information obtained in the study was that inferred from the consecutive day time den site locations. Unfortunately It was not possible to collect sufficient den site locations for any collared individual to be able to provide an estimate of the denning 'home range' as per Oakwood (1997). Oakwood (1997) found that the maximum distance recorded between successive dens was 2.1km for a male and 1.2 km for a female, which is comparable with the our results.

4.3 Recommended Further Research

4.3.1 Combined GPS-VHF Radio-Telemetry Studies

Recent advances in GPS collar technologies have made it feasible to deploy on Northern Quolls. WildSupply (Helensvale, QLD) have provided RPS Group with a test model of a light-weight GPS collar (27 g) that is capable of capturing 21 GPS fixes per day for a period of seven days. The test unit is combined with a VHF transmitter than is scheduled to operate continuously for a period of ~ 30 days to assist with the recapture of the animal and the recovery of the collar and the stored location data. In addition, WildSupply are in the process of testing units incorporating Robin Systems ultra low weight GPS tags (3 g) (Cellguide, 2012) and have indicated that they will be available for testing by Nov-Dec 2013 (Geoff Carey, pers. com). The Robin System GPS tags allow a range of battery and weight configurations, can provide up to eight months of operation (1 hourly fixes for 225 days at 6.2 g weight) and are capable of capturing GPS fixes in <70 msec.

When compared with traditional manual radio-tracking and automated radio-telemetry systems GPS collars have the following advantages including:

- Capable of capturing fixes in all types of terrain (as long as the view to the sky not too obscured);
- Not restricted to a limited area within which radio-signals can be detected;
- Have fewer biases; and
- Capable of obtaining positions frequently during day or night regardless of weather and terrain.

GPS collars have some disadvantages compared with VHF radio-tracking including:

- Collared animals must be recaptured in order to download the data. Retrieving the GPS collars could potentially be a time-consuming and expensive undertaking given the rugged terrain that characterises much of the project site. This is likely to be especially the case when animals are located in some of the deeply dissected valleys or areas away from vehicle access. It is likely that aerial radio-tracking will be required in order to initially locate the animal and then to transport staff and equipment required to recapture the animals once they are located;
- GPS collars are relatively expensive compared to VHF collars (~\$1000 and ~\$300, respectively); and
- Currently available light-weight GPS collars are still limited to animals >600 g body weight which limits the proportion of animals that it can be deployed upon.

Despite these constraints, the GPS collars that are currently available for use on Northern Quolls are likely to offer the most cost effective method to obtain information on the fine-scale habitat utilisation of Northern Quolls on the site.

It is recommended that WildSupply GPS collar is trialled on adult Northern Quolls on the MEWF site as soon as possible, as it is likely that the majority of the females will be dead by the end of the 2013 dry season (Nov-Dec), and further opportunities to collar adults with a body size of >600 g will be limited until approximately May-June 2014 when this year's young have grown sufficiently. In the event that Robin Systems light-weight GPS collars are made available in the near future, it is highly recommended that additional live-trapping and collaring of animals with these units is conducted on the site in order to gather fine-scale habitat utilisation data.

5.0 Conclusion

Obtaining fine-scale habitat utilisation information for *D. hallucatus* on the proposed Mt Emerald Wind Farm site was extremely challenging and ultimately, largely unsuccessful. In order to be able to develop effective mitigation strategies to avoid impacts to the local population of *D. hallucatus* on the project site from the proposed development, it is essential to continue to attempt to understand patterns of fine-scale habitat utilisation prior to construction beginning. Given the recent availability of light-weight combined GPS-VHF collars, it is probably not worth continuing with the use of the ARTS given the need to invest considerably more time and money to obtain accurate fixes, and the limited detection range of the system compared with GPS telemetry (i.e. no detection area limitations).

It is particularly important to determine if the rocky ridge habitats, which will be disproportionately impacted by clearing and ongoing disturbance such as noise, vibration and dust, compared with other habitat types including creek lines, level country or mid-slopes, are used preferentially for denning by females with dependent young. If this is found to be the case, then the potential impacts on the local *D. hallucatus* population could be much greater than would otherwise be indicated by the relatively small total area of proposed clearing (~51 ha or ~2% of the total area of the project site).

6.0 References

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