



IB Operations Pty Ltd  
Pilbara-leaf Nosed Bat radio-tracking survey  
Survey results report

October 2017

# Executive summary

This report presents the methods and results of the first documented radio-tracking study of the threatened Pilbara Leaf-nosed Bat (PLNB) (*Rhinonictoris aurantia*). The trapping and radio-tracking program was developed and implemented by GHD Pty Ltd (GHD) on behalf of FMG Iron Bridge (Aust) Pty Ltd (FMGIB) to assist with fulfilling the requirements of the condition of approval for the North Star Magnetite open cut iron ore mine.

## **Project background**

FMGIB was granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure, 110 kilometres (km) south-east of Port Hedland. The approval has been granted pursuant to the Conditions outlined in the Ministerial Statement 993. Condition 10 of the Ministerial Statement details the specific measures that FMGIB must implement to mitigate the impacts of the development to the PLNB colony located in Cave 13 due to mining activities.

A significant body of work, now exists around the assessment of bat usage of habitat within the North Star mine study area, as well as exploration for and assessment of other potential diurnal roost sites and foraging habitat in the surrounding landscape. These surveys have identified two sites with regular patterns of usage by PLNB – Chateau Cave and Joe’s Cave. The two sites have been categorised as a *Possible Non-permanent breeding roost or Permanent diurnal roost* (Chateau Cave) and a *Transitory diurnal roost* (Joe’s Cave).

FMGIB engaged GHD to develop and implement a radio-tracking program to assist with fulfilling the requirements of Condition 10-8 (ii) and to better understand the behaviour and movements of PLNB individuals from the Chateau Cave roost and Joe’s Cave (Zane’s George area). The aims of the radio-tracking program were to:

- Locate the alternate roost site or refine the area containing the alternate roost in the area of Joe’s Cave / Zane’s Gorge
- Determine if the tagged bats recorded from the Joe’s Cave / Zane’s Gorge area are using the known roost (Chateau Cave) and vice versa in order to understand inter roost movement of tagged PLNB individuals between a known roost and temporary / nocturnal roost
- Understand the nightly movement patterns of tagged PLNB individuals from a known roost (Chateau Cave roost colony).

## **Approach and methods**

The trapping and radio-tracking program focussed on the area between and in the vicinity of Chateau Cave and Joe’s Cave (herein referred to as the study area) including the majority of the North Star mining development and associated infrastructure envelope.

Field surveys were undertaken from the 9-28 June 2017 within the study area by GHD with the assistance from FMGIB and Njamal Traditional Owners. The survey was conducted under “Licence to Take Fauna for Scientific Purposes” (Regulation 17) Permit No. 08-000751-1 and Animal Research Authority (Project number GHD: 613519501).

The field survey included harp trapping, scat collection, ultrasonic surveys, radio-tracking and roost habitat searches. Harp traps were used to capture bats for the purpose of radio-tracking and to gain biological information about the species (e.g. sex, age, reproductive condition). Harp

traps were erected at three locations (Chateau Cave, Dingo's Lair Pool and Joe's Cave) for four nights.

A total of 51 bats of three species were captured. Seven PLNB were fitted with digitally encoded transmitters and monitored using an array of 11 base stations (stationary data logging receivers) for between 7 and 13 nights each from the 13- 27 June 2017. The receivers continuously recorded all signal detections and when a transmitter was detected (a detection), the receiver logged the transmitter ID, time (synchronized among receivers by GPS), antenna and signal strength.

Base stations were strategically positioned to understand the movements of PLNB individuals from a known roost location (Chateau Cave); to intercept possible flight movements between the Chateau Cave and Joe's Cave areas; and to assist with locating the alternate roost location. To supplement and validate the findings of the base stations, active searches for transmitters with handheld receivers were also completed. Active searches during early morning and day-time attempted to determine the location of each tagged roosting bat, whereas night-time searches focussed on detecting bat movement activity.

### ***Activity at known roost sites***

Analysis of the timing of the first and last detections with regard to civil twilight times was undertaken for each tagged bat to understand if bats were roosting in Chateau Cave and Joe's Cave during the survey or other roost sites. Overall, few detections were recorded within a 10 minute (mins) period near civil twilight suggesting that the tagged bats were not regularly roosting within these caves during the survey. In summary:

- Tag 104 was detected at Chateau Cave base station from a single detection on the 14<sup>th</sup> June at 17:54 on antenna 1 (facing the cave entrance). This detection occurs within 10 mins of civil twilight, inferring that the bat was in close proximity to the base station or possibly within Chateau Cave (in a chamber that prevented earlier signal transmission).
- Tag 104 was also recorded from two detections (06:36, 16<sup>th</sup> and 06:30, 23<sup>rd</sup> June) approximately 15 mins after civil twilight from JJ's base station located approximately 6.5 km west of Chateau Cave. Both records were from an antenna orientated north by north-west) toward an area east of Joe's Cave/ Zane's Gorge containing potential diurnal roosting habitat.
- Tag 106 was recorded from three detections (18:03-18<sup>th</sup>, 17:57-19<sup>th</sup> and 18:00-20<sup>th</sup> June) at Joe's Cave (c. 8 km's west of Chateau Cave) and also by the nearby Matt's base station (c. 1 km west of Joe's Cave base station) within 10 mins of civil twilight. The majority of the detections from Joe's Cave base station were from antenna orientated east and north at Joe's Cave entrance. The number of consecutive nights (three) and the multiple detections of similar timing, coupled with the signal strength and antenna orientation suggests that Tag 106 was roosting within or in close proximity to Joe's Cave.
- Tag 106 was also detected within approximately 10 mins of civil twilight 23<sup>rd</sup> June at Joe's Cave and JJ's base station on antenna orientated north and north by north-west. Given the timing of the record, it is possible the bat was in or in close proximity to Joe's Cave or in close proximity to another diurnal roost north-east of Joe's Cave.

### ***Alternate roost location***

This study provides evidence that other diurnal roosts exist in areas outside the reception range of the base stations, in particular the area north and north-east of Joe's Cave and probably to the north and east of Chateau Cave.

The lack of tagged bats occurring within Joe's Cave and Chateau Cave during the survey period and the absence of tagged bat activity for large portions of the survey period (e.g. Tags 104, 105 and 108), suggests a larger range occupancy than the base station range of reception.

The information reviewed from the survey suggests that other roost(s) could be in the vicinity of Joe's Cave/Zane's Gorge, probably within 3-4 km of Joe's Cave/Zane's Gorge in an area spanning from the north through to north-east.

Evidence for an additional roost location is also in part supported by the lack of data from Chateau Cave and the presence of activity data from the OPF base station for the area to the north and north-east of the ore processing facility. For example, Tag 107 was active outside the reception range of the receivers for the majority of the survey period, in particular for the later part of the PM period and the AM period for most of the survey nights. Furthermore, detection data for the night of the 19-20 June suggests that activity originated from the area to the north-west of the OPF base station. Data for the night of the 22-23 June highlights this pattern of movement and provides further evidence for another roost. During this night Tag 107 originated from the area north-west of the OPF base station. It was first detected by the OPF base station at approximately 18:41 on antenna orientated north and north by north-west before then passing through the reception range of the OPF base station. Tag 107 then moved south-west of the OPF base station. The final detections for the morning of the 23<sup>rd</sup> were from antenna orientated north and north by north-west suggesting that Tag 107 used a similar flight route to return to its point of origin, which is probably in the area north-west outside the reception range of the base station array.

### *Nightly activity and inferred movement patterns*

The detection data demonstrated that all tagged bats occurred within the reception range of the base station receivers for at least 5 of the 13 survey nights with three of the tagged bats being detected for 12 and 13 nights. The data also revealed that tagged individuals frequently commuted beyond the receiver range of the base stations. Activity was typically characterised by short bouts with few detections for most bats, yet periods of consistent activity were also often recorded for three tagged bats. Large gaps often greater than one hour and occasionally a whole night of no activity were more common than periods of consistent activity. The absence of detections from the survey period suggests the tagged PLNBs were active elsewhere and therefore required a larger area for foraging and possibly roosting than the overall base station range of reception.

The data from four of the seven tagged bats (Tags 106, 107, 109, 110) provided the most information for the analysis of movement within the study area. Each of the bats was active for the majority of the survey (7-12 nights), with detections recorded for both PM and AM periods for the majority of nights. The number and frequency of detections and the occasional periods of consistent activity (e.g. 15-30 mins) suggests that each of the bats was active within the reception range of the receivers for a reasonable portion of the survey period. The detection data revealed that three of the tagged bats (Tag 106, 109 and 110) commuted between the Chateau Cave area and Joe's Cave area. For example:

- Tag 106 moved from the release point at Chateau Cave (east) to the vicinity of Joe's Cave base station (west) during night of the 13-14 June. Analysis of a subset of the data determined that Tag 106 moved approximately 8 km's across a period of 38 mins. The timing of the detections across the multiple base stations between Chateau Cave and Joe's Cave base stations (Rise, Jimmy's Gap then Nate's Tower base station) infers an east to west pattern of movement.
- For five consecutive nights Tag 109 regularly moved between the Joe's Cave area and the Chateau Cave area. Some movements were one way (e.g. the night of the 21-22 June Tag

109 moved from Joe's Cave to Chateau Cave area but was not detected returning to the Joe's Cave area), and other nights included multiple movements in both directions (e.g. nights 22-23, 23-24, and 24-25 June). The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km, therefore for those nights where multiple movements were undertaken between the Joe's Cave and Chateau Cave areas and return the estimated straight line distance travelled would have exceeded 16 km for each of those nights.

- 21-22 June - Tag 109 was detected at Nate's Tower base station at 20:10 by two antenna, then at Rise base station at 20:14 (all antenna), then Chateau Cave base station (all antenna) at 20:15. The estimated time taken to move between the Joe's Cave and Chateau Cave areas was 13 mins.
- 23-24 June - Tag 109 moved from the range of reception of Nate's, Chateau Cave, and Rise base stations starting at 20:44, to Joe's Cave and Matt's base stations at approximately 21:02. The difference between the time of departure for Chateau cave base station and time of arrival at Joe's Cave base station is approximately 18 mins. Tag 109 returned to the Chateau Cave area, starting at Joe's Cave base stations (all detections on antenna orientated north by north-east) at approximately 01:36, then Mobile (Turkey nest) base stations at 03:27 (all detections on antenna orientated north), then Nates Tower base stations (multiple detections on all antenna) at 03:54, and finally Rise and Chateau Cave base stations at approximately 03:55. The difference between the time of departure from Joe's cave base stations and time of arrival at Chateau Cave base stations was approximately 2 hours 19 mins.

### **Conservation outcomes**

This study demonstrates that radio-tracking is a valid technique that can be successfully used to further the knowledge of this species. The outcomes of the study offer valuable insights regarding the application of radio-tracking for the PLNB and other microchiropteran bat species. Furthermore the study contributes valuable data for public record regarding the biology of the species.

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# 1. Introduction

## 1.1 Project background

FMG Iron Bridge (Aust) Pty Ltd (FMGIB) was granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure, 110 kilometres (km) south-east of Port Hedland (Figure 1). The approval has been granted pursuant to the Conditions outlined in the Ministerial Statement 993. One of the key factors conditioned was the clearing of fauna habitat, including critical roosting habitat for the Pilbara Leaf-nosed Bat (PLNB) (*Rhinonicteris aurantia*).

Condition 10 of the Ministerial Statement details the specific measures that FMGIB must implement to mitigate the impacts of the development to the PLNB colony located in Cave 13 due to mining activities. The intent of Conditions 10-3 to 10-11 is to ensure the viability of the PLNB population is maintained through the relocation and establishment of a 'viable portion' of the colony at Cave 13 to an alternative (either natural or artificial) site. In order to achieve this a PLNB Habitat Survey and Research Plan must be developed and implemented. Condition 10-7 outlines two objectives for the PLNB Habitat Survey and Research Plan, these are to:

- (i) Provide evidence of alternative natural maternity roost site(s) for the PLNB existing within a 30 km radius of Cave 13 which could support a viable portion of the colony of PLNB from Cave 13
- (ii) Demonstrate to the satisfaction of the CEO that a viable portion of the colony of Pilbara Leaf-nosed Bat from Cave 13 has relocated and established itself in an alternative maternal roost site.

To satisfy Condition 10-7 (i), it is required that a PLNB Habitat Survey and Research Plan is developed by the proponent and approved by the CEO in accordance with conditions 10-6 and 10-8 respectively. Condition 10-8 (ii) specifically states '*that the PLNB Habitat Survey and Research Plan shall include: a survey plan to collect information on additional natural maternal roost site(s) or potential artificial roost site(s), and any associated PLNB activity, within a 30 kilometre radius of the Cave 13*'.

FMGIB engaged GHD to develop a survey plan to fulfil certain requirements of Condition 10-8. A key component of this plan is to assess the behaviour and movement of PLNB individuals. In order to achieve this FMGIB engaged GHD to develop and implement a trapping and radio-tracking program (this commission) for PLNB within the North Star mine study area.

## 1.2 Current knowledge of the species habitat within the North Star study area

A significant body of work, undertaken with assistance from FMGIB, mainly by GHD, Ecologia Environment Pty Ltd, Bat Call WA Pty Ltd, and Ecoscape Pty Ltd, now exists around the assessment of bat usage of habitat within the North Star mine study area, as well as exploration for and assessment of other potential diurnal roost sites and foraging habitat in the surrounding landscape. These surveys identified two other sites with regular patterns of usage by PLNB – Chateau Cave and Joe's Cave.

Cave occupancy surveys for the PLNB within Cave 13, Joe's Cave and Chateau Cave during February 2016 (see GHD 2016a and 2016b) and review of studies undertaken to date have categorised the three sites according to the Threatened Species Scientific Committee (TSSC), Approved Conservation Advice for the PLNB (2016):

**Cave 13** – Category: *Transitory diurnal roost*. The information reviewed to date suggests Cave 13 is possibly occupied for parts of the year by the PLNB; however, it was not occupied during the period of the cave occupancy surveys (February and September 2016) suggesting the PLNB was not using Cave 13 as a maternity roost during the 2015-2016 breeding season. Furthermore, there is no evidence to indicate that the upper chamber or any other part of Cave 13 was used as a maternity roost during the period of the surveys undertaken to date.

**Chateau Cave** - Category: *Possible Non-permanent breeding roost or Permanent diurnal roost*. The results from the cave occupancy surveys undertaken in February and September 2016 determined that PLNB were present within the main chamber during the period of the survey. Both records occur within the 9-month breeding cycle of the PLNB (DotEE 2017) therefore the cave is considered to be important habitat for the PLNB and is probably used as a maternity roost (i.e. a roost used during the gestation-parturition-weaning period).

**Joe's Cave** – Category: *Transitory diurnal roost*. The results from the cave occupancy surveys undertaken in February and September 2016 determined the PLNB was not present within Joe's Cave during the period of the survey. The information reviewed to date suggests Joe's Cave is possibly occupied for parts of the year by the PLNB. However, there is no evidence to indicate that the main chamber has been used as a maternity roost during the period of the surveys.

Regional surveys undertaken within the North Star mine study area, outside the mining development envelope since November 2014 have identified two areas of interest which may harbour potential roost sites (GHD 2016a, GHD 2015b and GHD 2017c) including the area west of Zane's Gorge and Nicko's Gorge (Blue Square) (see Figure 2).

Given the results of the surveys undertaken to date (GHD 2016a and GHD 2015b) it is possible that a diurnal roost may occur within the Nicko's Gorge area. It was determined the likelihood of a PLNB roost occurring within the Blue Square would be limited to the south-west portion and southern boundary including Nicko's Gorge and possibly, but less likely a small area of the north-east portion of the Blue Square associated with the tributaries of Black Boy Creek. Helicopter surveys by FMGIB (September 2016) of the north-east portion including the Black Boy Creek area has further reduced the likelihood of a roost occurring in this area.

Surveys were also conducted by GHD for the alternate PLNB roost site west of Zane's Gorge from the 14 – 17 November 2016 (GHD 2017c). A desktop review was undertaken to refine the area of potential roost locations using the methods described in GHD (2017a, 2017c). The review also considered the findings of a reconnaissance helicopter survey undertaken in September 2016 by FMGIB, to further refine the search area. Thirty-nine locations were investigated as part of the surveys (GHD 2017c) including potential cave habitat, water sources and suitable sites for the placement of full spectrum recorders. Key findings included:

- The preliminary habitat assessments recorded five sites (labelled as potential roost sites - see Figure 2) that require further investigation. Four of the sites could not be accessed but appeared to contain some potential habitat (e.g. a large opening with a deep passage) to support roosting (e.g. temporary diurnal or maternity) opportunities.
- The fifth site (Bone Cave) could be categorised as a 'transitory diurnal roost' for a small number of PLNB, given the architecture and potential microclimate habitat of the cave. Three Ghost Bats were also recorded roosting in the back chamber of Bone Cave during the survey. Further survey is required to confirm this categorisation.

- Ultrasonic call analysis revealed that three sites with water recorded PLNB activity within 15 minutes of civil twilight<sup>1</sup> of which two sites may have a theoretical flight distance of approximately 5 km<sup>2</sup> including Zane's Gorge pool and Dingo Lair pool.
- A review of the call analysis data for Joe's Cave for the period of the survey further supports the recent determination that the roost is a 'transitory diurnal roost'.
- The field assessment and review of geological information suggests the area searched has the capacity to provide roosting habitat for the PLNB.

Recent and historical information (e.g. records from Joe's Cave and Nicko's Gorge) gathered to date in the North Star mine study area indicates the presence of an additional roost other than Chateau Cave. For example at Dingo's Lair pool PLNB calls were recorded from 18:53 (15/11/16) onwards. Based on the timing of the calls (first PLNB call at 18:53, civil twilight at c. 18:48) and source location of the calls (> 8 km west of Chateau Cave) and estimated flight speed (approximately 22 kph, McKenzie and Bullen 2009) it is unlikely that PLNB recorded at Dingo's Lair pool originated from Chateau Cave. Furthermore, there are alternative water sources closer to Chateau Cave (e.g. Fig pool and Cow pool, and more recent artificial sites) that PLNB are known to use. It is therefore reasonable to assume there is an alternate roosting site within the vicinity of Dingo's Lair pool/Joe's Cave area.

### 1.3 Study species

Provided below is a summary review of the current information regarding the roosting ecology and movement patterns of the PLNB. The majority of the information used to develop the summary was extracted from a literature review of the species completed by Specialised Zoological (2016) for FMGIB, Cramer et al, 2016 and the PLNB SPRAT from DotEE 2017. The information provides background context to the discussion of the key outcomes resulting from the radio-tracking survey.

#### 1.3.1 Roosting ecology

The PLNB is the only arid-zone population of *R. aurantia*, and survives in the Pilbara at close to its ecophysiological limits (Armstrong 2008). Records of occurrence are spread throughout the Pilbara region, though it is generally encountered in rocky areas that provide opportunity for roosting in caves or disused underground mines; particularly the ironstone hills of the Hamersley Range, the granite boulder piles within granite terrain, the disused underground mines in greenstone ranges of the eastern Pilbara, and the massive metamorphosed folded silcretes at the southern margins of the region (Armstrong 2001, 2003).

The PLNB inhabits relatively deep caves in ironstones and silcretes, and several disused underground gold and copper mines left behind at various times since the 1880's. They have one of the highest measured rates of pulmocutaneous water loss of any mammal and are unable to enter torpor (Kulzer et al. 1970; Baudinette et al. 2000), and thus have an obligate requirement for warm, humid roost microclimates (Churchill 1991; Armstrong 2000, 2001). Deeper caves and mines that can support these conditions are relatively uncommon, which limits roosting opportunity, area of occupancy, and results in aggregations in relatively few subterranean structures.

<sup>1</sup> Civil twilight (near sunset) calculated from Australian Government Geoscience Australia <http://www.ga.gov.au/bin/geodesy/run/sunrisenset>, Sunset determined by sight observations and Australian Government Geoscience Australia

<sup>2</sup> Theoretical flight range based on McKenzie and Bullen (2009) given its "mode" flight speed (i.e. the speed most often measured during free flight) as 6.1 m s<sup>-1</sup> (22 kph) and casual observations by Kyle Armstrong and Bob Bullen, pers. obs. Cited in Cramer et al 2016.

When not foraging, it is essential that it roosts in physiologically benign environments (28–32°C and 85–100% relative humidity) to maintain its body temperature and conserve body water with minimum energy expenditure (Kulzer et al. 1970; Baudinette et al. 2000).

The full range of roost microclimate conditions (temperature, relative humidity) has not been documented, but in the Northern Territory, studies by Churchill (1991) showed that the Orange Leaf-nosed Bat occupied areas with a temperature of 30–31 °C and vapour density of 30–31 g m<sup>3</sup> (>24 °C and >70% relative humidity in the Pilbara, and 27–28 °C and >90% relative humidity in the Kimberley; Armstrong 2000, 2001).

The PLNB often shares roosts with the Ghost Bat *Macroderma gigas*, Finlayson's Cave Bat *Vespadelus finlaysoni*, Common Sheath-tailed Bat, *Taphozous georgianus*, and possibly Hill's Sheath-tailed Bat *Taphozous hilli*, in some parts of its range. Some level of mortality from predation by Ghost Bats occurs when this species is present in the same roost, and in the Northern Territory the Orange Leaf-nosed Bat roosts in areas of caves that are inaccessible to the Ghost Bat (Churchill et al. 1988).

There have been very few direct observations of roosting clusters in the Pilbara (Armstrong 2001), since most colonies roost deep within mines or in spaces in caves that are unsafe or too narrow to be accessed by people. Little information is available on reproduction in the PLNB, though comprehensive studies were undertaken on the Orange Leaf-nosed Bat in the Northern Territory, including examinations of male and female anatomy and the seasonal usage patterns of caves (Churchill 1995).

### 1.3.2 Movements

Nightly and seasonal movements have not been studied in any detail for the PLNB. However movement within the Pilbara is related to the availability of suitable roosts that allow individuals to saltate across otherwise inhospitable landscapes. PLNB accumulate in the deepest structures during the hottest and driest parts of the year, and spread further afield when wetter conditions promote humid microclimates in shallower caves (Armstrong 2001).

Analysis of acoustic data in conjunction with knowledge of flight speeds and foraging strategy (Bullen and McKenzie 2004; McKenzie and Bullen 2009) predict that PLNBs are able to forage up to 20 km from a roost, which has been supported by casual observation (Kyle Armstrong and Bob Bullen, pers. obs. Cited in Cramer et al 2016).

PLNB emerge from their daytime roosts after dusk and usually after species such as Finlayson's Cave Bat and the Common Sheath-tailed Bat (Churchill et al. 1988; Armstrong 2001). At least some individuals remain near the entrance of the roost and continually enter and re-emerge for a prolonged period after their initial emergence (K.N. Armstrong unpubl. Obs cited in Specialised Zoological 2016). This 'lingering' behaviour might have a social function, since bats are sometimes observed following each other, but equally it might be related to feeding upon insect accumulations at entrances (Cramer et al. 2016).

They are also thought to rest in the diurnal roost during the night, as well as other shallower caves that might provide a temporary refuge when bats are foraging several kilometres from their diurnal roost (K.N. Armstrong unpubl. Obs cited in Specialised Zoological 2016).

Despite their frequent detection over pools (both generally at a landscape scale, and throughout the night at particular sites), it is not known if they drink. They forage in the open against vegetation (Bullen & McKenzie 2002), and flight behaviour is described as a "sinuous pattern of turns; zigzagging up and down ..." (Churchill et al. 1988), sometimes within centimetres of the ground, but typically up to 2–3 m in height (K.N. Armstrong unpubl. Obs cited in Specialised Zoological 2016).

The PLNB is a supremely acrobatic and high energy flier, intercepting insect prey whilst in flight, though is also able to fly slowly like the dusky leaf-nosed bat *Hipposideros ater* (Bullen & McKenzie 2002, 2004).

Churchill (1991, 1995) observed seasonal reductions in numbers in the largest colonies of the Orange Leaf-nosed Bat in the Northern Territory and concluded that most individuals dispersed to other roosts during the wet season. In the Pilbara, there is no evidence for a seasonal exodus during summer months, and observations of seasonal presence at confirmed and suspected roosts across the region suggest that most individuals contract back to a few of the largest and deepest structures following the period of building temperatures and relatively low rainfall between August and December (Armstrong 2001; (K.N. Armstrong unpubl. Obs cited in Specialised Zoological 2016).

Armstrong (2001) suggested the PLNB maintains gene flow within the region via the connections amongst underground structures that provide suitable roost microclimates—with key connections the product of the seasonal availability of ‘transitory diurnal roosts’, and the nightly flight range of individuals (Cramer et al. 2016). Thus, bats have the potential to disperse across the region by ‘saltation’ from roost to roost.

The availability of transitory diurnal roosts is dependent on the generally low and locally unpredictable nature of rainfall in the Pilbara (with most rain derived from localised thunderstorms and tropical depressions; Beard 1975; Gentilli 1972; Tinley 1991 cited in Specialised Zoological 2016), which controls the availability of groundwater seepage for elevating the humidity of roosts.

Information from movements on a regional scale comes from studies of phylogeography and population genetics (Armstrong 2006b, 2011b). The first study of population structuring within the Pilbara region using mitochondrial DNA markers found evidence for restricted gene flow across the Fortescue Valley between the mines of the eastern Pilbara and the caves in the Hamersley Range, and also over the Ashburton Basin to the silcretes of Barlee Range (Armstrong 2006b).

A more recent study (Armstrong 2011b) increased sample sizes and incorporated microsatellite markers presented evidence for strong female philopatry, with regional gene flow mediated by males (similar to the Ghost Bat; Worthington Wilmer et al. 1999). The implications of female philopatry coupled with the perennial occupation of certain roost sites are twofold: a seasonal female exodus (as occurs at Cutta cave and Tolmer Falls in the Northern Territory; Churchill 1995) appears not to occur; and recovery through recolonisation of females from adjacent areas following disturbance of breeding sites is unlikely in the short term.

## 1.4 Scope of works

FMGIB engaged GHD to develop and implement a radio-tracking program to assist with fulfilling the requirements of Condition 10-8 (ii) and to better understand the behaviour and movements of PLNB individuals from the Chateau Cave roost and Joe’s Cave (Zane’s Gorge area). The aims of the radio-tracking program were to:

- Locate the alternate roost site or refine the area containing the alternate roost in the area of Joe’s Cave / Zane’s Gorge
- Determine if the tagged bats recorded from the Joe’s Cave / Zane’s Gorge area are using Chateau Cave (vice versa) in order to understand inter roost movement of tagged PLNB individuals between a known roost and temporary / nocturnal roost
- Understand the nightly movement patterns of tagged PLNB individuals from a known roost (Chateau Cave roost colony).

The trapping and radio-tracking program focussed on the area between and in the vicinity of Chateau Cave and Joe's Cave (herein referred to as the study area). The straight line distance between Chateau Cave and Joe's Cave is approximately 8 km's (+/- 200 m) (Figure 2). The study area includes the majority of the North Star mining development and associated infrastructure envelope.

This report details the approach, methods and results for the trapping and radio-tracking program conducted during June 2017 within the study area.

## 1.5 Assumptions and limitations

This report has been prepared by GHD for FMGIB and may only be used and relied on by FMGIB for the purpose agreed between GHD and FMGIB as set out in Section 1.4 of this report. GHD otherwise disclaims responsibility to any person other than FMGIB arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

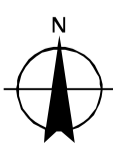
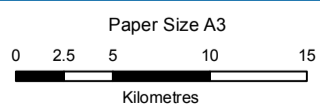
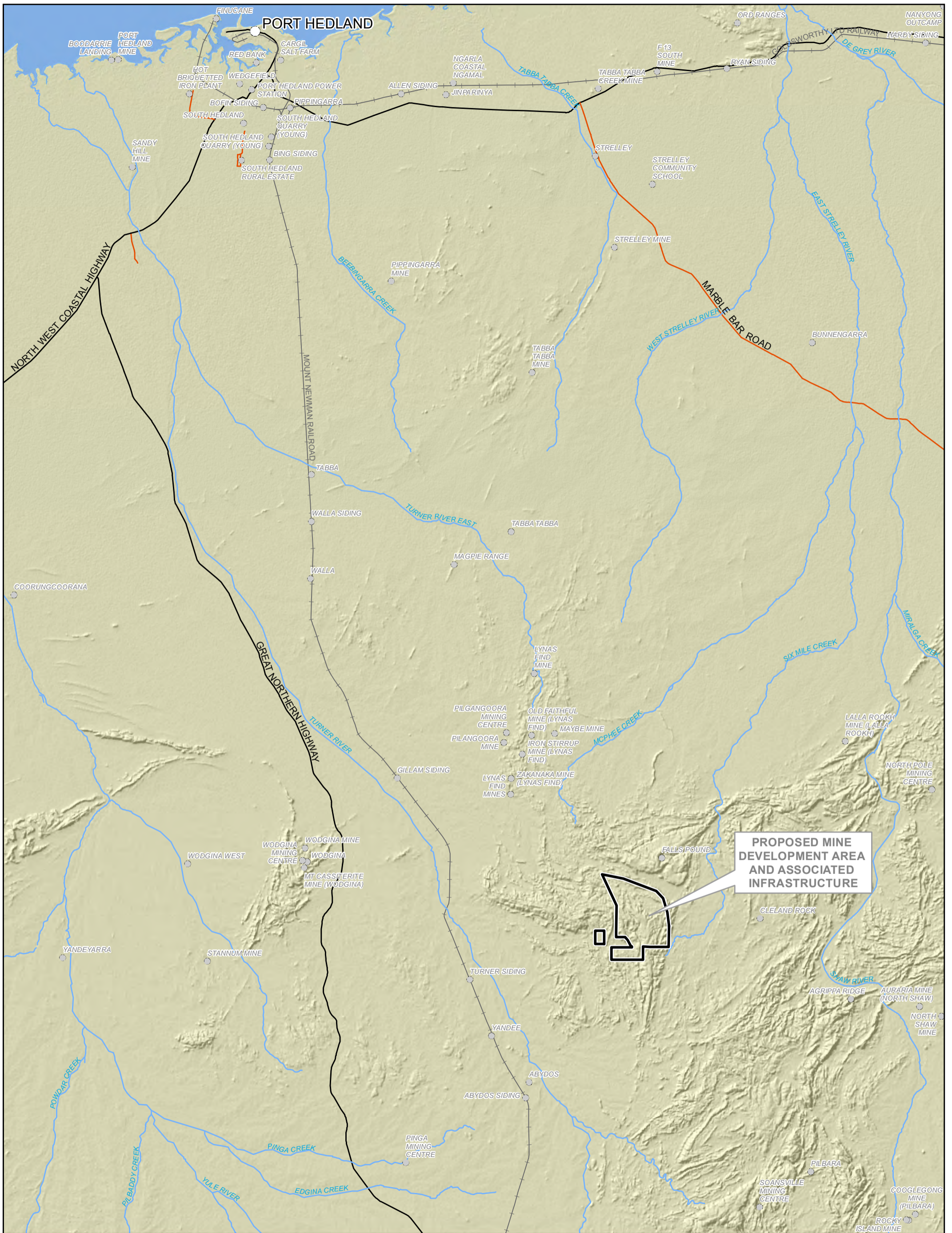
GHD has prepared this report on the basis of information provided by and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of infrastructure, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions may change after the date of this report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This assessment is based upon the study area shown in Figure 2.

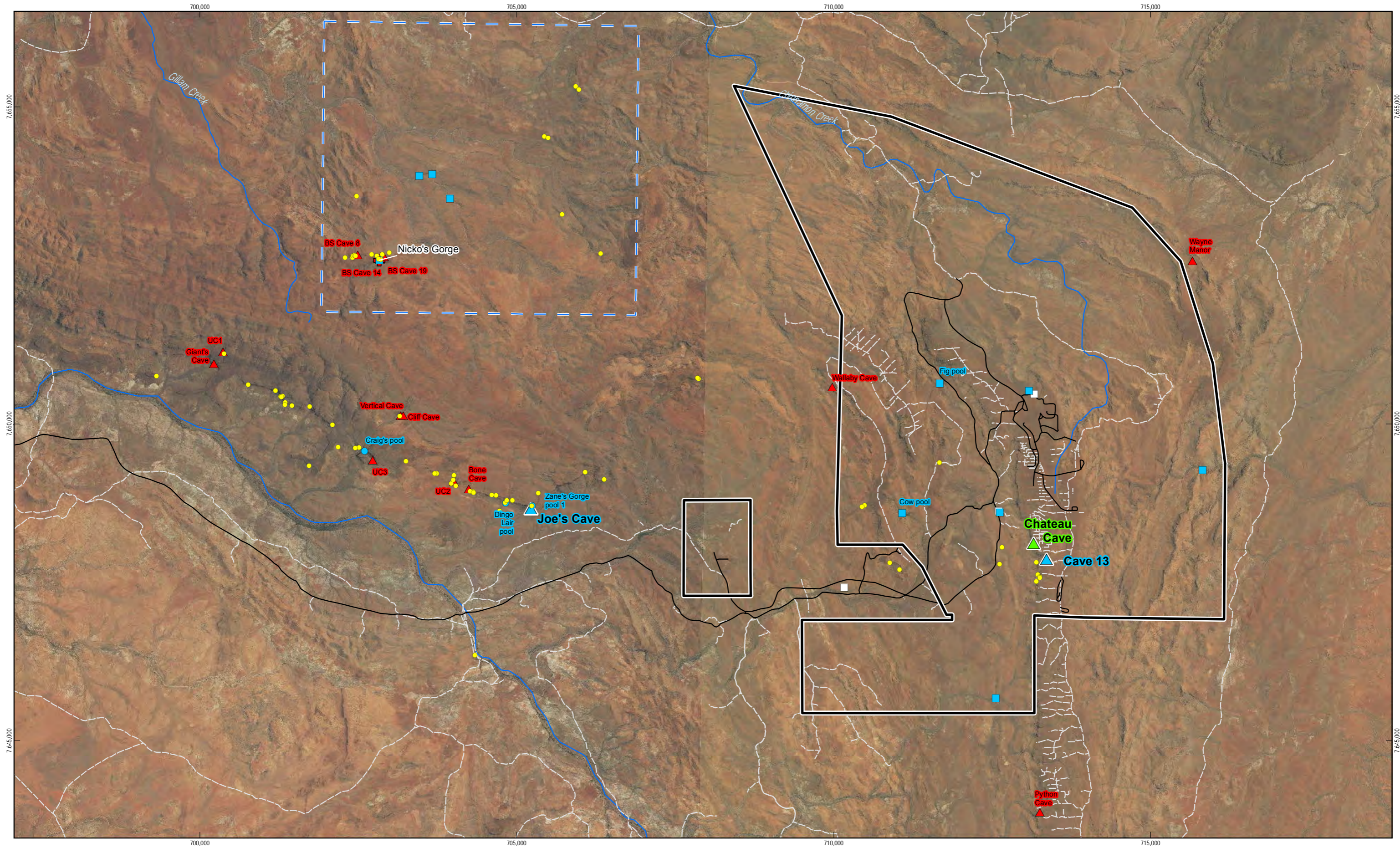


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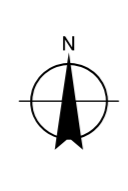
Job Number 61-35195  
 Revision 0  
 Date 21 Jul 2017

North Star Iron Bridge project area

Figure 1



Paper Size A3  
 0 0.5 1 1.5 2  
 Kilometres  
 Map Projection: Transverse Mercator  
 Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 50



**LEGEND**

- |   |  |                           |                       |
|---|--|---------------------------|-----------------------|
| <b>Bat Record</b>   | ▲ Potential roost location unknown type (habitat assessment) | ● Nocturnal refuge        | — River               |
| ● Pool with PLNB activity recorded within 15 mins of Civil Twilight | ▲ Transitory diurnal roost                                   | ■ Pool                    | ▭ MDE                 |
| ⊕ SM2 with PLNB activity recorded within 15 mins of Civil Twilight  | ▲ Permanent diurnal or non-permanent breeding roost          | □ Artificial pool         | ▭ Blue Box Study Area |
|   |  | — Road; Haul Road         |                       |
|   |  | — Minor Track; Drill Line |                       |



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	Revision   1
	Date   18 Oct 2017

**Known and potential roost locations for PLNB, North Star Mine** Figure 2

## 2. Methods

### 2.1 Field surveys

The field survey team comprised GHD Senior Ecologists Craig Grabham and Glen Gaikhorst, Joanna Riley (Kingfisher Consulting) and Jeff Turpin (Kingfisher Consulting). Senior Ecologists were supported by FMG Senior Environment Advisor, Matthew Dowling and Njamal Traditional Owners, Brandon Geary and Aiden Perry.

The survey was conducted under “Licence to Take Fauna for Scientific Purposes” (Regulation 17) Permit No. 08-000751-1 and Animal Research Authority (Project number GHD: 613519501).

Field surveys were undertaken 9-28 June 2017 within the study area. A summary of the field survey methods is provided below, with the results of these surveys presented in Section 3.

#### 2.1.1 Bat trapping

Harp traps (Faunatech Austbat Pty Ltd) were used to capture PLNB for the purpose of radio-tracking and to gain biological information about the species (e.g. sex, age, reproductive condition) as it is difficult, if not impossible to gain this information from other methods.

Harp traps were erected approximately 15 minutes before sunset at three locations (Chateau Cave, Dingo’s Lair Pool and Joe’s Cave) over the course of four nights. Sheets and other objects (e.g. large leafy branches) were used to funnel bats into the harp traps where possible. The set-up Harp traps are presented in Plates 1-3, with the location of each harp trap included in Figure 4. Table 1 summarises trap survey effort.

Trap(s) were continuously monitored by two Senior Ecologists for the duration of the survey with monitors positioned within 5 metres from the trap to ensure captured bats were retrieved as soon as possible. For each bat captured, the species, sex, age, reproductive condition, forearm length (+/-0.5 mm) and mass (+/- 0.5 g) was recorded. All bats were assessed and released at the point of capture.

Table 1 Harp trapping survey effort

Site	Traps	Date/survey effort	Notes
Chateau Cave	2 x standard 2 bank harps (4.2 m <sup>2</sup> ) at cave entrance and 1 x mini harp (2.2 m <sup>2</sup> ) in main passage of cave	13/6 – approx 4 hrs each trap 14/6 – approx 3 hrs each trap	EMT
Dingo’s Lair Pool	2 x standard harps placed in front of pool and along creek line	18/6 – approx 3.5 hrs each trap	EMT
Joe’s Cave	3 x standard harps at cave entrance	20/6 – approx 3.5 hrs each trap	EMT

An EcoMeter Touch microphone (EMT, Wildlife Acoustics) coupled with an iPad was used to monitor bat call activity in real time. The use of the EMT enabled an account of bat call activity including time of first bat call, species identification, and approximate activity levels.



Plate 1 Harp traps at Chateau cave



Plate 2 Harp trap at **Dingo's Lair Pool**

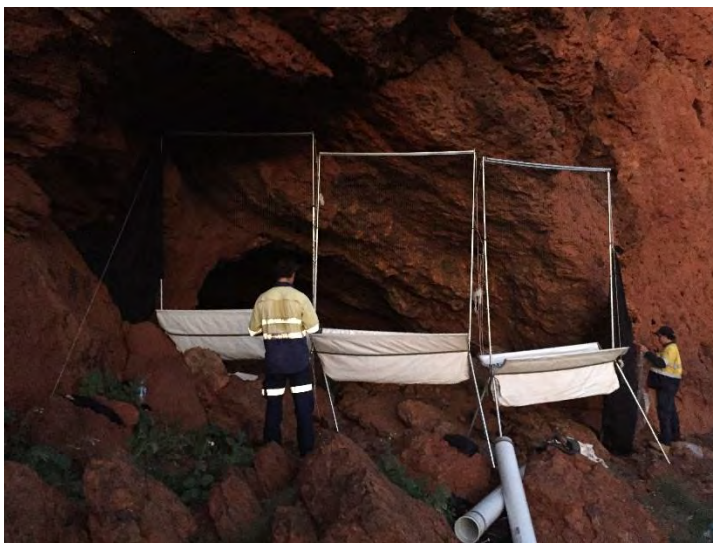


Plate 3 **Harp traps at Joe's Cave**

### 2.1.2 Scat collection

Scat samples from most PLNB were collected while briefly handling the captured animals maintained in calico bags. Scats were collected and placed in a 10 ml vial with self-indicating silica gel crystals (Rowe Scientific Pty Ltd) for later DNA analysis or food prey analysis. Scats were stored in this manner to aid in preventing genetic material from degrading and allow future assessment.

### 2.1.3 Radio tracking bats

#### **Transmitters**

Seven PLNB were fitted with digitally encoded transmitters (see Figure 13 and Figure 14). Each transmitter has a unique digital signature (code ID – see Table 2) although transmitters operate on the same frequency (151.890 MHz) allowing for near simultaneous monitoring of multiple transmitters which is not possible using traditional radio-telemetry systems. The transmitters (Lotek NTQB-2 Nano Tags; Lotek Wireless Inc.) weighed 0.34 g, which is less than 5% of the body mass of the minimum reported weight (8.7 g) of PLNB (Churchill 2008, Armstrong 2001, 2002). A small section of fur was trimmed from the mid-dorsal area (between the shoulder blades below the neck) to allow the transmitter to be attached with surgical grade biodegradable glue (Skin Bond, Pfizer Inc.). The transmitters have a pulse rate of 2 seconds resulting in a battery life of 14-16 days.

Table 2 Transmitter (tag) details

Tag code ID	Start time/date	End time/date	Number of detection nights
104	19:50 / 13/06/2017	20:47 / 25/06/2017	12 nights
105	20:35 / 13/06/2017	20:35 / 26/06/2017	13 nights
106	21:55 / 13/06/2017	06:02 / 23/06/2017	10 nights
107	19:10 / 14/06/2017	03:10 / 27/06/2017	13 nights
108	20:10 / 14/06/2017	20:33 / 25/06/2017	11 nights
109	19:20 / 20/06/2017	01:52 / 27/06/2017	7 nights
110	19:50 / 20/06/2017	05:10 / 27/06/2017	7 nights

Notes: Start time/date – time and date bat released with attached transmitter. End time/date – indicates time and date of last record for each tagged bat as base stations were decommissioned.

#### **Base station receivers**

After release bats were tracked using an array of 11 base stations (SRX 800-D1 stationary data logging receivers, Lotek Wireless Inc., Newmarket, Ontario, Canada) for between 7 and 15 nights. Base stations were strategically positioned to understand the movements of PLNB individuals from a known roost location (Chateau Cave); to intercept possible flight movements between the Chateau Cave and Joe's Cave areas; and to assist with locating the alternate roost location. The location of each base station is summarised in Table 3 and Figure 3 displays the location of each base station and the estimated range of reception. The typical setup of the base stations is shown in Plates 4-7.

The receiver at each base station was connected to 3 or 4 Yagi antenna (utilising either 3 or 6 elements) positioned at heights between 4 and 8 metres above the ground. The antenna array for each base station is detailed in Table 4. Antennas were monitored on alternating cycles of 3-5 seconds depending the number, location and position of the antenna/base station. The antenna array (type, number and direction) for each base station was constructed with regard to

localised physical sources of interference and orientated to monitor a different portion of the sampling area, but also in some circumstances allowing for overlap.

Receivers were set to record between 17:00 and 08:00 each day (a period of 15 hours) to conserve battery life and minimise the recording of miscellaneous data. Receivers recorded all transmitter detections within the range of reception including: Transmitter ID, date and time of detection (synchronized among receivers by GPS), antenna number, and signal strength. The status of each receiver was regularly checked and data was regularly downloaded.

Line of site (LOS) calibration tests were undertaken to estimate the range of reception for the base station antenna considering the topography and other signal. The test method was based on a similar LOS testing used during the March 2017 trial study (GHD 2017d) as described in Appendix A. Tests revealed a direct line of sight detection radius of approximately 2.2 km for the three-element antennas and approximately 2.0 km for the six-element antennas, although based on simultaneous detections on multiple towers, in some cases, detections did probably occur at greater distances for the six-element antenna. Similar tests for other studies have reported the six-element antenna is likely to have a greater LOS range (McQuire et al 2012); however the testing for this survey did not exceed 2 km.

Table 3 Base station details

No. / Name	Operational dates / effort	Base station (BS) elevation, position
1. Chateau Cave	13-28/6/17 / 15 nights	368 m (metres above sea level)/ front of cave along cliff edge. One of three antenna facing into cave. Note: base station battery failed night of the 19 <sup>th</sup> June.
2. Rise	13-25/6/17 / 13 nights	358 / on top of small knoll approx 300 m from Chateau Cave in valley – antenna orientated at Chateau Cave, north along valley and south along valley.
3. Jimmy's Gap	13-23/6/17 / 10 nights	359 m / a top cliff, overlooking pass and into two valleys. One antenna orientated toward Rise, and one antenna orientated toward Nate's Tower.
4. Fig Pool	13-26/6/17 / 12 nights	319 m / midday way along steep slope of valley opposite Fig Pool (permanent water). Antenna orientated toward pool, north along valley and south along valley. Note: base station battery failed nights of the 18 <sup>th</sup> and 19 <sup>th</sup> June.
5. Nate's Tower	13-26/6/17 / 13 nights	357 m / tower located on top of cliff face overlooking several valleys. Antenna orientated toward Chateau, north along valley and south along valley.
6. Japal	23-27/6/17 / 4 nights	254 m / located on western side of camp, low open wide valley plain. Placed to intercept east-west movements.
7. JJ's	14-27/6/17 / 13 nights	283 m / on top of small knoll. Antenna orientated toward Joe's, cliffs/possible roost sites and Japal.
8. Joe's Cave	13-27/6/17 / 14 nights	314 m / front of cave along cliff edge. Antenna orientated into cave, and east and west along cliff face.
9. Matt's Tower	14-27/6/17 / 13 nights	261 m / on top of small knoll. Antenna orientated toward Joe's, north toward cliffs/possible roost sites and west.
10. Mobile (Turkeys nest)	15-27/6/17 / 10 nights	229 m / on top of constructed water storage (Turkey nest) next to ephemeral creek. Two antenna were always orientated north and south along the ephemeral creek line. Note: antenna configuration changed during the survey period (see notes below and limitations section for further explanation).
11. OPF	18-27/6/17 / 9 nights	381 m / On top of small knoll approx 300 m from the ore processing facility. Antenna orientated toward OPF, and north-east and east into valley.

Table 4 Antenna array (orientation and type) for each base station

Base station	Antenna number (bearing degree's / element type)			
	1	2	3	4
CC	168 / 3	46 / 3	279 / 3	-
Rise	228 / 6	9 / 6	184 / 3	-
Jimmy Gap	39 / 3	301 / 6	130 / 3	-
Fig Pool	342 / 6	235 / 3	145 / 3	-
Nate's Tower	142 / 6	352 / 3	103 / 3	-
Japal	78 / 3	230 / 3	170 / 6	-
JJ's	320 / 3	65 / 3	255 / 3	-
Joe's	5 / 3	265 / 3	104 / 6	-
Matt's	67 / 6	292 / 3	11 / 3	-
Mobile (Turkey's nest) - A	5 / 3	190 / 3	265 / 6	85 / 6
Mobile (Turkey's nest) - B	5 / 3	190 / 3	-	-
OPF	50 / 6	323 / 6	125 / 3	265 / 3

Note: Mobile array configuration A from the 17-21 June consisted of 4 yagis. Configuration B from the 21-27 June consisted of two yagis.

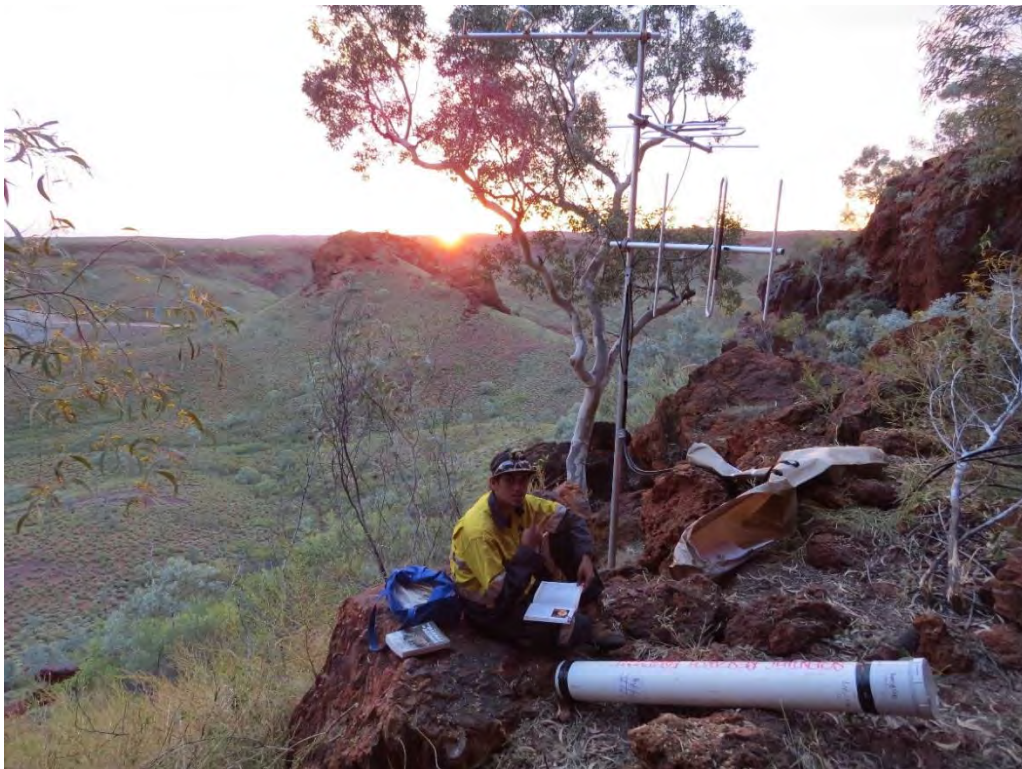


Plate 4 Chateau Cave base station looking toward Rise base station (M. Dowling)



Plate 5 Rise base station / looking south-east at Chateau Cave



Plate 6 **Joe's Cave base station** looking south-east



Plate 7 OPF base station looking north-east



Plate 8 **Nate's Tower** base station looking north-east

### Manual active tracking

To supplement and validate the base station data, night-time and day-time searches for transmitters were conducted with handheld receivers (SRX 800-M1 receiver, Lotek Wireless Inc) each with one three-element Yagi antenna. Figure 4 displays the search area covered by the manual tracking.

Handheld receiver searches during the early evening and into the night focussed on establishing the movement patterns of the bats (e.g. how far do they move, where do they move and do they move between caves). During early morning and day-time, handheld receiver searches attempted to determine the location of each tagged roosting bat.

During the evening/night field teams drove and walked along existing roads and access tracks and stopped at fixed locations and/or at regular intervals until a signal was received from a transmitter. Upon receiving a signal, effort was made to determine the direction and approximate distance of the transmitter from the receiver. Manual tracking on foot was mostly limited to daytime searches due to the lack of safe access. Manual tracking survey effort is summarised in Table 5. An example of the manual active tracking equipment in use is shown in Plate 8.

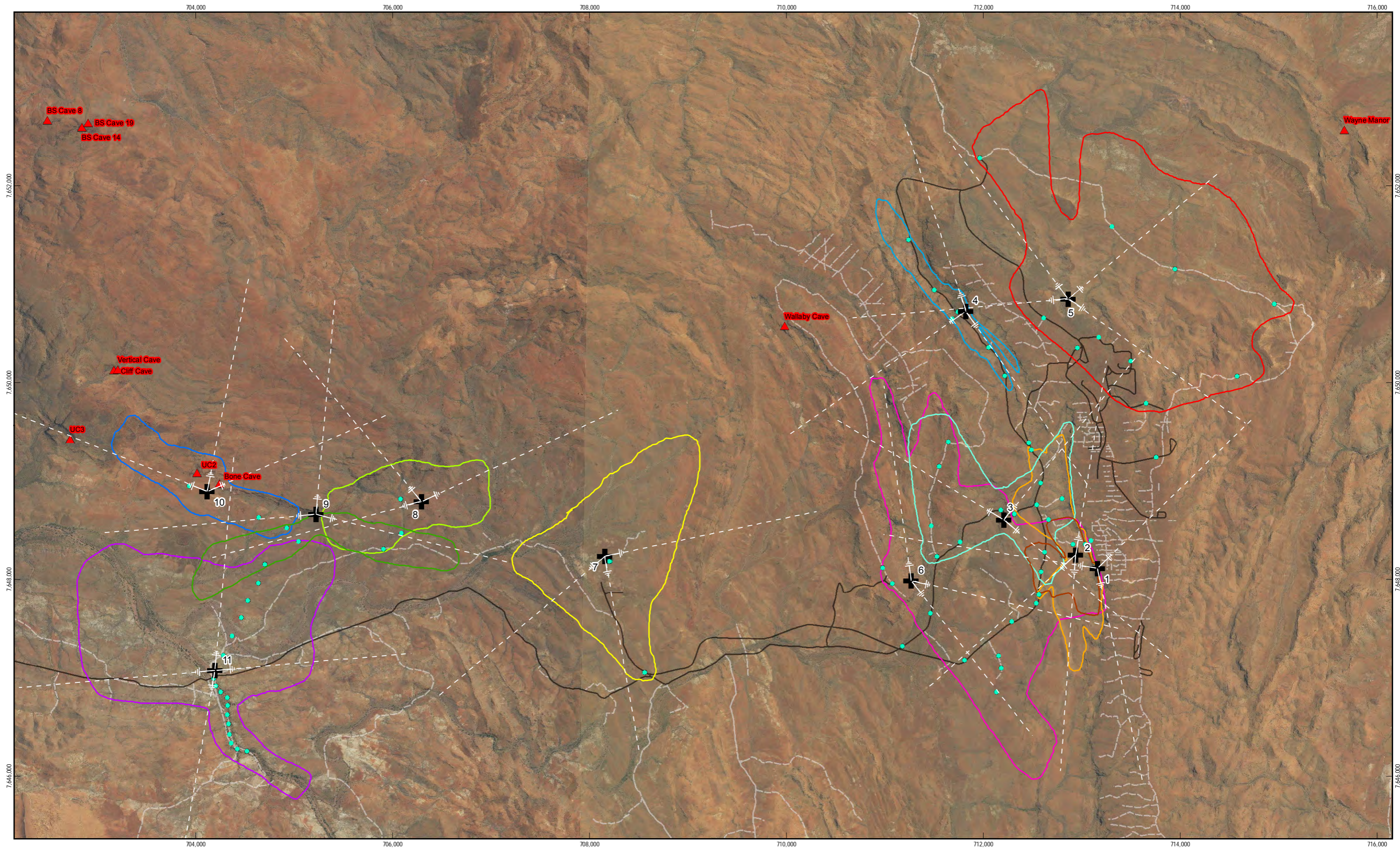
Table 5 Summary of manual tracking effort

Track log (Figure 4 reference = date). Approx. start / end time	Track and search description
15/6, 19:40/21:00	Night search bat activity - walk and drive between Chateau Cave and Jimmy's Gap. Cave 13 also checked for tagged bats
16/6, 19:20/21:30	Night search bat activity - walk and drive along tracks from Turkey's nest to Nate's Tower, Cow pool, Jimmy's Gap, OPF, along plateau to Chateau Cave and return to Japal. Cave 13 also checked for tagged bats
17/6, 19:00/20:30	Night search bat activity - walk and drive north of OPF along spinifex Hill track, then east of OPF into valley, then back to Japal camp
18/6, 18:00/18:30	Night search – whilst monitoring Dingo's Lair Pool harp traps
19/6, 17:55/19:05	Night search - walk between Joe's Cave and JJ's base station, and north of JJ's base station
20/6, 18:00/18:45	Night search - whilst monitoring Joe's Cave harp traps
21/6, 18:00/21:30	Night search - walk and drive along plateau from OPF to Glacier Valley, then back to Japal camp
22/6, 08:00/13:30	Day roost search – north-east of Joe's Cave/Zane's Gorge, north of JJ's base station
22/6, 18:00/20:25	Night search bat activity – along plateau from OPF to Glacier Valley, then back to Japal camp
23/6, 08:00/12:30	Day roost search – north-east of Joe's Cave/Zane's Gorge and north of JJ's base station
24/6, 07:20/09:00	Day roost search/tag search – along ephemeral creek and into low hills south of Joe's Cave

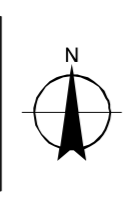
Track log (Figure 4 reference = date). Approx. start / end time	Track and search description
24/6, 19:00/21:30	Night search bat activity – including walk and check Chateau Cave and Cave 13 and along parts of plateau, then drive back to Japal camp
25/6, 08:00/10:15	Day roost search/tag search - Walk and drive north of OPF along Spinifex Hill track, then east of OPF into valley



Plate 9 Senior Ecologist Glen Gaikhorst undertaking manual tracking north-east of Joe's Cave / north of JJ's base station (photo - J. Riley)



Paper Size A3  
 0 500 1,000  
 Metres  
 Map Projection: Transverse Mercator  
 Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 50



**LEGEND**

- Radio receiver station
- Radio receiver antenna (bearing from north)
- Line of sight test point
- Cave
- Road; Haul Road
- Minor Track; Drill Line
- Radio receiver station maximum line of sight

**Estimated reception polygon**

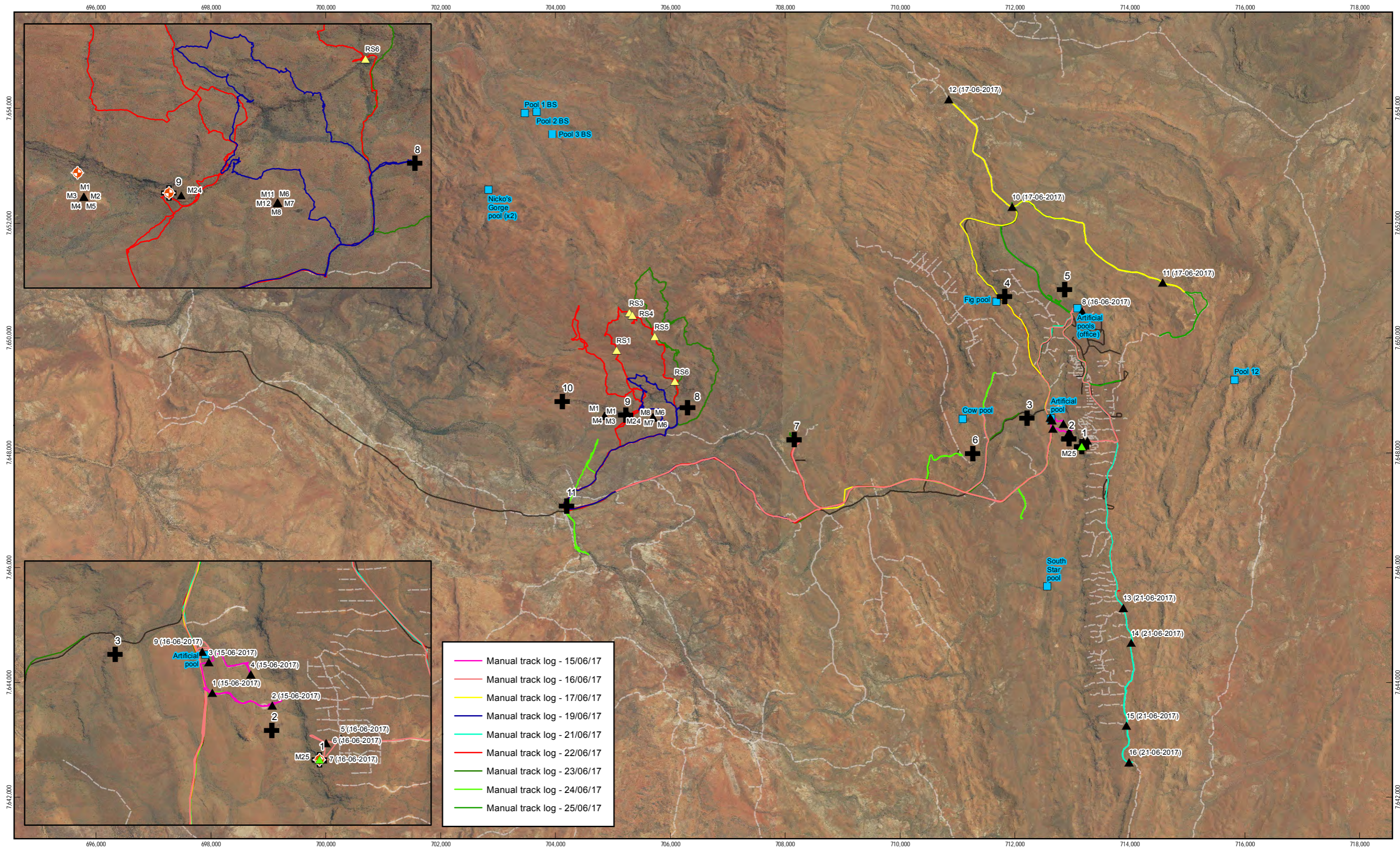
- Fig Pool - 4
- JJ's - 8
- Chateau Cave - 1
- OPF - 5
- Rise - 2
- Nate's Tower - 6
- Jimmy's Gap - 3
- Japal Village - 7
- Mobile (Turkey Nest) - 11
- Joe's Cave - 9
- Matt's Tower - 10



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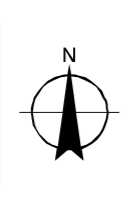
Job Number | 61-35195  
 Revision | 1  
 Date | 19 Oct 2017

Project area and base station array **Figure 3**



- Manual track log - 15/06/17
- Manual track log - 16/06/17
- Manual track log - 17/06/17
- Manual track log - 19/06/17
- Manual track log - 21/06/17
- Manual track log - 22/06/17
- Manual track log - 23/06/17
- Manual track log - 24/06/17
- Manual track log - 25/06/17

Paper Size A3  
 0 500 1,000 2,000  
 Metres  
 Map Projection: Transverse Mercator  
 Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 50



- LEGEND**
- ▲ Manual tracking point
  - ⊕ Harp trap
  - ⊕ Radio receiver station
  - Pool
  - ▲ Permanent diurnal or non-permanent breeding roost
  - ▲ Potential roost site
  - Road; Haul Road
  - Minor Track; Drill Line



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**Methods (manual tracking and harp traps)**

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**Figure 4**

## 2.2 Data analysis

Before analysing the data, bat detections for each base station were reviewed for potential errors (e.g. false detections) and outliers. For cases of dubious detections (e.g. a single detection well outside the time period of any other observations of the same tagged bat, or same time detections recorded on base stations greater than 2 km's apart), the fractional seconds (unique interval for each transmitter) of the detection time were examined. Dubious detections were discarded from further analysis.

Where possible the following was discussed for each tagged bat:

- First and last detection times – analysis of the timing of the first and last detections with regard to civil twilight (near sunset and sunrise) times was undertaken for each tagged bat to assist with understanding if bats were roosting in Chateau Cave or Joe's Cave, and to refine the location of other potential roost sites. The analysis considered the timing and signal strength of detections from all base stations closest to civil twilight (e.g. +/- 15 minutes) for each night for the survey period. This information is presented in table format for each tagged bat in the results section (see Table 12 as an example).
- Nightly activity patterns – analysis of detection data was undertaken to determine the nightly activity patterns for the survey period for each tagged bat. This analysis enabled an assessment of the amount of time (duration) each tagged bat was active within the study area, and frequency of activity within the study area, albeit limited to the reception range of the receivers. For each tagged bat the timing of each detection from all base stations (regardless of signal strength or antenna) was logged for each night. The data was presented for each night as a stacked bar chart and the temporal activity patterns for each tagged bat during the survey period was discussed (see Figure 6 as an example)
- Nightly movement patterns - estimated direction and where possible distance travelled based on transmitter detections each night and over the course of the period the individual was tagged. This was usually indicated by a pattern of signal strength for each signal detection typically reducing from one or two antenna, whilst departing the reception range of the base station and then over time a gain in signal strength from one or two antenna, whilst entering the reception range of another base station at another location. The interpretation of data, particularly for nightly movement patterns is further discussed below.

Other studies have noted that signal strength is generally proportional to the distance from the base station (although a number of factors may decrease signal strength, most commonly physical interference from objects that block the signal), and therefore, the direction of the transmitter relative to the base station can be deduced from the strength of the signal on multiple antennas (McQuire et al 2012). Over multiple detections, a flight path can be inferred (especially when detections span multiple towers) (McQuire et al 2012 and Nelson et al 2017).

To facilitate discussion of the data and visualise the detections over time for each tagged bat the data is presented as scatterplots, with detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station (see Figure 5 as an example). Scatterplots were then stacked starting with Chateau Cave (for Tags 104 – 108) or Joe's Cave (Tags 109 and 110) which represent the point of capture for these tagged bats. Other plots were then stacked from east to west (e.g. from Chateau Cave to Joe's Cave or vice versa) to demonstrate detections over time and infer movement and direction via visual comparison of the detections over time for each of the base stations.

To better understand potential flight paths (direction), the estimated distance travelled between base stations and provide a better visual representation of the data smaller subsets of detection data (e.g. for one or two nights or a part of a night) were also analysed and presented as scatterplots.

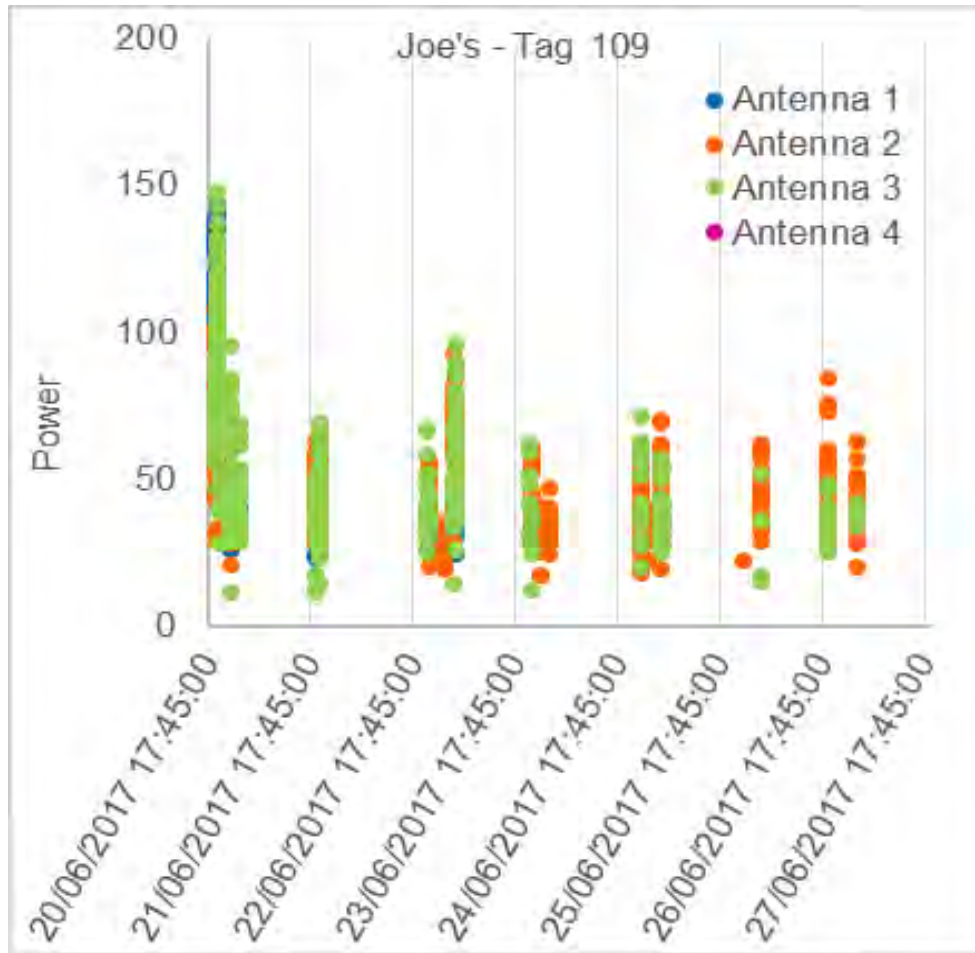


Figure 5 Detections recorded by **Joe's base station** for Tag 109 from 20–27 June

## 2.3 Survey conditions and weather

The Bureau of Meteorology (BoM) Marble Bar Station (Station number 004106) is approximately 120 km south-west of the study area and is the nearest weather station with continuous long-term data. Temperature and humidity measured at the Marble Bar Station for the survey period is presented in Table 6, with observational environmental data for the same period presented in Table 7. Overall temperatures were warm to hot during the day, cooling late evening with cool to cold and sometimes moderately windy mornings. Post midday temperatures were hot to warm, cooling late in the afternoon into the early evening. Trapping started just before sunset with temperatures ranging from 21-24 °C, and humidity at 38-60%. Wind was mild to absent.

One light short rain shower was recorded during the survey. Survey conditions were considered suitable for undertaking the targeted surveys and the weather was not considered a prohibiting factor.

Table 6 Temperature and humidity data for survey period (source: BOM)

Date	Min temp (°C)	Max temp (°C)	9 am Temp (°C)	9 am Relative humidity (%)	3 pm Temp (°C)	3 pm Relative humidity (%)
13/06/2017	13.2	28.4	19.1	24	27.3	12
14/06/2017	11.5	29.6	21.7	27	28.9	13
15/06/2017	11.9	29.8	23.3	25	29	14
16/06/2017	14.2	29.9	23.6	23	29.3	14
17/06/2017	17.1	30	22.6	26	29.2	14
18/06/2017	18.1	29.2	23	28	28.9	18
19/06/2017	16.4	28.2	21.9	27	27.5	19
20/06/2017	11.2	29	22.4	28	28.4	21
21/06/2017	11.7	30.9	22.7	34	29.9	22
22/06/2017	16.4	31.2	24.3	34	30.3	21
23/06/2017	15.6	30.2	23.1	39	29.4	26
24/06/2017	16.5	28.9	22.5	65	27.5	36
25/06/2017	16.4	29.2	22.4	47	28.7	14
26/06/2017	15.1	26.8	19.3	61	26.1	30
27/06/2017	13	24.9	17.5	60	24.5	34
28/06/2017	12.5	23	16.5	43	22.5	25

Table notes: data from BOM 2017 for Marble Bar weather station and data in italics from FMGIB – noting weather station located on top of hill

Table 7 Observational environmental data collected during survey

Date	Observation weather data and Sunset/Sunrise – Civil Twilight
13/06/2017	Observational at entrance of Chateau Cave at 17:50 Sunset below horizon (behind ridge of Nate’s Tower at c. 17:44) Cloud cover 5/8, Temperature 24°C, Humidity 38%, Wind – still, c. 3-4 days after full moon Sunset/Sunrise – Civil Twilight (CT) Chateau Cave - Sun rise 06:38/Sun set 17:29 / CT rise 06:14/CT set 17:54 Joe’s Cave - Sun rise 06:39/Sun set 17:30 / CT rise 06:14/CT set 17:54
14/06/2017	Observational at entrance of Chateau Cave Sunset below horizon (behind ridge of Nate’s Tower at c. 17:44) Cloud cover 3/8, Temperature 23°C, Humidity 45%, Wind – very light breeze, c. 3-4 days after full moon Sunset below horizon (behind ridge of Nate’s Tower at c. 17:45)
17/06/2017	Moon phase - last quarter moon
18/06/2017	Observational at Dingo’s Lair Pool at 17:45 Sunset below horizon 17:50 Cloud cover 1/8, Temperature 22°C, Humidity 35%, Wind – none
20/06/2017	Observational at entrance of Joe’s Cave Sunset below horizon 17:55 Cloud cover 1/8, Temperature 20°C, Humidity 38%, Wind – none
24/06/2017	Observational main passage of Chateau Cave at 20:22 Sunset below horizon 17:46 Cloud cover 1/8, Temperature 23°C, Humidity 53%, Wind – none Moon phase - new moon
25/06/2017	Observational main passage of Chateau Cave at 20:10 Sunset below horizon 17:46 Cloud cover 1/8, Temperature 24°C, Humidity 34%, Wind – none
27/06/2017	Sunset/Sunrise – Civil Twilight Chateau Cave - Sun rise 0642/Sun set 1732 / CT rise 0617/CT set 1756 Joe’s Cave - Sun rise 06:42/Sun set 17:33, CT rise 06:18/CT set 17:57

Table notes: Sun rise/set and Civil twilight times calculated from Australian Government Geoscience Australia - <http://www.ga.gov.au/bin/geodesy/run/sunrisenset> for two locations, Chateau Cave and Joe’s Cave. Observational data recorded by GHD during survey using hand held temperature and humidity gauge.

## 2.4 Limitations of survey

There has been no published or recorded attempt at radio tracking the PLNB to date as discussed with the Department of Parks and Wildlife WA (M. Page per comm February 2017). Furthermore there is little published information regarding the nightly movement patterns of this species. Consequently the design and implementation of the radio-tracking survey has largely relied on published information regarding other Australian bat species (e.g. Law et al 2005, Lumsden et al 2002, McConville and Law 2013, Pavey 1998a, Pavey 1998b) and literature from overseas, particularly regarding the use of automated base stations for monitoring bat movements and data collection (e.g. McQuire et al 2012 and Nelson et al 2017).

### *Impacts to the study species*

An important consideration in any study involving animal handling is potential behavioural responses to the capture event itself (McQuire et al 2012). Bats are not only difficult to study because they fly and are primarily active at night, but their small size, expensive flight cost, and rapid heat and water loss (Speakman & Thomas 2003) all make carrying the additional mass of a transmitter problematic (O’Mara et al 2014). It is possible that capture stress as well as carrying a radio-transmitter may have affected the movement behaviour of the PLNB tagged. However, because of the duration of the monitoring period (ranging from 7 to 13 nights) some of this concern may have been overcome/mitigated. Furthermore a wide range of movements were recorded for a number of tagged bats including some return events (where the bat

returned to the vicinity of the point of capture), therefore it is likely that most of the tagged individuals returned to normal movement patterns whilst carrying transmitters.

### ***Site conditions and survey coverage***

Weather experienced during the survey was suitable for undertaking trapping and radio-tracking surveys. There were no adverse weather conditions experienced during the survey which inhibited the survey program.

The terrain was prohibitive and it did constrain the survey design. For example, it was originally intended to place additional base stations north of the Joe's Cave/Zane's Gorge area however this was not possible within the current scope of works due to the difficulties of accessing these areas (e.g. no vehicle tracks and steep and uneven terrain). Thus, the location of all base stations could not be optimised with regards to locating the alternate roost site, particularly in this area north of Joe's cave/Zane's Gorge. In an attempted to overcome this limitation, daytime manual tracking was undertaken in the area north and north-east of Joe's Cave/Zane Gorge and by placing base stations in the most effective location with consideration to the aims of the survey and that could be safely accessed on foot and with good line of site.

Manual tracking at night was also difficult and mostly constrained to formed tracks and areas which were safely accessible on foot.

### ***Data collection and survey design***

There were a number of small gaps in the data due to equipment failure. The following gaps were recorded where the base station did not record data due to equipment failure:

- Fig Pool base station - 18 and 19 June due to a blown fuse in the inverter which resulted in a flat battery. This may have resulted in the loss of some movement data during this period.
- Chateau Cave base station – 19 June. The wiring to the battery had been tampered with and as a result disconnected, probably by an animal. It is unlikely the loss of this data has major implications for the survey results as movement and activity can be inferred from the antenna on the Rise base station pointing at Chateau.

The early absence/lack of data from some of the tagged bats (e.g. 107 and 108) prompted a review of the base station array and it was decided to place and/or relocate additional base stations to new locations. This in turn explains the main difference between the numbers of operating days for some of the base stations. For example Jimmy's Gap base station was operating for 10 nights before being decommissioned and moved to Japal Village. This base station was relocated to intercept any movements in the Japal Village area and to further understand potential bat movements between Joe's Cave and Chateau Cave. The OPF base station was operational from the 18-27 June. This base station was installed to understand potential bat movements north and north east of the Chateau Cave area and to capture movements in areas of habitat where little survey effort had been previously undertaken.

The Mobile (Turkey nest) base station was installed adjacent to an ephemeral creek in order to understand movements from the Joe's Cave along a potential foraging route. It should be noted that the configuration of the antenna array for Mobile base station was altered during the survey. From the 17-21 June the configuration consisted of four yagi antenna, which was reduced to two antenna from the 21–27 June. The zone of reception significantly reduced following the reduction of antenna, however two antenna were always orientated north and south along the ephemeral creek for the entire time the base station was active. The reduced zone of reception may account for the absence of some data for a few of the tagged bats (e.g. 110) during this period of the survey.

## 3. Results

### 3.1 Bat trapping and call analysis

#### 3.1.1 Number of species and individuals captured

A total of 51 bats of three species were captured during 4 nights of harp trapping at 3 locations. Eight PLNB were captured of which seven were tagged and released. Table 8 provides a summary of the number of species and individuals trapped at each location during the survey. Table 9 provides a summary of the key measurements taken for each of the PLNB captured and tagged during the survey. Appendix B provides a summary of the measurements and notes taken for all bats captured. Plates 10-16 display PLNB during the trapping and tagging process.

Table 8 Summary of bat captures for each location

Site	Species	Details
Chateau Cave (13 and 14 June 2017)	PLNB	13/6 - 3 x male (Tags 104, 105, 106) 14/6 - 3 x male (Tags 107 and 108). The third male captured 14/6 died c. 20-21 minutes after being retrieved from the harp trap. All others released at point of capture after applying radio tags. All individuals released within 30 min from point of capture except for first individual, which was released c. 40 mins unharmed from point of capture (including time in harp trap).
	Common Sheathtail Bat ( <i>Taphozous georgianus</i> )	21 x males and 9 x females. All released at point of capture unharmed. 3 x (unknown sex) escaped before processing.
	Inland Cave Bat ( <i>Vespadelus finlaysoni</i> )	1 (unknown sex) escaped before processing.
Dingo's Lair Pool (18 June 2017)	No bats captured	See Section 3.1.3
Joe's Cave Chateau Cave (20 June 2017)	PLNB	20/6 - 2 x female (Tags 109 and 110). All released at point of capture after applying radio tags. All released within 20 minutes from point of capture.
	Common Sheathtail Bat	6 x males and 2 x females. All released at point of capture unharmed.
	Inland Cave Bat	1 x individual (male). Released at point of capture unharmed.

Table 9 Summary of measurements and notes for each PLNB

Location /Date and Time	Sex	Forearm (mm)	Weight (g)	Ear (mm)	Foot (mm)	Body length (mm)	Wing joints	Reproductive condition	Teeth	Age	Colour	Tag
Chateau Cave 13/06/2017 – 19:15	M	47.8	8.5	0	0	42.2	Smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Some wear/not obvious	Sub-adult	Vibrant orange, darker brownish tips on back and back of head and neck	104
Chateau Cave 13/06/2017 – 20:10	M	46.6	8.5	0	0	40.2	Smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Some wear/not obvious	Sub-adult	Vibrant orange, darker brownish tips on back and back of head and neck	105
Chateau Cave 13/06/2017 – 21:27	M	47.8	9	0	0	46.7	No obvious cartilaginous band, blood vessels not distinct	-	Obvious signs of wear	Adult	Pale yellow/ fawn, not vibrant orange	106
Chateau Cave 14/06/2017 – 18:42	M	46.8	10	6.4/6.4	8.2/8.4	47.7	Smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Some wear/not obvious	Adult	Vibrant orange, darker brownish tips on back and back of head and neck	107
Chateau Cave 14/06/2017 – 19:46	M	47.4	9	7.8/7.6	8.7/8.6	0	Smooth with outline cartilaginous band, distinct blood vessels	-	Some wear/not obvious	Adult	Red-vibrant orange, darker brownish tips on back and back of head and neck area	108
Chateau Cave 14/06/2017 – 20:06	M	48.3	10	6.2/6.3	8.7/8.9	0	Smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Obvious signs of wear	Adult	Orange, darker brownish tips on back and back of head and neck	-
Joe's Cave 20/06/2017 – 19:20	F	45.6	8	0	8.4	49.65	Smooth with outline cartilaginous band, distinct blood vessels	Non-breeding, no obvious wear around nipples	No obvious wear	Sub-adult	Orange/orange-brown, darker tips on back and back of head and neck	109
Joe's Cave 20/06/2017 – 19:51	F	46.1	9.5	0	8.5	0	Obvious cartilaginous band/knobbly	Non-breeding, no obvious wear around nipples	No obvious wear	Sub-adult	Lighter yellow on belly / fawn back, neck and head. Light brownish tips on back and head.	110



Plate 10 Process of taking forearm measurements from PLNB. Note senior ecologist Craig Grabham securing bat whilst Jeff Turpin measures forearm and Brandon Geary records measurements (photo – J. Riley)



Plate 11 PLNB male captured at Chateau Cave 13/6/17 (photo – J. Riley)



Plate 12 PLNB captured at Chateau Cave 14/6/17 (photo - J. Riley)



Plate 13 PLNB captured at Chateau Cave 13/6/17 (photo - M. Dowling)



Plate 14 PLNB with tag 107 just prior to release - Chateau Cave 14/6/17 (photo - J. Riley)



Plate 15 PLNB during application of tag 108 – Chateau Cave 14/6/17 (photo - J. Riley)



Plate 16 PLNB - application of tag 110 – **Joe's Cave** 20/6/17 (photo - G. Gaikhorst)

### 3.1.2 PLNB call activity during the Emergence time response

FMGIB are currently undertaken long term monitoring of PLNB call activity at Chateau Cave using a full spectrum SM2BAT+ SongMeter recorder (Wildlife Acoustics Inc., USA) inside the entrance of the main chamber. A sample of the data was analysed to better understand the response of the PLNB to the trapping session. Analysis focused on the timing of the first and last PLNB calls for a period before, during and after the trapping session at Chateau Cave. Detailed analysis of the data is provided in GHD 2017f. Table 10 summarises the analysis results.

As with previous analysis results the first PLNB calls nearly always occur after other species, and were at least 30 minutes after civil twilight in the evenings. Of particular note is the timing of the first and last calls during the trap nights (13-14 June). The first calls for both nights were at least 2 hours following civil twilight indicating that the PLNB roosting within Chateau Cave detected the harp traps and probably delayed their emergence. Furthermore, the PLNB was captured at 19:15 (13 June) and 18:42 (14 June) well before the first call recorded by the SM2 inside Chateau Cave for both nights.

Table 10 Summary of call analysis at Chateau Cave for PLNB from 5-18 June 2017

Date	First call	Last Call	Notes
5/6	18:46	05:07	Inland Cave Bat and Common Sheathtail Bat calls recorded at least 10-15 mins before first PLNB call (same pattern for all night)
6/6	18:36	05:36	-
7/6	18:42	05:09	-
8/6	18:32	04:41	-
9/6	18:54	03:16	IR camera / Bat counter
10/6	18:50	04:22	IR camera / Bat counter
11/6	19:00	05:27	IR camera for part of the night
12/6	18:39	06:02	-
13/6	20:58	05:38	Trap night 1.
14/6	20:07	06:14	Trap night 2.
15/6	18:31	06:14	-
16/6	18:31	05:48	-
17/6	18:36	05:07	-
18/6	19:10	05:08	-

Table notes: IR camera and Bat counter used for roost emergence surveys to estimate the population size of the colony of PLNB that inhabit Chateau Cave, noting data yet to be analysed. Civil twilight at c. 17:55. Times highlighted in yellow are within 10 min (+/- 2 min) or occur after civil twilight at 06:14.

### 3.1.3 Behavioural observations during trapping

The EMT in combination with visual observations proved to be a useful tool to determine that many bats evaded the harp traps. It was estimated that approximately 17 PLNB evaded capture across the four nights of trapping. This was most obvious at Dingo's Lair Pool where calls of PLNB were observed on the EMT simultaneously as a bat in flight passed through or over or around the harp trap on at least seven separate occasions. It was determined the bats were probably aided by moon light, so subsequent trapping was undertaken during a darker night with less moonlight. Table 7 provides a summary of the bat activity noted during the trapping surveys.

Table 11 Summary of bat activity during trapping sessions from observation and EMT monitoring

Site	Details
Chateau Cave (13 June 2017)	EMT started at 18:15, c. 30 minutes after sunset. First call at 18:51 (PLNB and Inland Cave Bat). More than 110 PLNB calls were observed on the EMT during the trapping session. Overall bat activity was high with PLNB call activity comprising the majority of calls observed for both trapping sessions. Both common Sheathtail bat and Inland Cave Bat calls were commonly observed but not as frequently as PLNB calls. The audible 'trill' of the Ghost Bat was heard on five separate occasions and 3 visual observations of Ghost Bat in flight out front and above the cave entrance were recorded. At least 10+ PLNB individuals were also observed in torch light flying at height across the face of the cliff above the entrance of the cave during both survey nights. Observations were after 20:30 each night. The flight pattern of three individuals was tracked by torch light. They appeared to fly in a repetitive circle pattern at a distance of 20-30 m away from the entrance of the cave before then flying past the cave entrance to repeat the flight path or fly beyond the torch light.
Dingo's Lair Pool (18 June 2017)	EMT started at 18:10, c. 25 minutes after sunset. First call – 18:50 (Inland Cave Bat). First PLNB call at 19:40. More than 45 PLNB calls were observed on the EMT during the trapping session. Overall PLNB and other bat activity was constant. PLNB calls followed a pattern of continuous calls for a period of 1-2 mins followed by a period of no PLNB calls. PLNB call activity comprised the majority of calls observed. Both common Sheathtail bat and Inland Cave Bat calls were observed but not as frequently as PLNB calls.
Joe's Cave (20 June 2017)	EMT started at 18:00, c. 15 minutes after sunset. First call – PLNB at 18:15. The audible 'trill' of the Ghost Bat was heard on two separate occasions and one visual observation of Ghost Bat in flight out front of the cave was recorded. Both Common Sheathtail bat and Inland Cave Bat calls were also observed.

Note – EMT not used 14/6 at Chateau Cave

It was also observed that each species behaved differently during the capture, handling and release process. An account of the behavioural observations for the PLNB and Common Sheathtail bat during the trapping process is provided below.

#### **Pilbara Leaf-nosed Bat**

This species was generally agitated and/or aggressive when retrieved from the trap. It often took 1-2 mins for the individual to settle before measurements were taken and the tag attached. A calico catch bag was used as a chew device, which calmed most individuals.

Many PLNB were witnessed evading/escaping the harp traps including two individuals observed flying into the harp traps, sliding down the monofilament line to the centre poles, spreading their wings to then fly out of the trap and evade capture. The individuals that were captured were always retrieved as soon as possible, thus behaviour in the trap bag was not observed.

Apart from one individual, all tagged bats readily flew from the hand. Unfortunately, one individual failed its first flight attempt. It appeared to be agitated, possibly by the addition of the transmitter and when released from the hand it became tangled on the glove. It attempted to fly but instead awkwardly flapped to the ground. It was immediately retrieved and checked for any signs of harm/stress. The position of the transmitter was also checked again to ensure it was not impeding the individual's ability to fly. The bat was then released and readily flew from the hand during the second attempt.

The following notes regarding the deceased bat have been provided to assist with future handling and surveys for the species:

- The individual was retrieved from the harp trap on the night of the 14 June 2017 at c. 20:06 pm and determined deceased at c. 20:30 pm. This was the third PLNB to be captured during the second night of trapping at Chateau Cave
- The bat died whilst in a small calico bag used for weighing. When placed in the bag the individual was agitated but not aggressive (e.g. did not bite). After waiting for the bat to settle in the bag for a period of c. 1 min the principle researcher noted that there was no movement and the bat was at the bottom of the bag (not at the top as most bats will climb to the top of the bag when elevated)
- We attempted to revive the individual by gently massaging the chest area for c. 2-3 mins whilst monitoring for signs of life. The bat was examined for any signs of external injury/possible causes of death and none were noted
- The deceased individual was an adult male, probably mature/not juvenile with obvious teeth wear, wing joints formed with no obvious cartilaginous gaps, testes not regressed but did not appear enlarged, forearm length 48.3 mm, weight 10 g, and fur was cream-yellow/dull orange and was mostly matted/rough compared to other individuals
- The cause of death was not evident given the lack of any obvious external injuries or other signs of stress. It was noted the bat was a mature adult, probably aging and this may have been a contributing factor towards its death. The specimen was lodged with the WA Museum in accordance with the permit requirements.

### ***Common Sheathtail Bat***

This species was generally easy to handle and take measurements for a large micro bat species. Most individuals would remain calm/motionless when handled, although some (<10%) became agitated and/or aggressive and attempted to bite.

Upon entering harp traps most common sheathtail bat crawled into the closest corner of the catch bag and settled. This species formed small groups in the harp trap and appeared most calm when next to/on top of another of the same species.

When retrieved from the harp trap the species would cling to the calico catch bag or sometimes avoid handling and evade the first recovery attempt. Most individuals would readily fly from the hand however some individuals would remain motionless and may have been in an early state of torpor. These individuals would be gently massaged and warmed prior to release.

## 3.2 Base station radio-tracking data

The data recorded by the automated base stations was downloaded and analysed to understand the nightly activity and movement patterns of each of the tagged PLNB. Seven of the base stations operated for 13 to 15 nights and four operated for 4 to 11 nights (Japal, OPF, Jimmy's Gap and Mobile-Turkey's nest). Seven PLNB were tracked by the base stations for between 7 and 13 nights between the 13-27 June 2017.

### 3.2.1 Transmitter 104

It was difficult to analyse activity and movement (both direction and distance) for Tag 104 as the data recorded by the base stations consisted of infrequent and mostly weak signal detections (Figure 6 and Figure 7). Although Tag 104 was active for 12 of the 13 tracking nights, the majority of activity consisted of short sporadic bursts of few detections (Figure 6). The lack of and random frequency of detections suggests the bat was most active outside the reception range of the receivers for the majority of the survey period. It is possible that some of the bat activity occurred within 'blind spots' of the base station array, however, it is unlikely to comprise a large portion of the survey period, particularly given the mobile behaviour of bats and duration of the tracking survey, which should have partially overcome this potential limitation.

The majority of the detections occurred within the first 3 hours of being released on the night of the 13<sup>th</sup> June (see Figure 6 and Figure 7). Within this period detections were almost entirely within an area overlapping the reception range of Jimmy's Gap, Rise and Nate's Tower base stations (BS). After 22:30 on the night of the 13<sup>th</sup> June, Tag 104 moved out of the reception range of the base station array (Figure 7).

The next detection for 104 was at the Chateau Cave BS on the 14<sup>th</sup> June at 17:54 (single detection, power = 132) on antenna 1 (facing the cave entrance). This single detection is the most interesting as it occurs one minute before civil twilight (Table 12) inferring that the bat was in close proximity to the base station or possibly within Chateau Cave (in a chamber/cavity that prevented earlier signal transmission). The later scenario is possible, however there are no further detections close to that time (next detection at 20:01, power 21 at Rise), nor was there a detection record indicating the bat entered the cave the morning of the 14<sup>th</sup>. Furthermore, there were no detections on the nearby Rise BS to correlate that the bat was roosting in Chateau Cave. Chateau Cave was also checked for tagged bats the mornings of the 14<sup>th</sup> and 15<sup>th</sup> June using the hand-held manual receiver. No tagged bats were detected.

Single weak detections (power <30) were also recorded by Rise at 20:01 and JJ's at 23:14 on the 14<sup>th</sup> June before moving out of reception range until the 16<sup>th</sup> where it was detected again (all single detections consisting of weak signal strength) for 5 consecutive nights on JJ's BS. The final detection was recorded from Nate's Tower BS on the 25<sup>th</sup> June after a period of almost two nights with no detections (Figure 7).

Many of the detections listed from JJ's (although mostly weak) were from late in the morning with two detections (16<sup>th</sup> and 23<sup>rd</sup> June) recorded approximately 10 mins after civil twilight (Table 12). Both records were from antenna 1 (orientation, north by north-west) toward the area (east of Joe's Cave BS – Figure 3).

Table 12 Summary of first and last detections each night June 2017 - Tag 104

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	13-14	19:50 (released)	Jimmy's Gap and Rise	20:57	Nate's and Jimmy's Gap
2	14-15	17:54	Chateau Cave A1, P-132	23:14	JJ's
3	15-16	02:34	JJ's	06:39	JJ's A-1 P-13
4	16-17	21:01	JJ's	05:58	JJ's
5	17-18	-	-	05:00	Jimmy's Gap
6	18-19	-	-	00:57	JJ's
7	19-20	-	-	04:06	JJ's
8	20-21	02:14	JJ's	05:41	Jimmy's Gap
9	21-22	-	-	01:05	JJ's
10	22-23	03:16	JJ's	06:30	JJ's A-1 P-13
11	23-24	20:36	Japal	-	-
12	24-25	-	-	-	-
13	25-26	20:47	Nate's	-	-

Table notes: A = antenna number. P = power (signal strength of detection). Times highlighted in green are within 5 mins (+/- 2 min) of civil twilight c. 17:55, with a theoretical flight distance of c. of up to 1.8 km (e.g. the bat is capable of flying c. 1.8 km at 22 km/h with 5 mins). Times highlighted in blue are within 5-10 mins (+/- 2 min) of civil twilight c. 17:55, with a theoretical flight distance of up to c. 3.6 km. Times highlighted in yellow are within 10 min (+/- 2 min) or occur after civil twilight at 06:14, with a theoretical flight distance of up to c. 3.6 km. Refer Table 6 for sunrise/sunset and civil twilight times. Note: theoretical flight distance based on analysis of McKenzie and Bullen 2009 and casual observations by Kyle Armstrong and Bob Bullen, pers. obs. Cited in Cramer et al 2016.

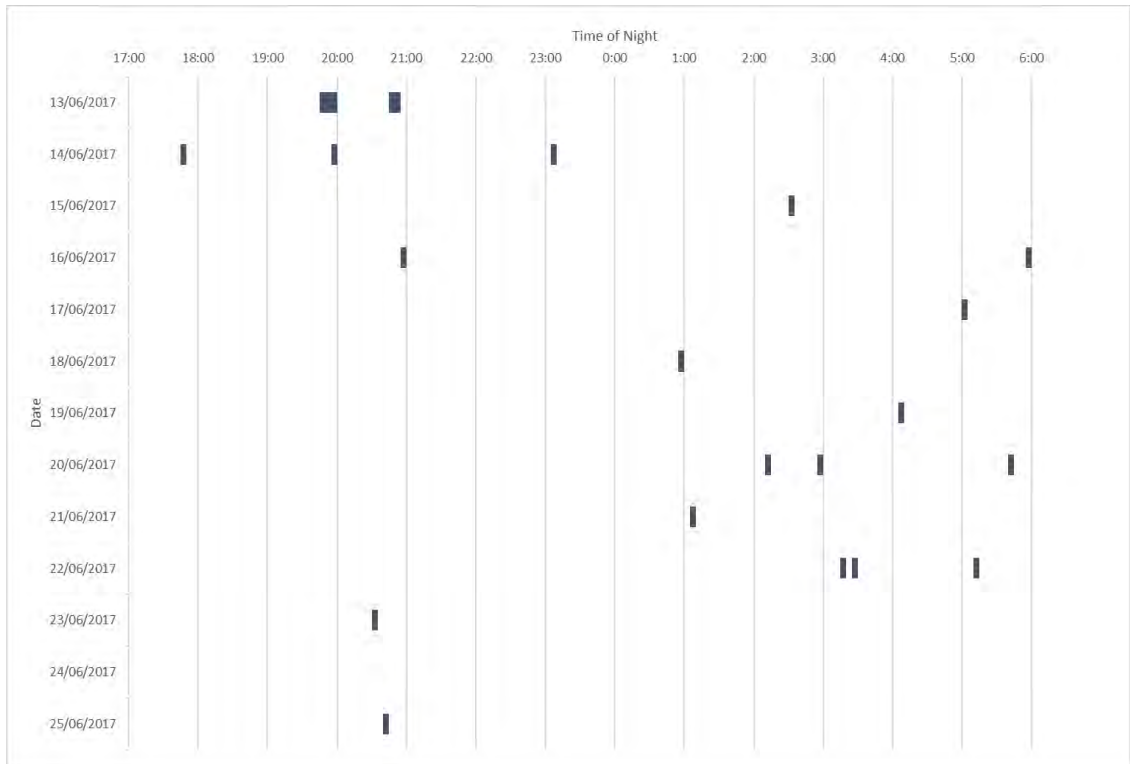


Figure 6 Nightly activity patterns for Tag 104

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Activity may consist of foraging, movement, resting or roosting. Civil twilight c. 17:55 and 06:14.

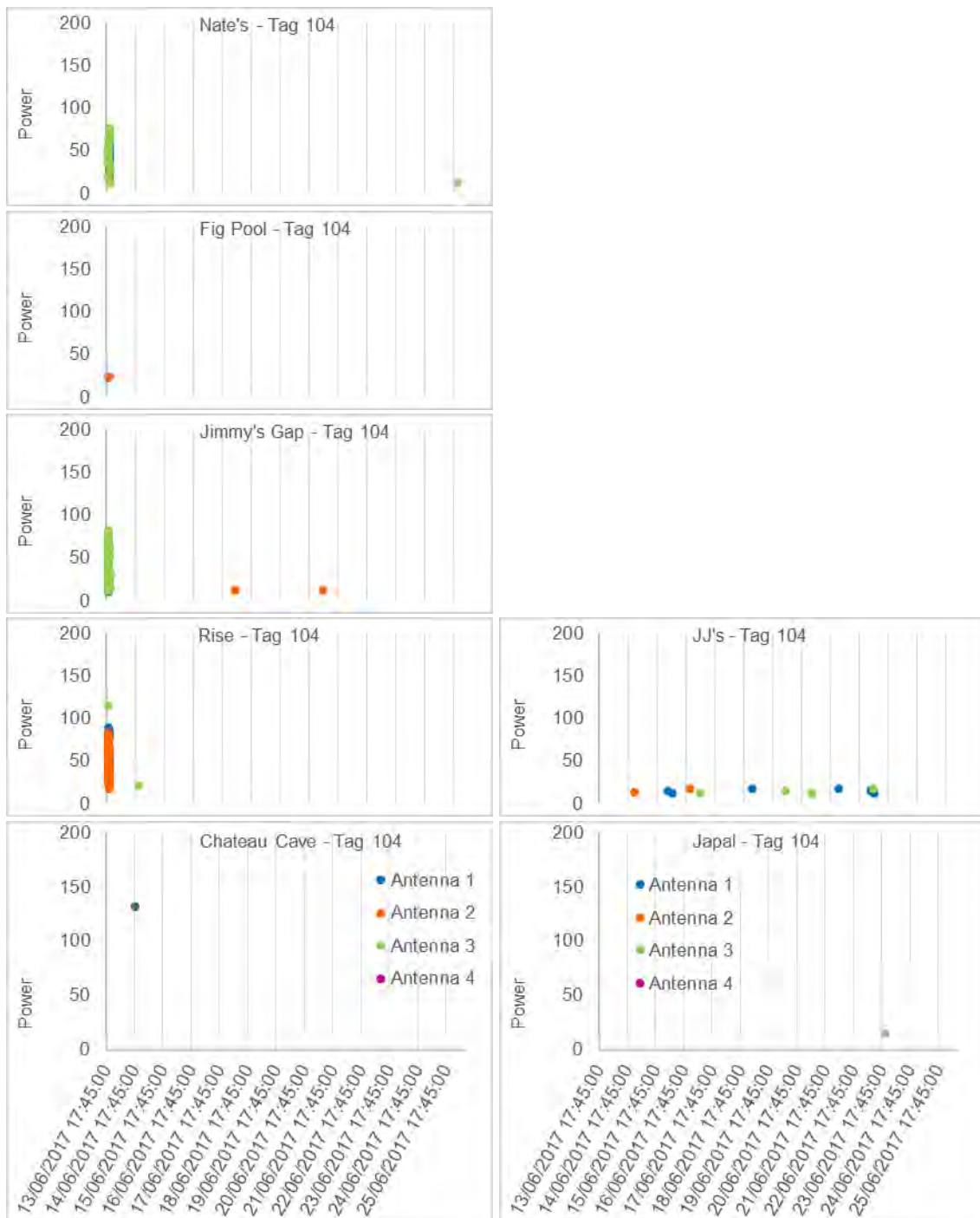


Figure 7 Base station detections for Tag 104 from the 13-25 June

Notes: No detection data for Joe's, Matt's, Mobile (Turkeys nest), or OPF base stations. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Chateau Cave (point of capture), then stacked from east to west (e.g. from Chateau Cave to JJ's BS) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.

### 3.2.1 Transmitter 105

It was also difficult to analyse activity and movement for Tag 105 as the data recorded by the base stations consisted of infrequent and mostly weak signal detections. Although detected by seven base stations, the majority of detections for Tag 105 were from four base stations during the first night of tracking, particularly within 1-2 hours following release (Figure 8 and Figure 9). Detections were then typically infrequent for the remainder of the survey period and although active for each of the 13 tracking nights (Table 13 and Figure 8), the majority of activity consisted of short sporadic bursts with few detections. The lack of and random frequency of detections suggests the bat was most active outside the reception range of the receivers for the majority of the survey period. It is possible that some of the bat activity occurred within 'blind spots' of the base station array, however, it is unlikely to comprise a large portion of the survey period.

The majority of the detections occurred within the first 2 hours of being released on the night of the 13<sup>th</sup> June (Figure 8 and Figure 9). Within this period detections were almost entirely within an area overlapping the reception range of Jimmy's Gap, Rise and Nate's Tower BS. After 22:00 on the night of the 13<sup>th</sup> June, Tag 105 moved out of the reception range of the base station array. It then reappeared as a few of weak single detections (power <30) across the night of the 14<sup>th</sup> June at JJ's then Jimmy's Gap base stations.

The majority of detections from the 15<sup>th</sup> through to the 23<sup>rd</sup> June were from JJ's base station (2-3 weak signal detections each night across multiple antenna). Although many of these detections are isolated, the data suggests a pattern of activity in this area. Final detections were from Japal base station (one each night) from the 23<sup>rd</sup> to the 26<sup>th</sup> June.

There was no clear pattern of movement or activity for Tag 105 (Figure 8 and Figure 9), although one detection record occurs well after civil twilight from JJ's BS on the morning of the 20<sup>th</sup> June (Table 13). Given the timing of the record, (at least 15 mins past civil twilight) it is possible that the bat was flying to, and possibly in very close proximity to a diurnal roost. Furthermore, records from JJ's BS from late morning (e.g. 05:54 and 05:58, Table 13) also supports the possibility of a nearby diurnal roost.

An analysis of the approximate detection locations over time and the overall level of activity within the area covered by the base station array further suggests that Tag 105 spent most of its time outside the zone of reception of the base station array.

Table 13 Summary of first and last detections each night June 2017 - Tag 105

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	13-14	20:35 (released)	Rise, Jimmy's Gap	22:09	Nate's
2	14-15	19:27	JJ's	05:29 07:10*	JJ's A-1, P13 Jimmy's Gap A-2, P21*
3	15-16	18:52	Nate's	03:01	JJ's
4	16-17	05:19	JJ's	05:36	JJ's
5	17-18	20:36	JJ's	05:50	Jimmy's Gap
6	18-19	00:31	JJ's	05:54	JJ's
7	19-20	20:11	JJ's	06:37	JJ's A-1, P13
8	20-21	03:27	JJ's	03:51	JJ's
9	21-22	21:23	JJ's	05:06	JJ's
10	22-23	02:44	JJ's	05:58	JJ's
11	23-24	19:16	Nate's	04:31	Japal
12	24-25	20:32	Japal	-	-
13	25-26	-	-	03:50	Japal

Table notes: \* indicates dubious data. The timing of the record is in daylight, furthermore there are no detections within 5 mins of this for the same base station. A = antenna number. P = power (signal strength of detection). No calls recorded within 10 mins (+/- 2 min) of civil twilight c. 17:55. Times highlighted in yellow are within 10 min (+/- 2 min) or occur after civil twilight at 06:14. Refer Table 6 for sunrise/sunset and civil twilight times.

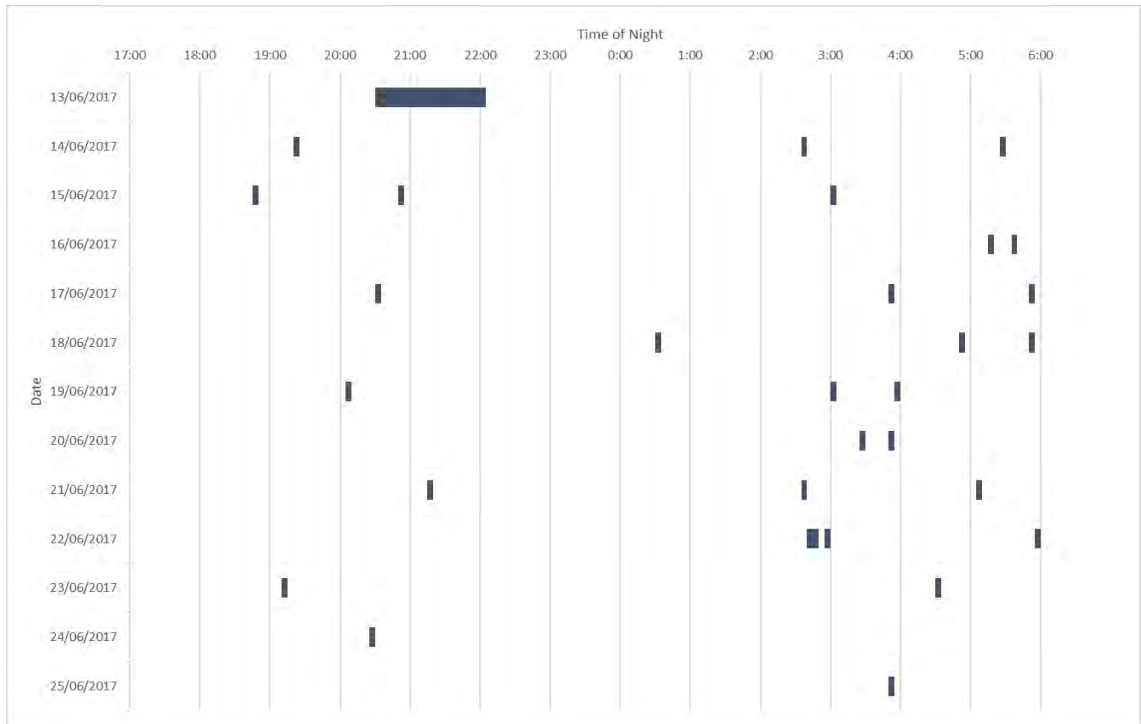


Figure 8 Nightly activity patterns for Tag 105

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Activity may consist of foraging, movement, resting or roosting. Civil twilight c. 17:55 and 06:14.

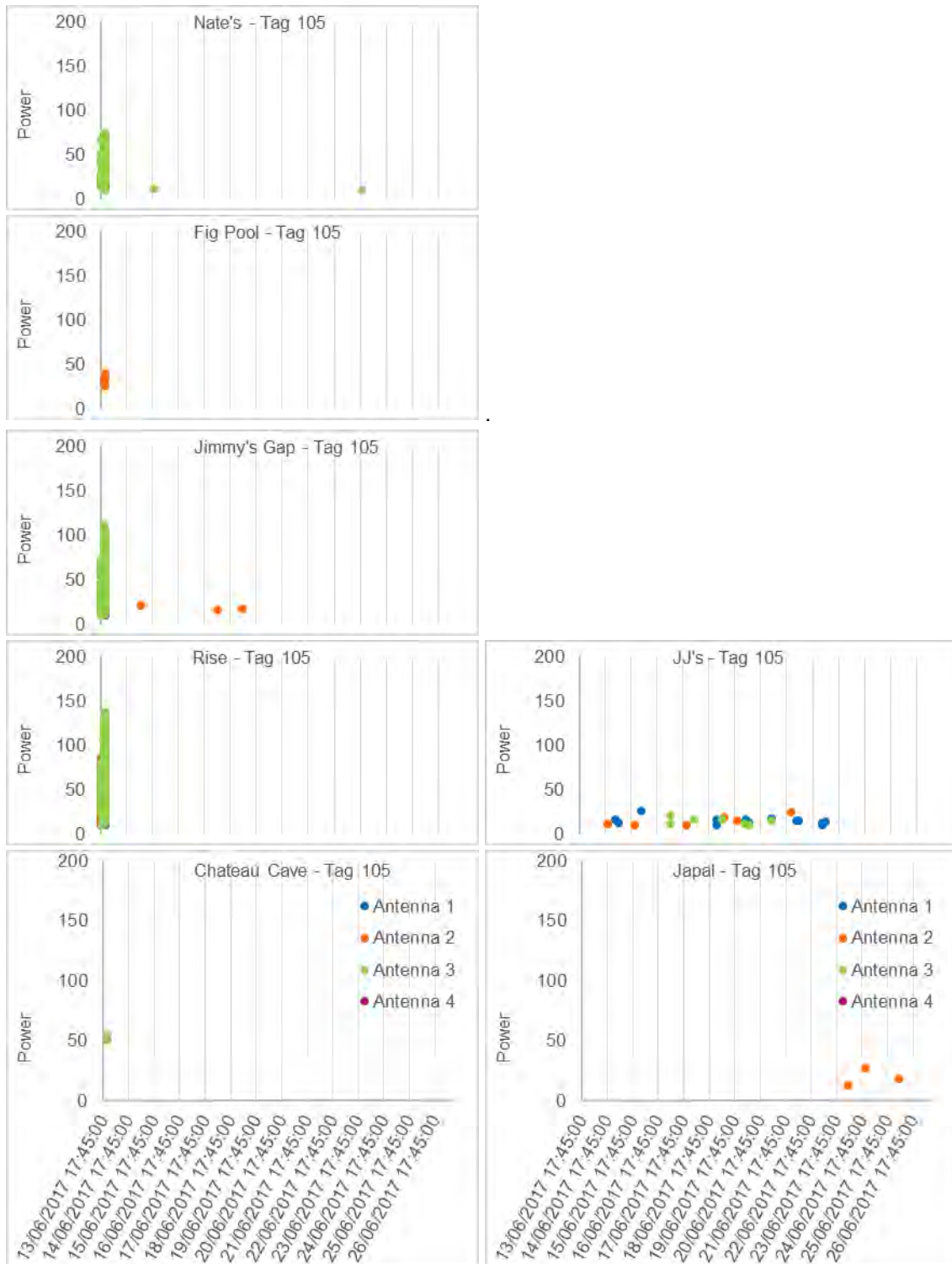


Figure 9 Base station detections for Tag 105 from the 13-26 June

Notes: No detection data for Joe's, Matt's, Mobile (Turkeys nest), or OPF base stations. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Chateau Cave (point of capture), then stacked from east to west (e.g. from Chateau Cave to JJ's BS) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.

### 3.2.1 Transmitter 106

Tag 106 was captured at Chateau Cave and released at 21:55, 13<sup>th</sup> June and was tracked for 10 nights using the base stations (Table 14 and Figure 10 and Figure 11). Tag 106 was also detected using hand-held receivers over the course of three nights (see Section 3.3.1, Table 19). Tag 106 was active for each of the 10 tracking nights, with detections recorded for both PM and AM periods for five of the tracking nights. The number and frequency of detections and the periods of constant activity (e.g. 15-30 mins) (Table 14) suggests the bat was active within the reception range of the receivers for a reasonable portion of the survey period.

#### *Timing of first and last detections each night*

For three (18-20 June) of the 10 nights Tag 106 was detected at Joe's Cave and Matt's BS (c. 1 km west of Joe's Cave BS) within 5 or 10 mins of civil twilight near sunset (Table 14). The detections at Joe's Cave BS for the three nights were approximately 1-2 mins earlier than the detections at Matt's BS. The majority of detections from Joe's Cave BS were from antenna 3 (orientated east), then antenna 1 (orientated north at Joe's Cave entrance), with some detection from antenna 2 (orientated west). All detections from Matt's BS were from antenna 1 (orientated north-east) (Table 14 and Figure 11). The number of consecutive nights (three), with detections of similar timing (+/- 5 mins), coupled with the signal strength and antenna orientation suggests that Tag 106 was roosting within or in close proximity to Joe's Cave (Table 14). It is worthwhile noting that the detections at JJ's BS were at least 15 mins past the first detection at Joe's or Matt's BS for each of the three nights indicating that Tag 106 regularly moved west, away from its potential roost location near Joe's Cave.

In addition to the early evening detections, a near sun rise detection within approximately 10 mins of civil twilight on the morning of the 23<sup>rd</sup> June was also detected at Joe's Cave and JJ's BS (both antenna 1 orientated north and north by north-west) (Table 14). Given the timing of the record, it is possible the bat was flying to, and possibly in close proximity to a diurnal roost.

#### *Activity and inferred movement*

Analysis of the detections for each night from the 13-23 June (Figure 10) indicates that Tag 106 was regularly active during the early evening between 18:00 and 19:00 for most nights, with most detections from the Joe's, Matt's and JJ's BS. Sporadic activity was recorded during the morning periods for seven nights, also from Joe's, Matt's and JJ's BS (Figure 10 and Figure 11).

Tag 106 was active in the area of Chateau Cave, Rise, Jimmy's Gap and east of Nate's Tower BS for a short period (c. 15 mins) from time of release on the 13<sup>th</sup> June at 21:55 to 22:10. From 22:11 to 01:05 there were no detections, suggesting that Tag 106 was active outside the zone of reception of the base stations (Figure 10 and Figure 11). Tag 106 was then detected again at Chateau Cave BS at 01:06, 14<sup>th</sup> June for a period of 4-5 mins. Tag 106 did not return to the Chateau Cave area (including Rise and Jimmy's Gap BS) during the period of the survey after the night of the 13-14 June (Figure 11).

A noticeable pattern of activity and movement for Tag 106 can be seen from a review of the detection data for the nights of the 13<sup>th</sup> and 14<sup>th</sup> June (Figure 11). Tag 106 has moved from the release point at Chateau Cave to the vicinity of Joe's Cave BS both nights. A subset of the data for the morning of 14<sup>th</sup> June was analysed to understand the movement of Tag 106 during this period (Figure 12). The timing of the detections across multiple BS (Rise, Jimmy's Gap then Nate's Tower BS) indicates Tag 106 moved from Chateau Cave to Joe's Cave, inferring an east to west pattern of movement. Tag 106 moved from Chateau Cave BS starting at approximately 01:06, 14<sup>th</sup> June (3 antenna including antenna orientated at entrance of Chateau Cave, P = 56 - 118), to Joe's Cave BS at approximately 01:44 am, 14<sup>th</sup> June. (2 detections, P = 72 and 99 both Antenna 1 – bearing 5 orientated at the entrance of Joe's Cave). The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km. The difference between the time of

departure for Chateau cave BS and time of arrival at Joe's Cave BS is approximately 38 mins. There is a small window of time where Tag 106 was not detected by a base station between Nate's Tower BS and Joe's Cave BS (c. 27 mins between 01:16 and 01:43 am). It is possible that Tag 106 passed through the area directly between the two base stations as both Japal and JJ's were not operating for the night of the 13-14 June. Tag 106 was also detected between c. 03:18 am and 03:33 am (a period of c.15 mins) on all three antenna at Joe's Cave BS (Figure 12).

Following the detections on the night of the 13-14 June Tag 106 was detected at Joe's Cave BS at approximately 18:47, 14<sup>th</sup> June (multiple detections antenna 3, P = 48-96, one detection antenna 1, P = 53) and at regular intervals each minute from 18:48-18:52. There were also multiple detections during the same period from JJ's BS (east). From the night of the 14-23 June Tag 106 was detected by Joe's and Matt's JJ's (Figure 11). Detections from this period suggest a general movement pattern from an area north of Matt's and Joe's Cave BS, probably in close proximity to the Joe's Cave/Zane's Gorge area (Figure 2) toward Joe's Cave where the bat appears to be active for short periods between 10-50 mins before moving out of the reception range of the base stations from approximately 19:00 through to 02:00-03:00 am in the morning where it is infrequently detected (Figure 10) by mostly antenna 1 (orientated north) and 3 (orientated west) on JJ's BS. Given the lack of detections from Mobile (Turkey nest) BS it is unlikely that the bat moved south of the Joe's Cave area during the survey for the period that this base station was operating.

Table 14 Summary of first and last detections each night June 2017 - Tag 106

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	13-14	21:55 (released)	Chateau Cave and Rise	03:33	Joe's
2	14-15	18:20* 18:40	Rise* Joe's	05:35	Jimmy's Gap
3	15-16	18:26	Matt's	04:36	JJ's and Joe's
4	16-17	18:12	Matt's	05:05	JJ's and Joe's
5	17-18	18:11	Matt's	22:15	Matt's
6	18-19	18:03-18:16 / 18:04-18:14 (consecutive minutes)	Joe's (A 1, 2 and 3, P=26 – 103, >50% detections A3) / Matt's (A1, P=67-91)	04:19	JJ's and Joe's
7	19-20	17:57-18:52 / 17:59-18:23 (consecutive minutes)	Joe's (A 1 and 3, P=31-101, >80% detections A3) / Matt's (A 1, P= 77-91)	18:52	Matt's
8	20-21	18:00-18:27 / 18:02-18:16 (consecutive minutes)	Joe's (A 1 and 3, P=51-102, >90% detections A3) / Matt's (A 1, P=18-90)	21:02	JJ's and Joe's
9	21-22	02:55	JJ's and Joe's	05:36	JJ's and Joe's
10	22-23	-	-	06:02	JJ's and Joe's both A-1, P-14

Table notes: A = antenna number. P = power (signal strength of detection). Times highlighted in green are within 5 mins (+/- 2 min) of civil twilight c. 17:55, with a theoretical flight distance of c. of up to 1.8 km. Times highlighted in blue are within 5-10 mins (+/- 2 min) of civil twilight c. 17:55, with a theoretical flight distance of up to c. 3.6 km. Times highlighted in yellow are within 10 min (+/- 2 min) or occur after civil twilight 06:14, with a theoretical flight distance of up to c. 3.6 km. Refer Table 6 for sunrise/sunset and civil twilight times.

\* indicates dubious data: Tag 106 was detected at Rise BS at 18:20 (single detection antenna 3, P = 59) then Chateau Cave BS at 18:47:24 (single detection antenna 1, P = 142) early the evening of the 14th June. Tag 106 was also detected at Joe's Cave BS between 18:47:01 and 18:47:55 (multiple detections antenna 3, P = 48-96, one detection antenna 1, P = 53) and at regular intervals each minute from 18:48-18:52. Given the multiple consistent detections from Joe's Cave BS and nearby JJ's and Matt's BS it has been assumed that the detections for the same period at Chateau Cave and Rise BS are dubious and should be disregarded.

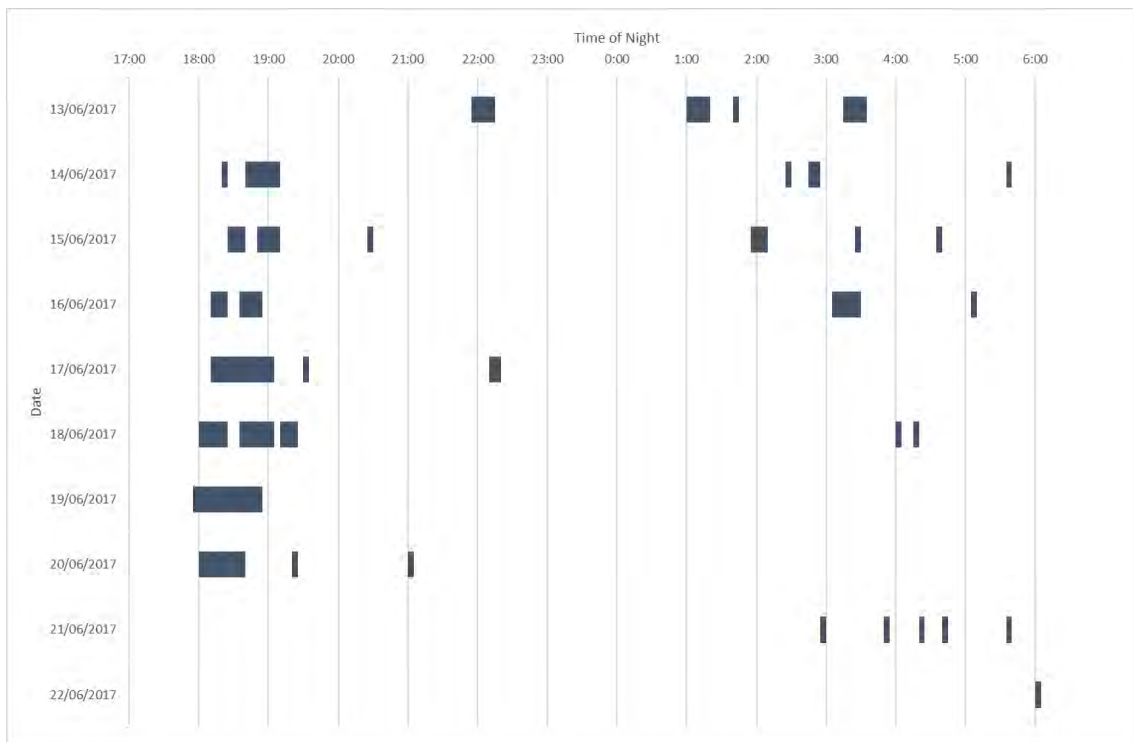


Figure 10 Nightly activity patterns for Tag 106

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Civil twilight c. 17:55 and 06:14.

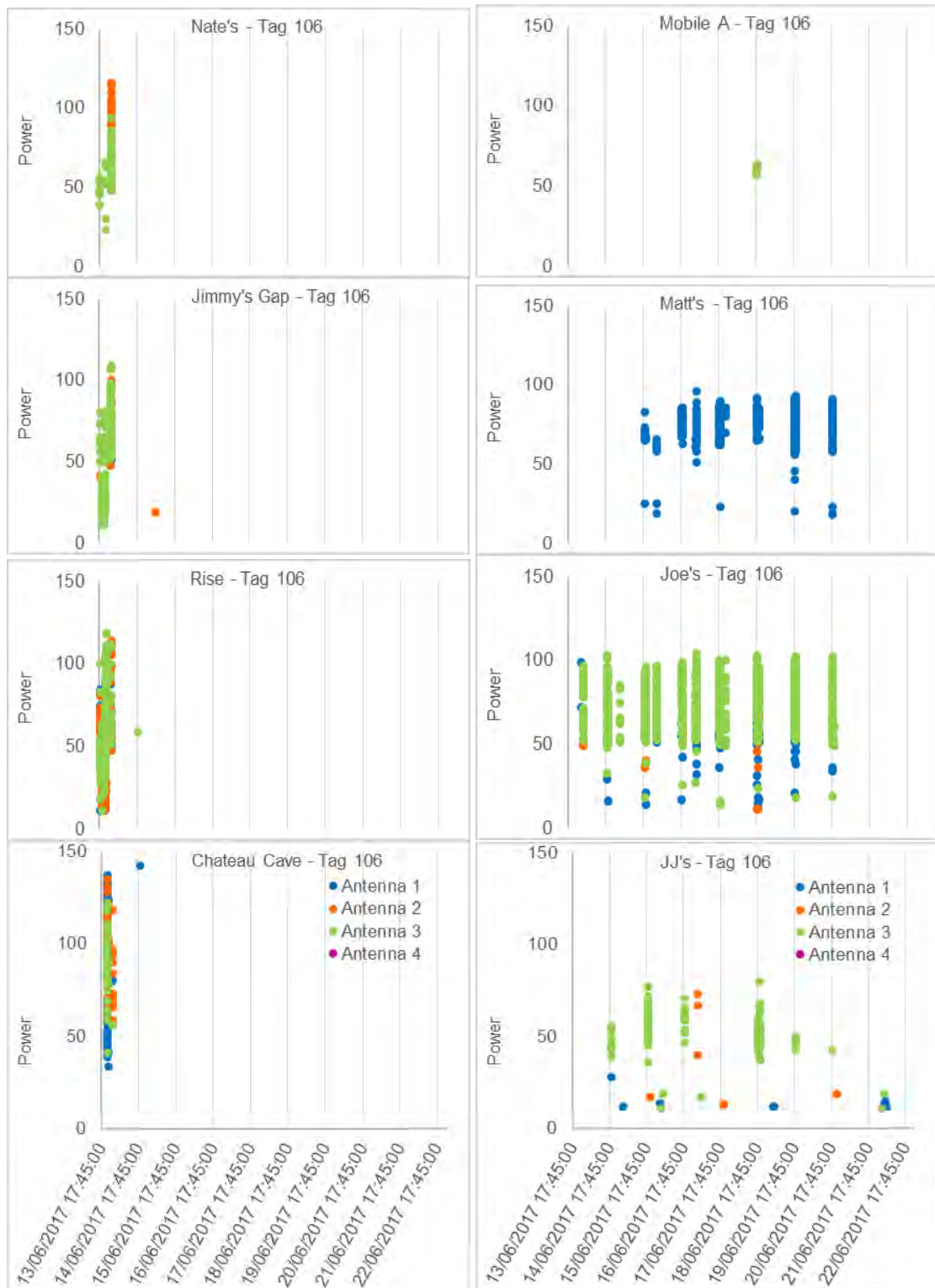


Figure 11 Base station detections for Tag 106 from the 13-26 June

No data recorded for Tag 106 from Fig Pool, Japal or OPF BS. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Chateau Cave (point of capture), then stacked from east to west (e.g. from Chateau Cave to Matt's BS) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.



Figure 12 Tag 106 - Inferred pattern of movement (AM period) from c. 01:00 to 04:00, 14 June

Inferred movement over time (east to west) from Chateau Cave BS starting at c. 01:06, 14/6, to Joe's Cave BS at c. 01:44 am, 14/6. The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km. The difference between the time of departure for Chateau cave BS and time of arrival at Joe's Cave BS is c. 38 mins. Tag 106 was also detected again between c. 03:18 am and 03:33 am (a period of c.15 mins) on all three antenna at Joe's Cave BS.

### 3.2.1 Transmitter 107

Tag 107 was captured at Chateau Cave and released at 19:10, 14<sup>th</sup> June, then tracked for 13 nights by the base stations (Figure 13 and Figure 14). No detections were recorded for the night of the 16-17 June, however Tag 107 was detected for a portion of each of the 12 nights, although detections for both PM and AM periods were recorded for only three nights (Table 15). This information indicates Tag 107 was active outside the reception range of the receivers for the majority of the survey period, in particular for the later part of the PM period and the AM period for most of the survey nights.

#### *Timing of first and last detections each night*

Tag 107 was not detected by any of the base stations within a time close to civil twilight. The earliest detections occurred at 18:28 and 05:10 at the OPF BS. Few detections occurred within 30 mins of civil twilight and the majority of the first and last detections were at OPF BS (Table 15). This base station was located on top of the plateau near the ore processing facility (Figure 3, Plate 7).

#### *Activity and inferred movement*

Analysis of the detections for each night from the 14-26 June (Figure 13 and Figure 14) indicates that Tag 107 was active (albeit sporadic and in short burst) during the first 2-3 hours of the night (18:30-21:30) for most tracking nights (n=8) with the exception of the night of release. Many of the nights failed to record detections during the AM period (n=7) suggesting that Tag 107 was active outside the range of reception for these nights during the AM period. During the night of the 14<sup>th</sup> June following its release Tag 107 was active for an extended period in the Chateau Cave area. Tag 107 was detected across multiple antenna on multiple base stations (Chateau Cave, Rise, Jimmy's Gap and Nate's Tower BS) for a period of approximately 3 hours (Figure 14). It is worth noting that the majority of detections with the greatest signal strength on Nate's Tower BS were from the antenna orientated east (toward Chateau Cave) and north-east (toward Jimmy's Gap) during this period. After this large period of activity Tag 107 was absent from the reception range of the base station array until near 04:00 am on the 15<sup>th</sup> June when it was again detected by Rise and Jimmy's Gap BS (Figure 14).

From the 18<sup>th</sup> June for the remainder of the survey period Tag 107 was most notably active in the range of reception of the OPF BS (Figure 14). During this period first and last detections for each night were mostly recorded by the OPF BS. For example on the night of the 19-20 June, the first detection was at 18:28 by OPF BS on antenna 1 and 2 (orientated north and north by north-west) for a period of approximately 6 mins (18:28-18:34, P= 19-38). Next detections were also by OPF on antenna 1 and 2 for a period of approximately 13 mins (20:10-20:23, P = 19-66) including three detections by Nate's Tower on antenna 2 (orientated north, P = 19-24). Final detection for the night of the 19-20 June was by OPF BS at 20:11, approximately 1 hour, 40 mins from the first detection. This pattern of activity suggest Tag 107 was active outside the reception range of the base stations for the majority of the survey period.

A subset of data for the night of the 22-23 June was analysed to understand nightly movement patterns (Figure 15). Tag 107 was first detected by the OPF BS on the night of the 22<sup>nd</sup> June at approximately 18:41 on antenna 1 and 2 (north and north by north-west). Apart from a short activity bout at near 21:00 (Table 15), it was next detected by multiple antenna from the OPF BS at approximately 03:13, 23<sup>rd</sup> June and was active within the range of the OPF BS for approximately 15 minutes (including being detected by all four antenna for a period of 2-3 minutes). From approximately 03:32 it was occasional detected by antenna 3 (orientated west/south-west) for a period of approximately 45 minutes. From reviewing the detections it appears that Tag 107 originated from the area north-west of the OPF BS. It has then passed

through the reception range of the OPF BS being detected by all four antenna over a period of 2-3 minutes, before moving south-west of the OPF BS.

Tag 107 was next detected almost simultaneously by Jimmy's and Nate's Tower BS at approximately 04:32. Between 04:34 and 04:44 it was detected at multiple BS including Jimmy's Gap, Nate's, Rise, Chateau Cave, Fig Pool and JJ's. The absence of detections from the OPF BS during this period indicates Tag 107 had moved outside of the reception range of the OPF BS. Tag 107 was not detected by any base station for a period of approximately 5 minutes from 04:45 onwards, indicating that it had moved outside the range of reception of the base stations or was active in a blind spot within the base station array reception range. Tag 107 was then detected by antenna 3 (orientated west/south-west) at OPF BS, then all four antenna for a period of approximately 5 minutes from 04:51. The final detections for the morning of the 23<sup>rd</sup> June were from antenna 1 and 2 (north and north/north-west) OPF BS at 05:11 (Figure 15), suggesting that Tag 107 used a similar flight route to return to its point of origin, which is probably in the area north-west outside the reception range of the OPF BS.

Table 15 Summary of first and last detections each night June 2017 - Tag 107

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	14-15	19:10 (released)	Chateau Cave and Rise	04:06	Jimmy's
2	15-16	19:15*	JJ's*	-	-
3	16-17	-	-	-	-
4	17-18	18:34	Nate's	19:41	Nate's
5	18-19	18:26	OPF	20:11	OPF
6	19-20	18:28	OPF	20:23	OPF
7	20-21	18:40	OPF	20:15	OPF
8	21-22	19:28	OPF	-	-
9	22-23	18:41	OPF	05:11	OPF
10	23-24	18:45	OPF	20:41	OPF
11	24-25	02:28	OPF	03:50	OPF
12	25-26	23:27	OPF	03:16* 00:47	Japal* OPF
13	26-27	02:46	OPF	03:10	OPF

Table notes: \* indicates dubious data. No calls recorded within 10 mins of civil twilight (set) or civil twilight (rise)

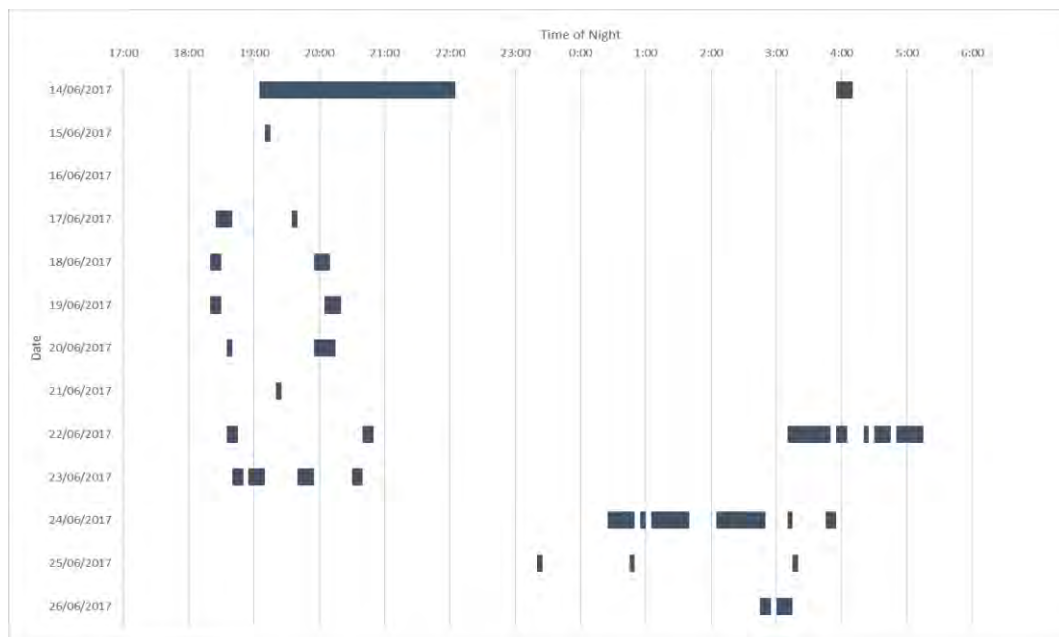


Figure 13 Nightly activity patterns for Tag 107

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Civil twilight c. 17:55 and 06:14.

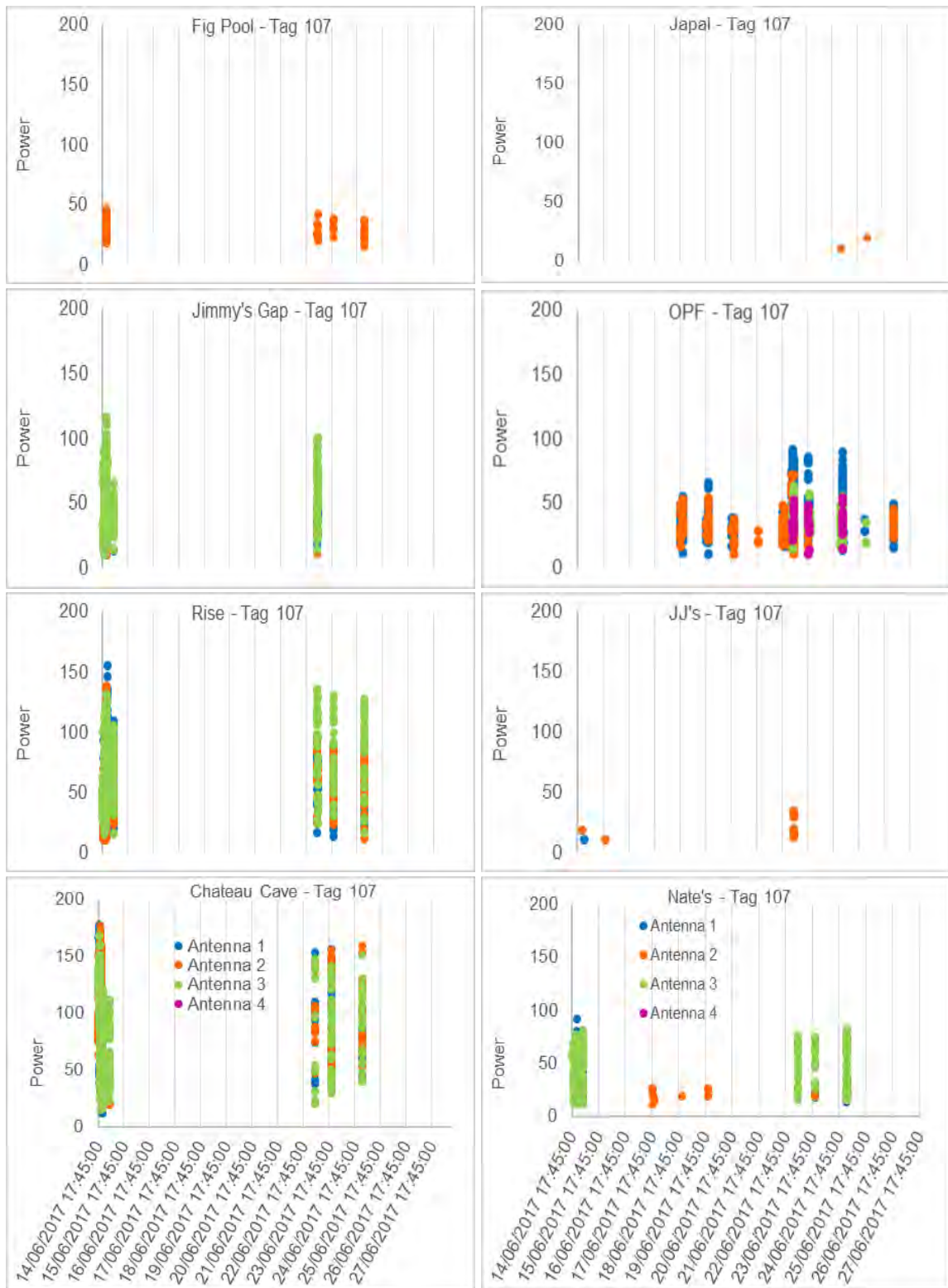


Figure 14 Base station detections for Tag 107 from the 14-27 June

NOTE no data for Joe's, Matt's or Mobile (Turkey nest) base stations for 107. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Chateau Cave (point of capture), then from east to west (e.g. from Chateau Cave to JJ's BS) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.

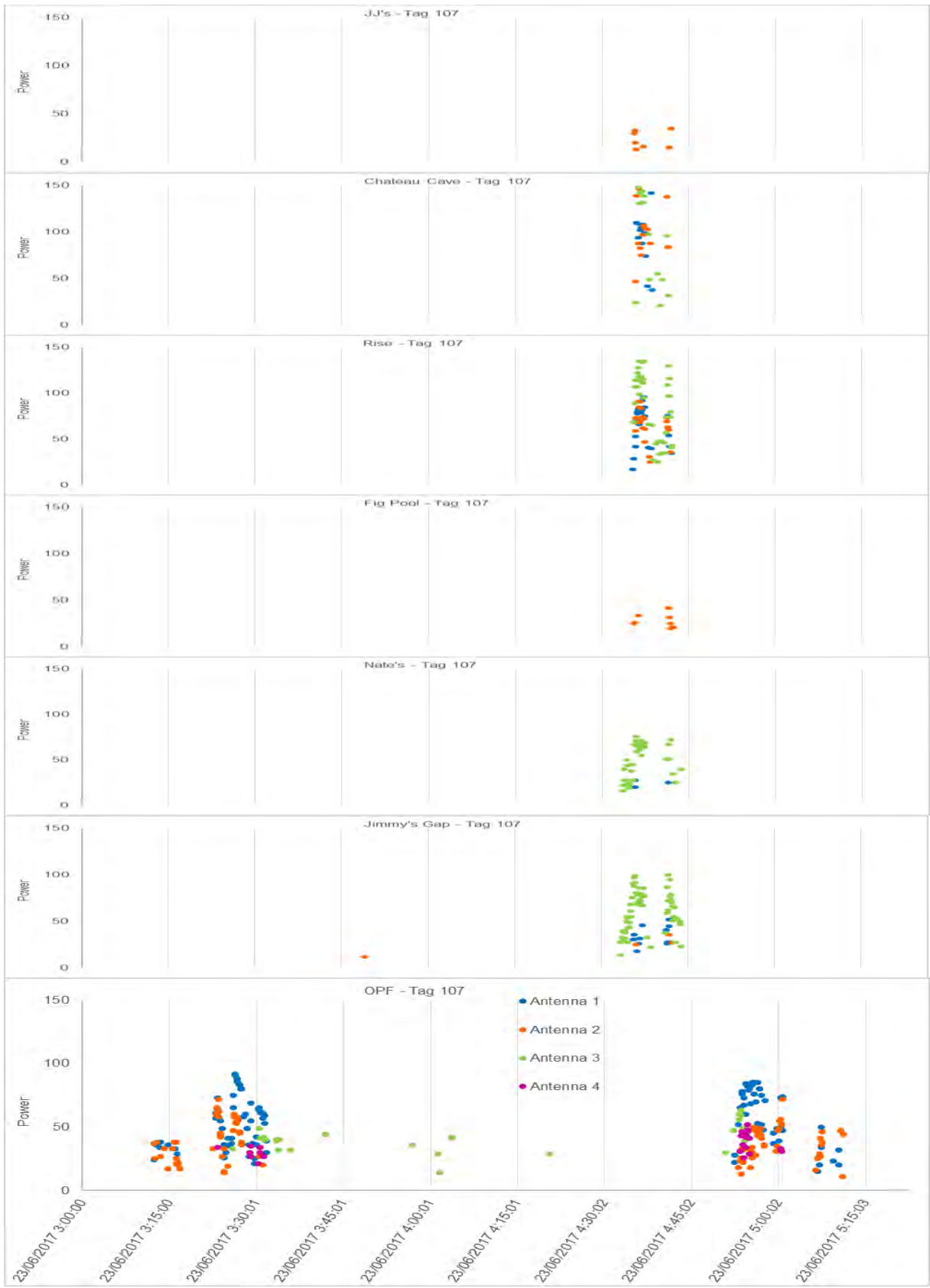


Figure 15 Base station detections for Tag 107 from the c. 03:00 to 05:15 AM, 23<sup>rd</sup> June

### 3.2.2 Transmitter 108

It was difficult to analyse movement and activity for Tag 108 as few and infrequent detections were recorded by only five of the base stations (Figure 16 and Figure 17). No detections were recorded for six of the 12 tracking nights (Table 16 and Figure 16). Activity consisted of a few short sporadic bursts with few detections. The majority of activity occurred within the first hour of release. The lack of and random frequency of detections suggests this bat was most active outside the reception range of the receivers for the majority of the survey period (Figure 16 and Figure 17).

Table 16 Summary of first and last detections each night June 2017 - Tag 108

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	14-15	20:10 (released)	Chateau Cave, Rise & Jimmy's Gap	20:49	Jimmy's Gap
2	15-16	-	-	-	-
3	16-17	-	-	04:57	JJ's
4	17-18	-	-	-	-
5	18-19	-	-	04:55	JJ's
6	19-20	-	-	-	-
7	20-21	18:45	JJ's	02:45	JJ's
8	21-22	-	-	-	-
9	22-23	01:49		05:32	JJ's
10	23-24	-	-	-	-
11	24-25	-	-	-	-
12	25-26	20:33	Nate's	-	-

Table notes: No calls recorded within close proximity of civil twilight.

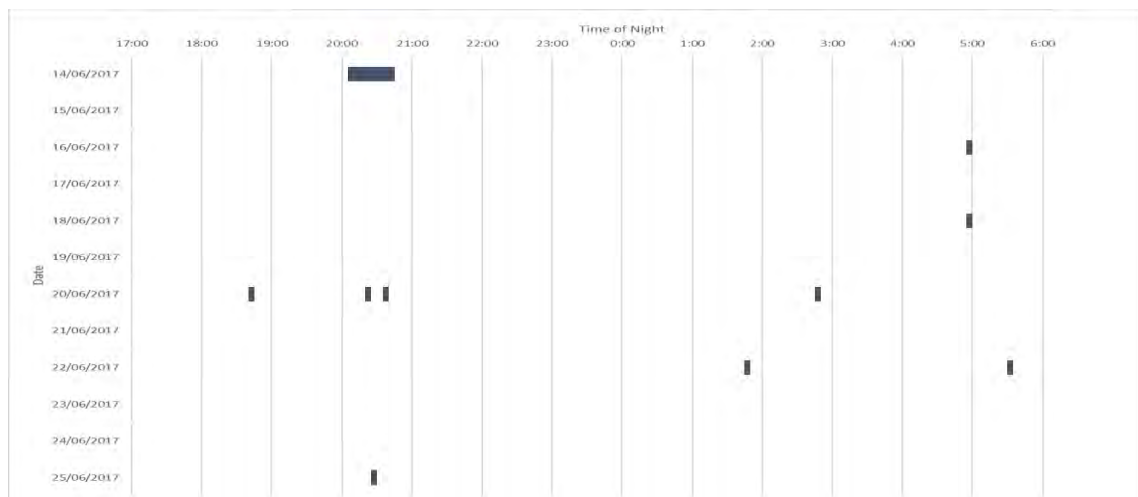


Figure 16 Nightly activity patterns for Tag 108

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Civil twilight c. 17:55 and 06:14.



Figure 17 Base station detections for Tag 108 from the 14-24 June

Note no data for Fig Pool, Japal, Joe's, Matt's, Mobile (Turkey nest) or OPF base stations for 108. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Chateau Cave (point of capture), then stacked from east to west (e.g. from Chateau Cave to JJ's BS) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations

### 3.2.3 Transmitter 109

Tag 109 was captured at Joe's Cave and released at 19:25, 20<sup>th</sup> June and was tracked for seven consecutive nights by 10 base stations up to the completion of the surveys on the 27<sup>th</sup> June (Figure 18 and Figure 19). Tag 109 was also detected (single detection) using a hand-held receiver (see Section 3.3.1, Table 19). More detections and periods of consistent activity and a greater number of nightly movements were recorded for Tag 109 compared to any other tagged PLNB. Detections and periods of consistent activity were regularly recorded each night and during the PM and AM periods for six nights (Table 17). The number and frequency of these detections and the frequent periods of consistent activity (e.g. 15-30 mins and greater) (Figure 18) suggests that the bat was active within the reception range of the receivers for large portion of the survey period.

#### *Timing of first and last detections each night*

Tag 109 was not detected by any of the base stations at a time close civil twilight. The earliest detection occurred at 18:42, 21<sup>st</sup> June at JJ's and Joe's BS. The closest detection to civil twilight was at 04:35, 25<sup>th</sup> June at Nate's Tower BS. No detections occurred within 30 mins of civil twilight (Table 17). The majority of the first and last detections were from Nate's, then Joe's BS.

#### *Activity and inferred movement*

Analysis of the detections for each night from the 20-26 June indicates Tag 109 was frequently active throughout the night with most activity for the majority of the nights occurring during the latter part of the evening, through the middle of the night into the early morning (Figure 18 and Figure 19).

Following its release, Tag 109 was active in the area of Joe's Cave until approximately 01:00 on the morning of the 21<sup>st</sup> June. The next detection was the evening of the 21<sup>st</sup> June at JJ's and Joes' Cave BS at 18:42 (Table 17 and Figure 19). For the next five nights Tag 109 regularly moved between the Joe's Cave area and the Chateau Cave area. Figure 20 displays the nightly movement patterns between Joe's Cave BS and Chateau Cave BS. Each of the red boxes outlines one of the five nightly movements undertaken by Tag 109 between the Joe's Cave and Chateau Cave areas. Some movements are one way (e.g. the night of the 21-22 June Tag 109 moved from Joe's Cave to Chateau Cave area but was not detected returning to the Joe's Cave area), whereas other nights included multiple movements in both directions (e.g. nights 22-23, 23-24, and 24-25 June). The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km, therefore for those nights where multiple movements were undertaken between the Joe's Cave and Chateau Cave areas (vice versa) the estimated straight line distance travelled would have exceeded 16 km for each of those nights. This estimate does not consider, foraging and roosting events during the course of the night.

A subset of the data for the nights of the 21-22 and 23-24 June was analysed to further understand activity and movement for Tag 109.

- 21-22 June - following a period of activity in the Joe's Cave area (c. 20 mins from 19:42 – 20:02) Tag 109 was next detected at Nate's Tower BS at 20:10 over the course of approximately 3 mins (20:10-20:14, antenna 1 orientated south-east and antenna 2 orientated north) (Figure 20). The next detection was at Rise BS at 20:14 (all antenna), then Chateau Cave BS (all antenna) at 20:15. The estimated time taken to move between the Joe's Cave and Chateau Cave areas was 13 mins. It remained in the Chateau Cave area for approximately 42 mins being detected multiple times by multiple antenna on Chateau Cave, Jimmy's Gap and Rise BS before broadening its activity area to include Nate's Tower BS range of reception (antenna 1 orientated south-east

and 3 orientated east) from 20:18-20:57. From 20:57-21:00 (c. 4 mins) Tag 109 was detected exclusively by antenna 3 (orientated west), Chateau Cave BS.

- 23-24 June - between 20:00-23:50 (Figure 21) Tag 109 moved from Nate's, Chateau Cave, and Rise BS starting at c. 20:44, to Joe's Cave and Matt's BS at approximately 21:02. The difference between the time of departure for Chateau cave BS and time of arrival at Joe's Cave BS was approximately 18 mins. Tag 109 also returned to the Chateau Cave area, starting at Joe's Cave BS (all detections on antenna orientated north by north-east) at approximately 01:36, 24/6, then Mobile (Turkey nest) BS at c. 03:27, 24<sup>th</sup> June (all detections on antenna orientated north), then Nates Tower BS (multiple detections on all antenna) at 03:54, 24<sup>th</sup> June, Rise BS (predominantly antenna 2 orientated north) and Chateau Cave BS (antenna 2 orientated at the cave entrance) at approximately 03:55, 24<sup>th</sup> June (Figure 22). The difference between the time of departure from Joe's cave BS and time of arrival at Chateau Cave BS was approximately 2 hours 19 mins. The final detection was recorded approximately 10 minutes later from Nate's Tower BS at 04:06 on antenna 3 (orientated east).

Table 17 Summary of first and last detections each night June 2017 - Tag 109

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	20-21	19:25 (released)	Joe's and Matt's	01:01	Joe's
2	21-22	18:42	JJ's and Joe's	20:18	Rise
3	22-23	20:43	Nate's	04:04	Nate's
4	23-24	20:44	Nate's	04:06	Nate's
5	24-25	22:09	Japal	04:35	Nate's
6	25-26	21:04	Nate's	03:30	Joe's
7	26-27	18:57	Japal	02:01	Joe's

Table notes: No calls recorded within 10 mins of civil twilight.

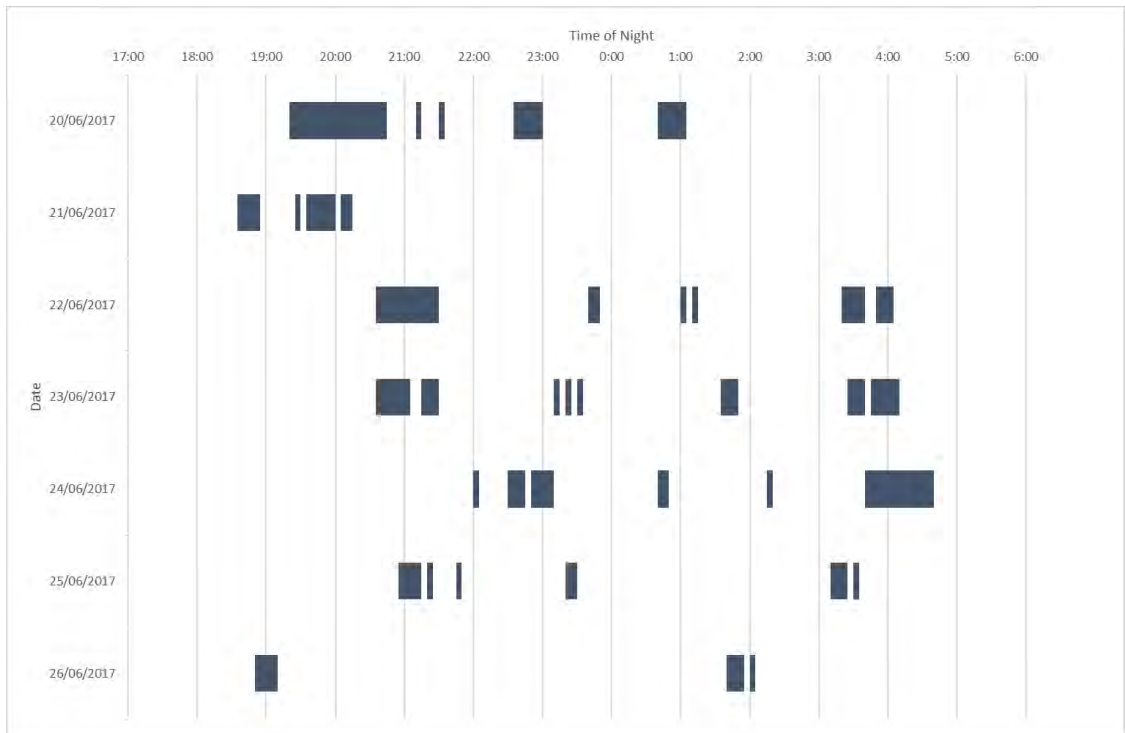


Figure 18 Nightly activity patterns for Tag 109

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Civil twilight c. 17:55 and 06:14.

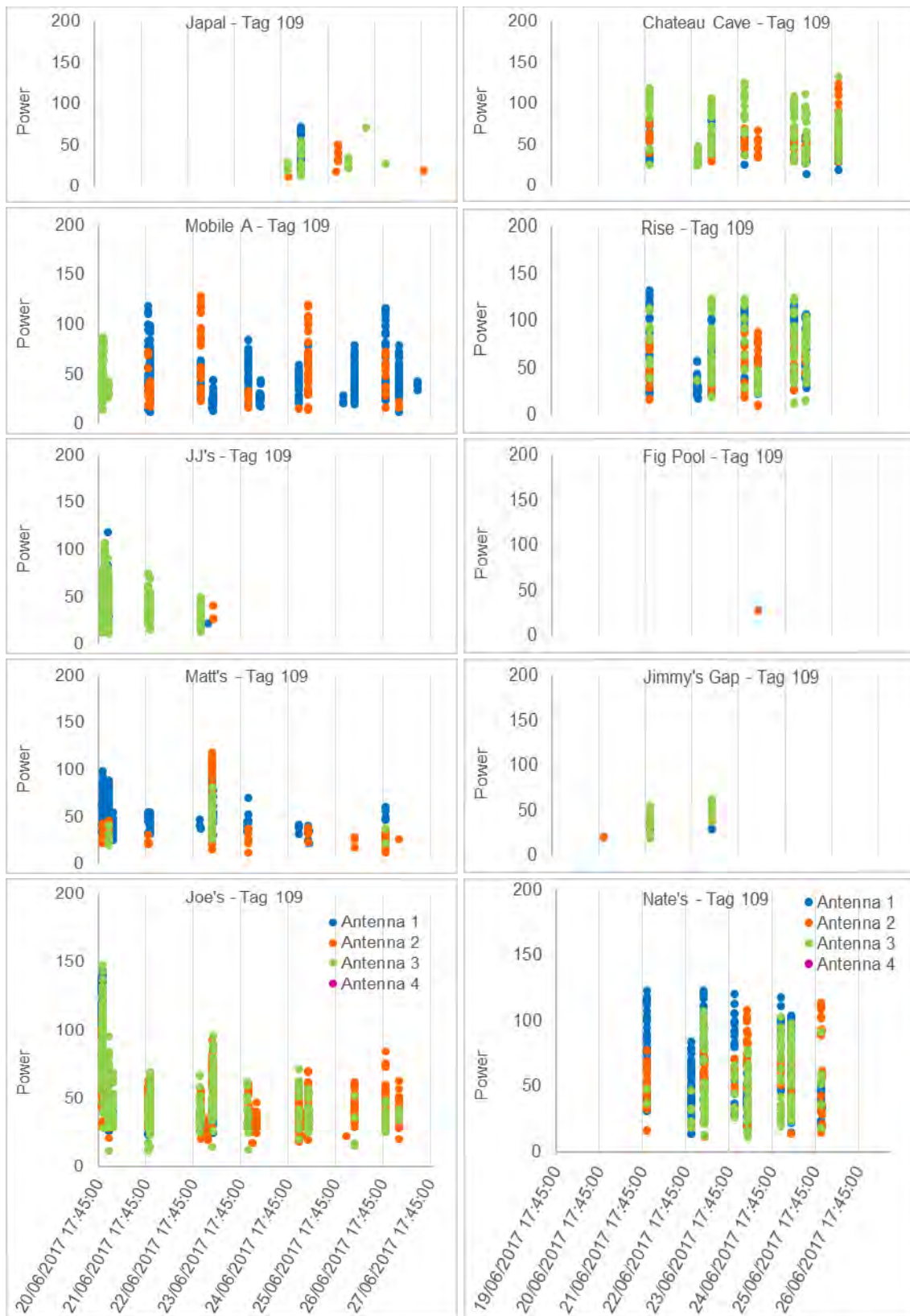


Figure 19 Base station detections for Tag 109 from the 20-27 June

NOTE no data for OPF base stations for 109. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Joe's Cave (point of capture), then stacked from west to east (e.g. from Joe's Cave to Chateau Cave) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.

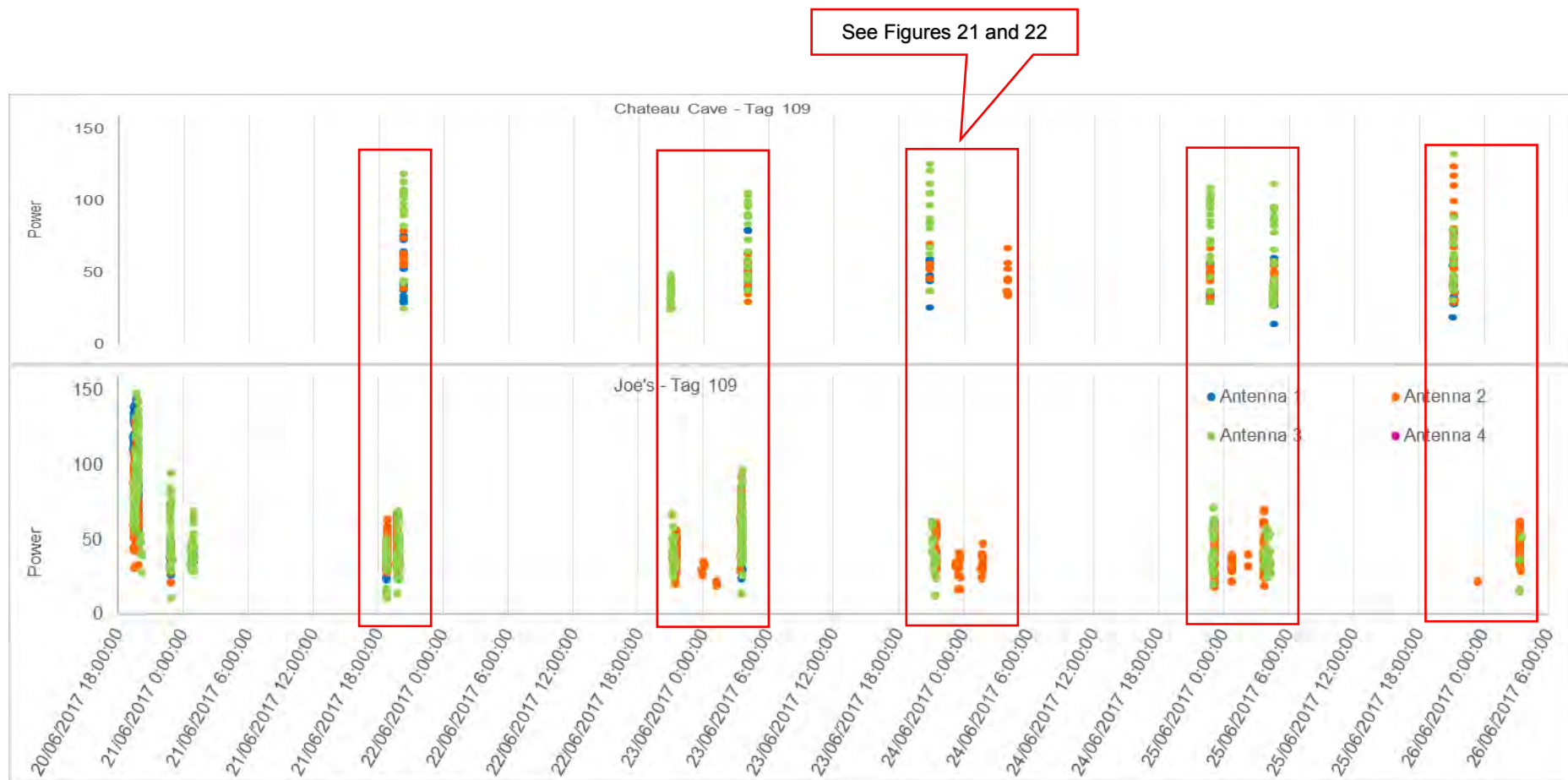


Figure 20 Base station detections Joe's Cave and Chateau Cave for Tag 109 from the 20-26 June

Each of the red boxes outlines one of the five nightly movements between the Joe's Cave and Chateau Cave areas for Tag 109. Some movements are one way (e.g. the night of the 21-22 Tag 109 moved from Joe's Cave to Chateau Cave area but did not return to the Joe's Cave area), where as other nights included multiple movements in both directions (e.g. nights 22-23, 23-24, and 24-25 June). The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km, therefore for those nights where Tag 109 made multiple movements between the Joe's Cave and Chateau Cave areas (vice versa) the estimated straight line distance travelled would have exceeded 16 km for each of those nights. This estimate does not consider all commuting events or foraging and roosting events during the course of the night.

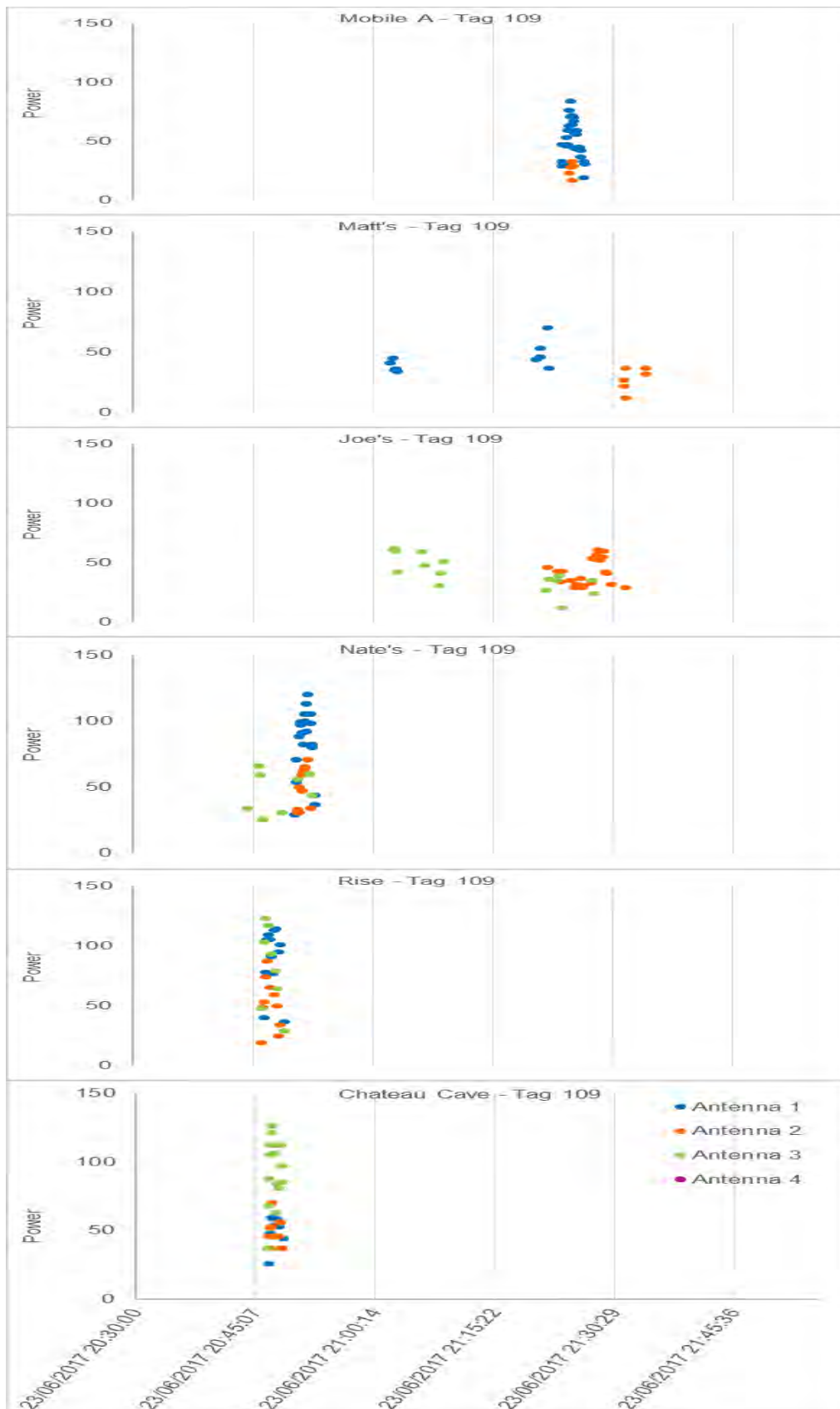


Figure 21 Base station detections Tag 109 (PM period) from 20:30-22:00, 23<sup>rd</sup> June

The scatterplot indicates the inferred movement over time is from east to west - from Nate's, Chateau Cave, and Rise BS starting at c. 20:44, to Joe's Cave and Matt's BS at c. 21:02. The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km. The difference between the time of departure for Chateau cave BS and time of arrival at Joe's Cave BS is c. 18 mins. Note: no detections recorded by OPF, JJ's, or Fig Pool for this period.

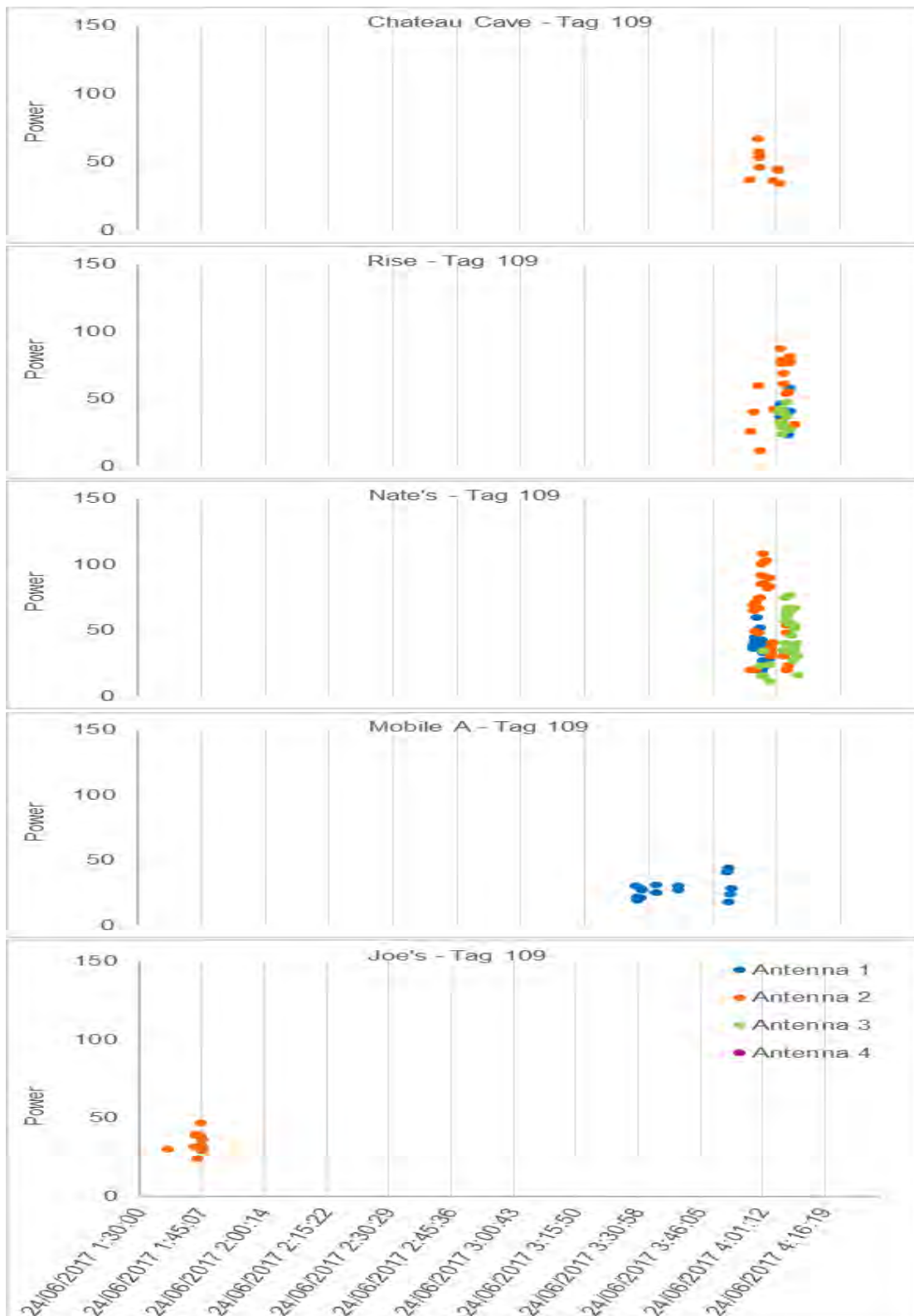


Figure 22 Base station detections Tag 109 (AM period) from 01:30 to 04:30 24 June

The scatterplot indicates the inferred movement over time is from west to east - from Joe's Cave BS to Chateau Cave BS. Starting at Joe's Cave (all detections on antenna orientated north by north-east) at c. 01:36, then Mobile (Turkey nest) BS at c. 03:27 (all detections on antenna orientated north), then Nates Tower BS (multiple detections on all antenna) at 03:54, to Rise BS (predominantly antenna 2 orientated north) and Chateau Cave BS (antenna 2 orientated at the cave entrance) at c. 03:55. The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km. The difference between the time of departure from Joe's cave BS and time of arrival at Chateau Cave BS was c. 2 hours 19 mins. Note: no detections recorded by OPF, JJ's, Japal or Fig Pool BS for this period.

### 3.2.4 Transmitter 110

Tag 110 was captured at Joe's Cave and released at 19:53, 20<sup>th</sup> June and was tracked for seven nights by the base stations (Table 18 and Figure 23 and Figure 24). Detections were recorded for each of the seven tracking nights, however the majority of activity consisted of short sporadic bursts (Figure 23). The lack of and random frequency of detections suggests that the bat was most active outside the reception range of the receivers for the majority of the survey period (Figure 23 and Figure 24), although it is possible that some of the bat activity could occur within 'blind spots' of the base station array. Many of the first and last detections recorded were isolated (e.g. no other detections were recorded within 30 minutes by the same or nearby base stations) and of low signal strength ( $P < 30$ ), making inferences difficult. Also, as Japal BS was deployed at a later period data may have been missed from this area for the three of the seven tracking nights.

During the night of the 20-21 June the majority of activity was in the Joes' Cave area and nearby base stations. However, over the course of the night Tag 110 moved beyond the reception range of the receivers. Apart from a couple of isolated detections, from Joe's Cave and Jimmy's Gap BS, there were no other detections for the remainder of the night of the 20-21, suggesting Tag 110 moved away from the Joe's Cave area outside the reception range for the majority of the night (Figure 24 and Figure 25). The final (single) detection for the night was at Jimmy's Gap BS at 5:02 am (antenna 3 orientated north-west) (Figure 25 and Table 18).

The next detection was at 19:16 on the night of the 21-22 June at Nate's Tower followed by multiple detections at Jimmy's Gap, Rise and Chateau BS (Figure 25). During a 4 min period many of the detections were recorded on each consecutive minute by two or three of the base stations, suggesting that Tag 110 was active in the area where the reception range for each base station overlapped. Tag 110 then moved out of the reception range of the base station array for most of the night until a single detection at 05:05, 22<sup>nd</sup> June by JJ's BS (Figure 24).

From the 23<sup>rd</sup> of June activity was recorded by Japal BS, apart from two isolated detections at the OPF and Nate's Tower BS. Two detections were recorded approximately 10 mins after civil twilight at Japal BS (Table 18) for the 24<sup>th</sup> and 25<sup>th</sup> June. Both records were from antenna 2 (orientation, south-west). Given the similar timing of the records (within 10 mins of civil twilight) over consecutive nights, it is possible that the bat was on route to a roost site in the vicinity of the Joe's Cave/Zane's Gorge area. It is important to highlight the lack of other detection data from other antenna from Japal BS and from other base stations within close proximity for this period of the detections. Furthermore there is an absence of any obvious cave habitats (i.e. low ranges) in the general area of the detections.

Table 18 Summary of first and last detections each night June 2017 - Tag 110

Tag night	Date	Time first detection	Base station	Time last detection	Base station
1	20-21	19:53 (released)	Joe's	05:02*	Jimmy's Gap*
2	21-22	19:16	Nate's	05:05	JJ's
3	22-23	01:25	JJ's	05:35	JJ's
4	23-24	21:58*	OPF*	06:12	Japal (A-2, P-19)
5	24-25	19:30*	Nate's*	06:07	Japal (A-2, P-12)
6	25-26	19:35	Japal	07:40*	Japal (A-3, P-45)*
7	26-27	-	-	05:10	Japal

Table notes: \* indicates possible dubious data. There are no detections within 15 mins of this detection or from nearby BS and/or the timing of the record is in daylight. No calls recorded within 10 mins (+/- 2 min) of civil twilight c. 17:55. Times highlighted in yellow are within 10 min (+/- 2 min) or occur after civil twilight 06:14, with a theoretical flight distance of up to c. 3.6 km. Refer Table 6 for sunrise/sunset and civil twilight times.

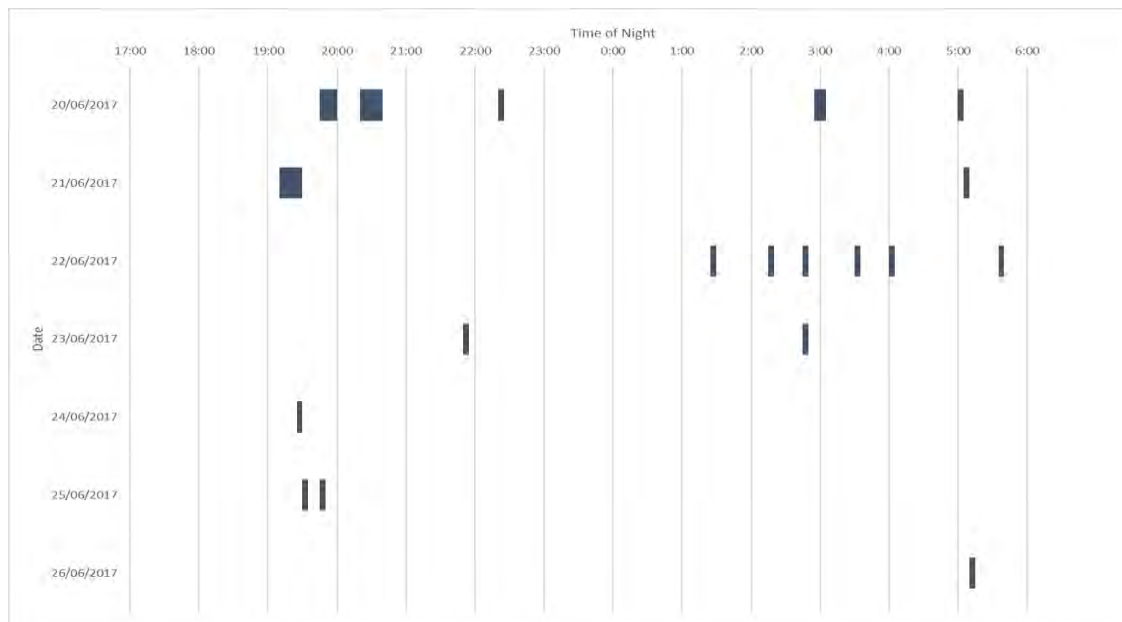


Figure 23 Nightly activity patterns for Tag 110

Bars indicate c. start, duration and end of each activity period for each survey night. Each activity period consists of all detections for all base stations combined. Civil twilight c. 17:55 and 06:14.

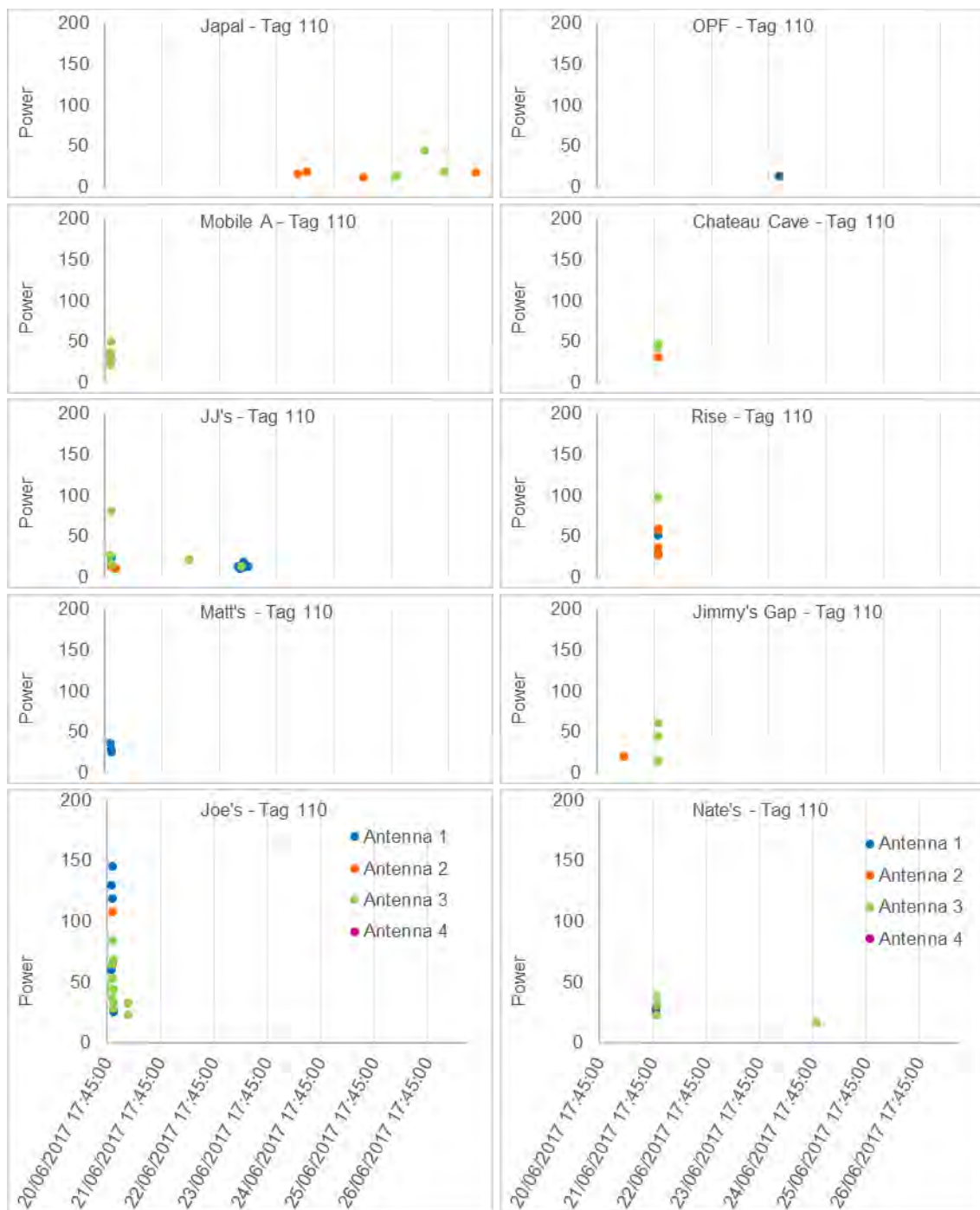


Figure 24 Base station detections for Tag 110 from the 20-27 June

Note no data for Fig Pool base station for 110. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Joe's Cave (point of capture), then stacked from west to east (e.g. from Joe's Cave to OPF BS) to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.

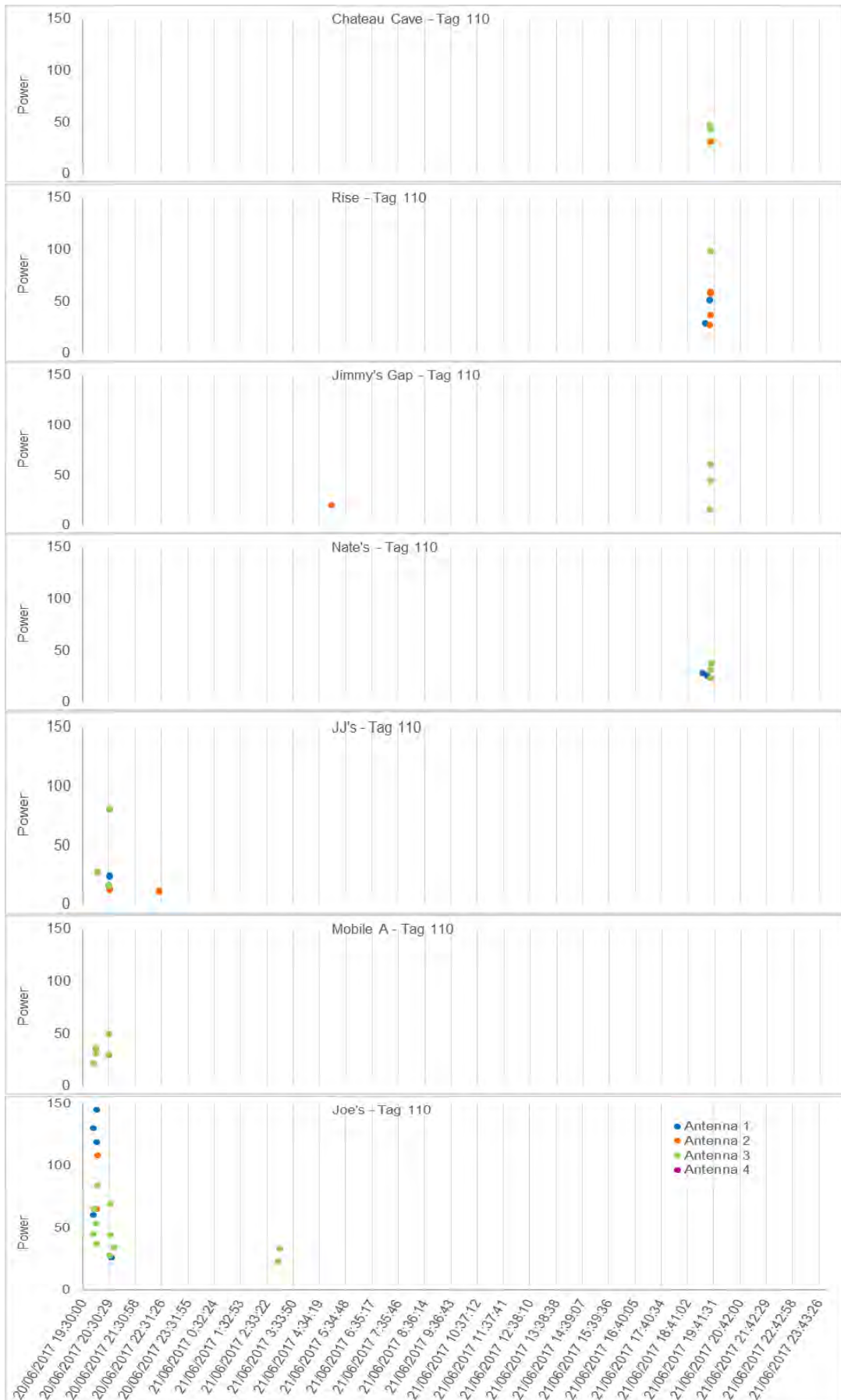


Figure 25 Base station detections for Tag 110 from 20-21 June

### 3.3 Manual tracking data

Manual radio tracking using hand held receivers was also undertaken from between the 14-25 June including six day-time searches for diurnal roosts and tags and eight night-time searches to track foraging and commuting activity of tagged bats. Table 5 summarises the survey effort and Figure 4 displays the approximate route of the manual radio-tracking searches.

#### 3.3.1 Detections of tagged bats

Twenty-four detections were recorded for Tag 106 and one detection was recorded for Tag 109. No other detections were recorded during the survey period using this method. In addition to the detection data, a search of Cave 13 on the night of the 14<sup>th</sup> June, recorded one Ghost Bat inside the cave (Plate 17).

All detections for Tag 106 were within the reception range of the base stations located within the Joe's Cave/Zane's Gorge area and were within the first hour of civil twilight. The one detection for Tag 109 was in close proximity to Chateau Cave at 22:42 during a night-time search of Chateau Cave and surrounds. Survey results are summarised in Table 19.

The detections recorded for Tag 106 for the 18<sup>th</sup>, 19<sup>th</sup> and 20<sup>th</sup> June validate the detections recorded by the base stations in the same area, particularly Joe's Cave, Matt's and JJ's BS. One of the detections recorded on the 19<sup>th</sup> June was within 5 mins of civil twilight, and subsequent detections for the same night were also recorded within 10 mins of civil twilight. The timing of these detections on the 19<sup>th</sup> June supports the possibility of another diurnal roost within the vicinity of the Joe's Cave/Zane's Gorge area.



Plate 17 Ghost Bat – Cave 13, 14 June 2017 (photo – M. Dowling)

Table 19 Summary results for manual (hand held) radio-tracking

Date/time	Map reference (Figure 4)	Latitude	Longitude	Bearing (estimated direction of bat activity)	Assumed activity	Tag details and field notes
18/06/2017 18:08:19	M1	- 21.252355	118.97412	77	Foraging	106 emerged to east of Joe's Cave. Signal strength (P) = 75
18/06/2017 18:10:12	M2	-21.25236	118.97413	110	Foraging	106, P=75
18/06/2017 18:14:21	M3	- 21.252362	118.97414	108	Foraging	106 foraging in valley south Joe's Cave P=71
18/06/2017 18:16:49	M4	- 21.252366	118.97414	169	Commuting	106 moved rapidly south, can't hear 1 min later, P=50
18/06/2017 18:19:55	M5	- 21.252365	118.97413	195	Commuting	Possibly 106 (although ID not on display) - heard very low signal-no reading. Possibly heading south along creek, through valley opposite Mobile (Turkey nest) BS
19/06/2017 18:00:49	M6	- 21.252494	118.98224	163	Foraging	106 emerged to south
19/06/2017 18:03:36	M7	- 21.252495	118.98227	157	Foraging	106, P=82
19/06/2017 18:06:06	M8	- 21.252493	118.98226	160	Foraging	106 foraging in valley south of Joe's Cave P=102
19/06/2017 18:10:25	M8	- 21.252511	118.98226	153	Foraging	106 P= 81-100 foraging in valley south of Joe's Cave
19/06/2017 18:12:23	M10	- 21.252504	118.98226	141	Foraging	106 P=85
19/06/2017 18:15:34	M11	- 21.252503	118.98225	158	Foraging	106 P = 85. Possibly not too far south as pointed antenna into valley, louder closer
19/06/2017 18:21:05	M12	- 21.252499	118.98225	169	Foraging	106 P= 89
19/06/2017 18:24:53	M13	-21.25251	118.98226	167	Commuting	Lost signal, 106 heading south fast, P= 51 then gone
19/06/2017 18:27:24	M14	- 21.252502	118.98225	18.27	Foraging	106 back, moved east, P=75
19/06/2017 18:30:14	M15	- 21.252502	118.98226	148	Foraging	106, P= 58-90
19/06/2017 18:33:22	M16	- 21.252502	118.98227	158	Foraging	106, P =100, moved west
19/06/2017 18:35:42	M17	- 21.252506	118.98225	146	Foraging	106, P 44 - 100, possibly moving north / south
19/06/2017 18:37:34	M18	- 21.252506	118.98226	159	Foraging	106, P=105, closer

Date/time	Map reference (Figure 4)	Latitude	Longitude	Bearing (estimated direction of bat activity)	Assumed activity	Tag details and field notes
19/06/2017 18:42:35	M19	- 21.252494	118.98225	154	Foraging	Losing signal every now and then, but comes back P=80-100
19/06/2017 18:46:25	M20	- 21.252496	118.98226	153	Foraging	-
19/06/2017 18:49:49	M21	-21.25251	118.98226	167	Foraging	106, P=79
19/06/2017 18:55:55	M22	- 21.252492	118.98225	162	Commuting	106 disappeared again. Weak signal then no signal for 5 mins
19/06/2017 18:59:56	M23	- 21.252497	118.98225	161	Foraging	Few random beeps from 106, possibly behind hills
20/06/2017 18:25:20	M24	- 21.252254	118.97822	127	Foraging	106 emerged to east, crackling pattern, no tag ID, then gone. Possibly moved further east
24/06/2017 22:42	M25	- 21.256159	119.05407	315	Foraging	Tag 109 was foraging around the front of Chateau Cave for approximately 1 minute before flying out of range of the receiver over top (east).

Table notes: P = power (signal strength of detection). Times highlighted in green are within 5 mins (+/- 2 min) of civil twilight (set) c. 17:55. Times highlighted in blue are within 5-10 mins (+/- 2 min) of civil twilight c. 17:55.

### 3.3.2 Roost searches

The search for the other roost sites focussed on the area north of Joe's Cave BS and JJ's BS. The survey noted nine sites of which all were subject to a preliminary habitat assessment. In summary:

- Seven sites were labelled as nocturnal refuge (TTSC 2016) based on the location of the site and habitat structure of the cave
- Two sites were determined potential diurnal roosts (unknown type). Based on the habitat structure it is unlikely they could support breeding or large aggregations of PLNB, however the sites may provide temporary diurnal refuge and could therefore be labelled potential transitory diurnal roosts (TTSC 2016). Further survey is required to confirm the status of these potential roosts
- At least four locations were noted during the survey in the area searched north of JJ's BS and north-east of Joe's Cave that were not accessible. It is possible these locations harbour diurnal roosts, however further investigation is required to confirm the potential of these sites as roost habitat
- Evidence of Ghost Bat was recorded at one site - RS4 (shown in Figure 4 and evidence discussed in Appendix C)

- Two additional sites, described as large cave openings, with possible other smaller openings were noted approximately 0.5-1 km further north of the search area. Further investigation is required to confirm the potential of these sites as roost habitat.

The location and description of each site is provided in Appendix C.

## 4. Discussion

This report presents the methods and results of the first documented radio-tracking study of the PLNB. The trapping and radio-tracking program was developed and implemented by GHD to assist FMGIB with fulfilling the requirements of the condition of approval for the North Star Magnetite open cut iron ore mine.

### 4.1 Activity at known roost sites

An aim of the radio-tracking program was to determine if tagged bats from the Joe's Cave / Zane's Gorge area are using a known roost (Chateau Cave) and vice versa in order to understand inter roost movement between a known roost and temporary / nocturnal roost.

Analysis of the timing of the first and last detections with regard to civil twilight times was undertaken for each tagged bat to assist with locating or refining the location of other roost sites and understand if bats were roosting in Chateau Cave and Joe's Cave during the survey. This information was also reviewed in combination with other survey results (e.g. presence and absence and inferred nightly movements).

Overall, few detections were recorded within the period near civil twilight near sunset (n=6) and civil twilight near sunrise (n=2) to suggest that the tagged bats were regularly roosting within the Chateau Cave and Joe's Cave during the survey. Three tagged bats occasionally used Joe's Cave or an area nearby Joe's Cave for roosting. In summary:

- Tag 104 was captured and released at Chateau Cave on the 13<sup>th</sup> June and was detected at Chateau Cave base station from a single detection on the 14<sup>th</sup> June at 17:54 on antenna 1 (facing the cave entrance). This detection occurs within 10 mins of civil twilight, inferring that the bat was in close proximity to the base station or possibly within Chateau Cave (in a chamber that prevented earlier signal transmission). The later scenario is possible, however there are no other detections close to that time (next detection at 20:01, at Rise BS), nor was there a detection record indicating the bat entered the cave prior to the record. Alternatively Tag 104 may have entered the cave from the east via the plateau, during the period the antenna were cycling on both Chateau Cave and Rise base stations. This scenario is possible however it is unlikely Tag 104 also avoided detection by the antenna orientated east toward Chateau Cave on Nate's Tower
- Tag 104 was also recorded from two detections (06:36, 16<sup>th</sup> and 06:30, 23<sup>rd</sup> June) approximately 15 mins after civil twilight from JJ's BS located approximately 6.5 km west of Chateau Cave. Both records were from antenna 1 (orientated north by north-west) toward an area east of Joe's Cave/ Zane's Gorge containing potential diurnal roosting habitat. Given the timing of the detections it is possible that the bat was flying to, and possibly in very close proximity to a diurnal roost
- Tag 106 was captured and release at Chateau Cave on the 13<sup>th</sup> June and was recorded from three detections (18:03-18<sup>th</sup>, 17:57-19<sup>th</sup> and 18:00-20<sup>th</sup> June) at Joe's Cave (c. 8 km's west of Chateau Cave) and also by the nearby Matt's BS (c. 1 km west of Joe's Cave BS) within 10 mins of civil twilight. The detections at Joe's Cave BS for the three nights were approximately 1-2 mins earlier than the detections at Matt's BS. The majority of detections from Joe's Cave BS were from antenna 3 (orientated east), then antenna 1 (orientated north at Joe's Cave entrance), with some detection from antenna 2 (orientated west). All detections from Matt's BS were from antenna 1 (orientated north-east). The number of consecutive nights (three) and the multiple detections of similar timing (+/- 5 mins), coupled with the signal strength and antenna orientation suggests that Tag 106 was roosting within or in close proximity to Joe's Cave. It is worthwhile noting the detections at JJ's BS were at

least 15 mins past the first detection at Joe's or Matt's BSs for each of the three nights. This suggests that the origin of the detections, if not from Joe's Cave were from a site in close proximity to Joe's Cave

- Tag 106 was also detected within approximately 10 mins of civil twilight 23<sup>rd</sup> June at Joe's Cave and JJ's BS (both antenna 1 orientated north and north by north-west). Given the timing of the record, it is possible that the bat was in or in close proximity to Joe's Cave or in close proximity to another diurnal roost north-east of Joe's Cave
- Tag 110 was captured and released at Joe's Cave on the 20<sup>th</sup> June and was recorded from two single detections approximately 10 mins after civil twilight at Japal BS on 24<sup>th</sup> and 25<sup>th</sup> June. Both records were from antenna 2 (orientation, south-west). Given the timing of the records, it is possible that the bat was commuting to a diurnal roost. However, it is important to highlight the lack of other detection data from other antenna from Japal BS and from other base stations within close proximity for the same time period. Furthermore there is an absence of any obvious cave habitats in the approximate area of the detections.

## 4.2 Alternate roost location

In addition to understanding the usage of known roost locations the radio-tracking program also aimed to locate an alternate roost site(s) or refine the area containing an alternate roost site for PLNB in the area of Joe's Cave / Zane's Gorge. This study provides evidence that other diurnal roosts probably exist in areas outside the reception range of the base stations, in particular the area north and north-east of Joe's Cave and probably to the north and east of Chateau Cave.

The lack of tagged bats occurring within Joe's Cave and Chateau Cave during the survey period and the absence of tagged bats for large portions of the survey period (e.g. Tags 104, 105 and 108), suggest a larger range occupancy than the base station range of reception. This further supports the existence of other roost site(s), in addition to Chateau Cave and Joe's Cave beyond the range of reception of the base stations.

The manual tracking and roost search survey results undertaken in the area north of JJ's BS and north and north east of Joe's Cave recorded temporary diurnal refuge roosts and potential transitory diurnal roosts, although no sites that could support breeding or a large aggregation of PLNB were recorded. However, sites (e.g. openings along cliff faces, at heights) that were not safe to access, which could provide potential roost opportunities were recorded. The information reviewed from the survey suggests that other roost(s) could be in the vicinity of Joe's Cave/Zane's Gorge, probably within 3-4 km of Joe's Cave/Zane's Gorge in an area spanning from the north through to north-east.

Evidence for an additional roost location is also in part supported by the lack of data from Chateau Cave and the presence of activity data from the OPF BS (e.g. Tag 107), for the area to the north and north-east of the ore processing facility. For example, Tag 107 was captured at Chateau Cave but was notably active for seven consecutive nights from the 18<sup>th</sup> June in the range of reception of the OPF BS. This detection data indicates that Tag 107 was active outside the reception range of the receivers for the majority of the survey period, in particularly for the later part of the PM period and the AM period for most of the survey nights. Furthermore, a subset of the data was reviewed for the night of the 19-20 June-the first detection for Tag 107 was at 18:28 by OPF BS (antenna 1 and 2, orientated north-east and north-west) with activity recorded for a period of approximately 6 consecutive mins. Next detections were also by OPF on antenna 1 and 2 for a period of approximately 13 mins but included three occasional detections by Nate's Tower on antenna 2 (orientated north). Final detection for the night of the 19-20 June was by OPF BS at 20:11, approximately 1 hour, 40 mins from the first detection. This pattern of activity was observed for most of the survey period, although Tag 107 was also active in the Chateau Cave area for a small portion of this period. This information suggests that

Tag 107 was active within the reception range of the OPF BS but also outside the reception range of the base stations for most nights. The orientation of the antennas (north and north-west), coupled with increasing signal strength, then decreasing signal strength early in the evening across multiple antennas as time progressed suggests that activity originated from the area to the north-west of the OPF BS. A subset of data for the night of the 22-23 June highlights this pattern of movement and provides further evidence of another roost. During this night Tag 107 originated from the area north-west of the OPF BS. It was first detected by the OPF BS at approximately 18:41 on an antenna orientated north and north by north-west. It has then passed through the reception range of the OPF BS being detected by all four antenna, before moving south-west of the OPF BS. The final detections for the morning of 23<sup>rd</sup> June were from antennas orientated north and north by north-west at 05:11, suggesting that Tag 107 used a similar flight route to return to its point of origin, which is probably in the area north-west outside the reception range of the base station array.

### 4.3 Nightly activity and inferred movement patterns

In addition to locating other roost sites and understanding inter roost movements the study aimed to determine the nightly movement patterns of tagged PLNB individuals from a known roost (Chateau Cave roost colony). However the data collected suggests the individuals tagged were not roosting within Chateau Cave during the survey, however were active in the area during the survey (e.g. foraging).

The detection data demonstrated that all tagged bats occurred within the reception range of the base station receivers for at least 5 of the 13 survey nights with three of the tagged bats being detected for 12 and 13 nights. The data also revealed that tagged individuals frequently commuted beyond the receiver range of the base stations. Activity was typically characterised by short bouts with few detections for most bats, however periods of consistent activity (15-30 mins) were also often recorded for three tagged bats (106, 107 and 109). However, large gaps often greater than one hour and occasionally a whole night of no activity were more common than periods of consistent activity. The absence of detections from the survey period suggests the tagged PLNBs were active elsewhere and therefore utilised a larger area for foraging and possibly roosting than the overall base station range of reception. It is possible that some of the bat activity occurred within 'blind spots' of the base station array, however, it is unlikely to comprise a large portion of the survey period, particularly given the mobile behaviour of bats and duration of the tracking survey, which should have partially overcome this potential limitation.

Analysis of movement (both direction and distance) for three of the seven tagged bats (Tag 104, 105 and 108) was problematic as the detection data recorded consisted of infrequent and often weak signals. Although two tags (104 and 105) were active for 12 and 13 tracking nights, the majority of activity consisted of short sporadic bursts of few detections.

The data from four of the seven tagged bats (Tags 106, 107, 109, 110) provided the most information for the analysis of movement within the study area. Each of the bats was active for the majority of the survey (7-12 nights), with detections recorded for both PM and AM periods for the majority of nights. The number and frequency of detections and the occasional periods of consistent activity (e.g. 15-30 mins) suggests that each of the bats was active within the reception range of the receivers for a reasonable portion of the survey period.

Furthermore, it was obvious from the detection data that three of the tagged bats (Tag 106, 109 and 110) commuted between the Chateau Cave area and Joe's Cave area. It was difficult to be precise regarding the direction and distance commuted, however we were able to infer direction, distance and duration (time) from the detection data from Tags 106 and 109 for several movements within the study area. For example:

- Tag 106 moved from the release point at Chateau Cave (east) to the vicinity of Joe's Cave BS (west) during night of the 13-14 June. Analysis of a subset of the data for the morning of 14<sup>th</sup> June (01:06 to 01:44 am) determined Tag 106 moved approximately 8 km across a period of 38 mins. The timing of the detections across the multiple base stations between Chateau Cave BS and Joe's Cave BS (Rise, Jimmy's Gap then Nate's Tower BSs) infers an east to west pattern of movement
- For five consecutive nights Tag 109 regularly moved between the Joe's Cave area and the Chateau Cave area. Some movements were one way (e.g. the night of the 21-22 June Tag 109 moved from Joe's Cave to Chateau Cave area but was not detected returning to the Joe's Cave area), and other nights included multiple movements in both directions (e.g. nights 22-23, 23-24, and 24-25 June). The estimated straight line distance between Chateau Cave and Joe's Cave is 8 km, therefore for those nights where multiple movements were undertaken between the Joe's Cave and Chateau Cave areas and return the estimated straight line distance travelled would have exceeded 16 km for each of those nights. Obviously this estimate does not consider, foraging and roosting events during the course of the night
- 21-22 June - Tag 109 - following a period of activity in the Joe's Cave area finishing at 20:02, Tag 109 was next detected at Nate's Tower BS at 20:10 by two antenna, then at Rise BS at 20:14 (all antenna), then Chateau Cave BS (all antenna) at 20:15. The estimated time taken to move between the Joe's Cave and Chateau Cave areas was 13 mins
- 23-24 June - Tag 109 moved from the range of reception of Nate's, Chateau Cave, and Rise BSs starting at 20:44, to Joe's Cave and Matt's BSs at approximately 21:02. The difference between the time of departure for Chateau cave BS and time of arrival at Joe's Cave BS is approximately 18 mins. Tag 109 returned to the Chateau Cave area, starting at Joe's Cave BS (all detections on antenna orientated north by north-east) at approximately 01:36, 24<sup>th</sup> June, then Mobile (Turkey nest) BS at 03:27 (all detections on antenna orientated north), then Nates Tower BS (multiple detections on all antenna) at 03:54, and finally Rise and Chateau Cave BSs at approximately 03:55, 24<sup>th</sup> June. The difference between the time of departure from Joe's cave BS and time of arrival at Chateau Cave BS was approximately 2 hours 19 mins.

#### 4.4 Conservation outcomes

This study demonstrates that radio-tracking is a valid technique that can be successfully used to further the knowledge of this species and offers valuable insights regarding the application of radio-tracking for the PLNB and other microchiropteran bat species. Furthermore the study contributes valuable data for public record regarding the biology of the species.

#### 4.5 Suggestions for survey improvements

##### **Survey design**

Following a review of the line of sight testing and estimated range of reception it was determined that the base station locations could have been placed further apart. It is recommended that future surveys place the base stations at least 2 km apart (straight line distance) for 3-element antenna. In some circumstances, pending line of sight testing a separation distance of 3 km's or more could be achieved, particularly for 6-element antenna.

##### **Animal welfare considerations**

The study team discussed the possible cause of the individual PLNB death and means of minimising the chance of such an incident occurring again. The cause of death was not obvious

given the lack of any visible external injuries or other signs of stress. However, it was noted that the bat was a mature adult, probably aging and this may have been a contributing factor toward its death. In order to reduce the chance of the incident occurring again the following mitigation measures were implemented for the remainder of the field survey. The mitigation measures may be beneficial for future trapping and radio-tracking surveys to reduce the chance of such an incident occurring again:

- The handling period from point of capture, taking measurements, tagging and release of additional PLNB was reduced from less than 30 minutes to 20 minutes or less. For future surveys it is suggested a maximum handling period of 30 minutes be set, however 20 minutes be the target
- Trapping ceased immediately at the location of the deceased bat as it would place other individuals of the local colony at risk if trapping at the same location had continued. Additional trapping (including trapping for the recovery of tagged individuals) was not undertaken at the site for the remainder of the survey
- The potential impact of re-trapping a site and attempting to recapture tagged individuals may pose a greater risk to those individuals compared with not trapping and allowing the transmitters to eventually fall off the bats. Given the lack of data from the radio-tracking base stations positioned at the two trap sites (Chateau Cave and Joe's Cave) to suggest that tagged bats were occupying these roosts, further disturbance, and risk of trap death to tagged bats was determined to be a greater risk than not recapturing these individuals. It was decided to not recover tagged bats at any site during the survey. It is recommended that future trapping and radio-tracking surveys in the study area adopt the same approach.

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# Appendices

# Appendix A – Line of sight test method

## Trial study (March 2017)

### *Introduction*

GHD completed a trial radio-tracking study using digital encoded radio-transmitters at the North Star Mine site during March 2017 to assist with understanding the line of sight potential for the transmitters and base stations and the location of the base station array. The trial aimed to better understand the potential limitations of the method including the potential animal welfare issues regarding the length of the antenna.

One concern we have regarding this method is the length of the radio-transmitter antenna with regard to the size of the bat. The whip / flexible antenna is 180 mm long (standard length for ntqb-2 transmitters). The PLNB has a forearm length of 45.2–47.8 mm and c. body length of 44.8-55 mm (Armstrong 2001, 2002, Van Dyck et al 2013, Churchill 2008). The antenna length could be greater than 4 x longer than the body length of the PLNB and may impeded the ability of the bat to hang from its roost and other activities. Trimming of the antenna may be required to reduce this risk, however this potential welfare issue must be considered alongside the potential impacts to the radio-tracking survey (e.g. reduced antenna length may reduce signal transmission distance and strength).

The objectives of the trial were to:

- Document the line of sight signal distance for a sample of the base station tower locations
- Better understand the impedances to signal strength and direction within the study area
- Identify the best location for each base station considering the possible flight paths of PLNB between Chateau Cave and Joe's Cave and the alternative roost site in the Joe's Cave area considering the outputs of the trial study
- Use the information from the trial to discuss the appropriate antenna length for the proposed radio-tracking program.

### *Assumptions*

Calibration tests for similar receiver arrays and similar (ntqb-1) transmitter types (noting that the antenna length was not reduced for this study) in open terrain in Canada with fewer sources of physical interference and greater tower heights revealed a line-of-sight detection radius c. 5 km for the five-element antennas and c. 12 km for nine-element antennas (McGuire et al 2012). For this trial we have assumed a minimum of 2 km for a three-element antenna.

According to McGuire et al 2012, signal strength is generally proportional to the distance from the tower and therefore, the direction of the transmitter relative to the tower can be deduced from the strength of the signal on multiple antennas. Over multiple detections, a flight path can be inferred, especially when detections span multiple towers. It is important to note that a number of factors may decrease signal strength, most commonly physical interference from objects that block the signal. It is therefore important to understand any impedance to signal direction before commencing the survey.

### *Methods*

The trial survey included three tests. GHD senior zoologist Glen Gaikhorst and FMG Senior Environmental Scientist Matt Dowling completed the survey over a period of three days from the 5 – 7 April 2017. No bats were used during the trial.

#### Test 1 - Line of sight test

This test was undertaken using two transmitters with full-length antenna. Transmitter 1 (code tag 101) was attached to small c. 1 m plastic (non-metal) pole for walking to test sites.

Transmitter 2 (code tag 100) was attached to a c. 1.5 m plastic (non-metal) pole on car for duration of survey.

Base stations were established at five locations (see Figure 2). Base stations consisted of an SRX800-D receiver, connected to one 3-element yagi antenna positioned atop a 4.5 m high single pole fixed to a base plate. The antenna was directed along the proposed flight path/fly way or intended direction of the transmitter test point. One person was positioned at the base station for the duration of the test to listen for signal via headphones connected to the receiver, and to oBServe the flashing lights on the receiver. The second person walked to a test point with the transmitter, located between 200 and 2000 m from the base station. At each test point at the start and finish time and gps waypoint as recorded. This enabled the data to be synchronised with the gps enabled time and date recorded for each data log by the receiver. See Attachment 2 for more detail regarding this method.

#### Test 2 - Cave test

This test was undertaken using one transmitter (code tag 100) with full-length antenna. A base station was placed approximately 5-10 m from the entrance of Chateau Cave with the antenna orientated toward the entrance. See Attachment 2 for more detail regarding this method.

#### Test 3 - Reduced antenna length test

A line of sight test was conducted using both transmitters side by side. The antenna of transmitter number 2 was cut by 50 mm (from c. 180 to 130 mm). The same method was employed as for the line of sight tests described in Section 2.1, however all five test points were deliberately located within line of sight of the base station along a vehicle track. No visible signal impedances were recorded.

### **Results**

#### **Summary**

- 1100 data points were logged for both tags by the base stations (all stations combined, tag 100 = 364, tag 101 = 736 data points) – see attached spreadsheet (tab – base and base gps)
- No data was collected for any of the radio tracking test points for any of the base station locations during the line of sight tests (see Figure 3 Rev 1 and attached excel spreadsheet), however data was collected for the cave and reduced antenna tests
- It appears that the majority of the data was not collected during the ‘tests’ and appears to have been logged by the receiver whilst the tag was within close proximity to the base station (probably during the initial set up or decommissioning of the base station). This was determined from a review of the time and dates associated with each data file logged on the receiver compared to the time and date data of the test points
- A small portion (n = 42) of the data points logged by the base stations receivers were correlated with track log files and displayed in Figure 3 Rev 2. None of the data points fall within the time period for the line of sight tests
- Data points logged by the base stations receivers was graphed (time vs power plots - see various taBS in attached excel spreadsheet) for each of the base stations.

#### Test 1 - Line of sight

For the line of sight tests we assumed a minimum of 2 km for three-element antenna. Although no data logged by the base stations during the test period, data logged outside the test period that correlated with track log files (n = 42) was reviewed and mapped (see excel spreadsheet tab base v tracks MAP and Figure 3 Rev 2).

The maximum distance achieved was less than 1 km (ranging from 200 – < 500 m). The majority of data points logged a weak-moderate signal strength (power output between 26-50) with occasional strong signal strength (power output > 100).

### Test 2 - Chateau Cave test

For the Chateau Cave test 125 data points were logged from tag 100 by the base station located at the entrance of Chateau Cave. An additional 233 points were logged by the base station from tag 101 located at the entrance near the base station (see attached spreadsheet - tab – CC test and Plate 1 below). The test period was between 3:32 and 3:38 pm 5/4/2017.

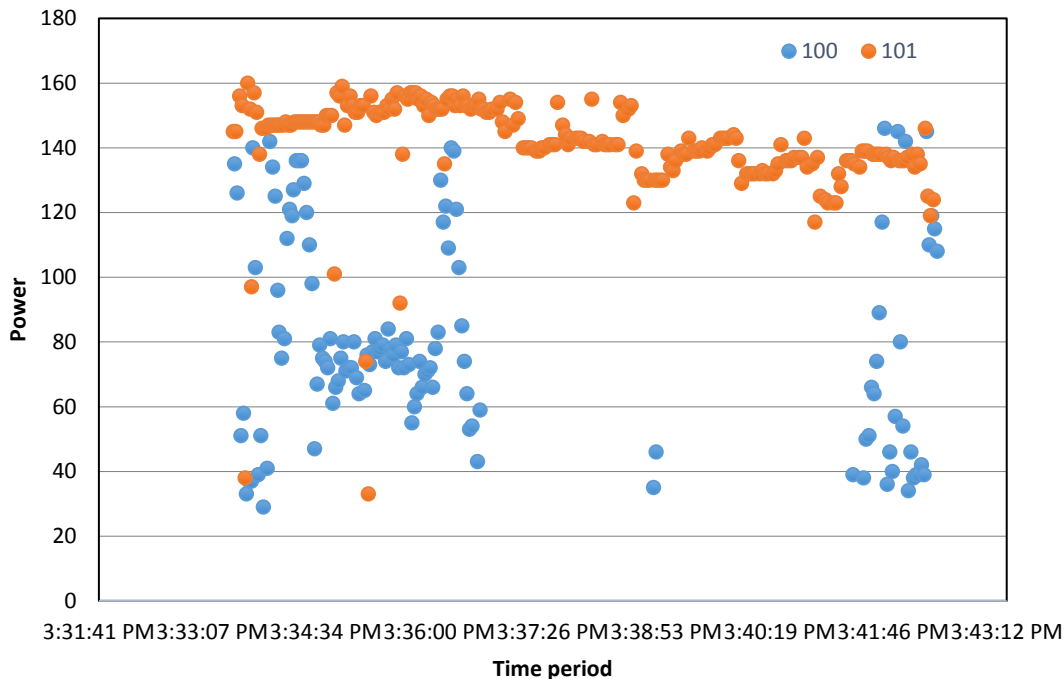


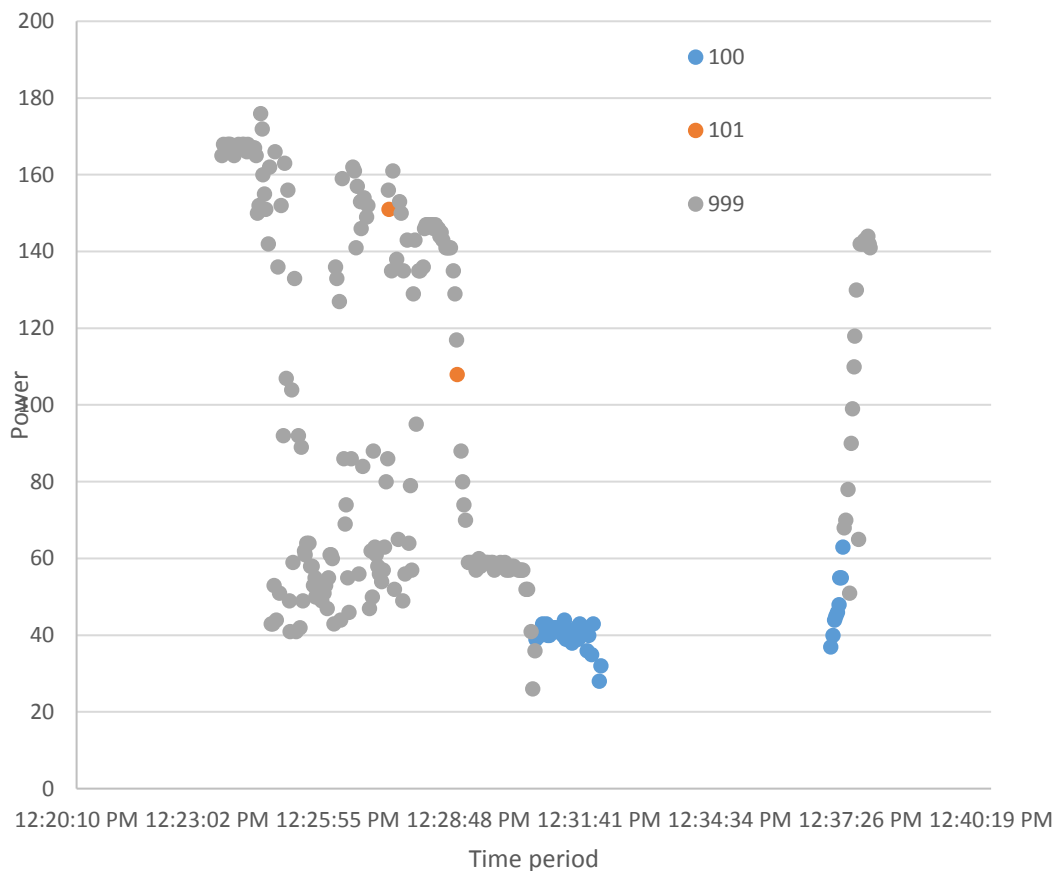
Plate 1 – Time v power plot for Chateau Cave test (Test 2). Blue dots = tag 100, Red dots = tag 101

The data collected for the Chateau Cave test indicates that a receiver with an antenna pointed at the cave entrance can receive signals from within the cave (albeit this was not in the main chamber) using the coded transmitter with a full length antenna.

### Test 3 – Reduced antenna length

Poor results were recorded for the distance test with the reduced antenna length. It appears that the base station receiver did not log any data for tag 101 (reduced antenna length) for the period of the test from 12:28-12:37 pm 7/4/17.

Data was logged by the base station receiver for tag 100 (full length antenna) for the test period although the power levels logged (signal strength) were weak-moderate (c. 25-70). Many logged entries for the test did not record (recognise) the unique tag code. These entries appear as 999 and also appear to coincide with the same time period the receiver was logging data for tag 100. See Plate 2 and the attached excel spread sheet (tab distance all) Plate 1



**Plate 2 – Time v power plot for distance test for reduced antenna length (Test 3). Blue dots = tag 100 (antenna 190 mm), Red dots = tag 101 (antenna reduced 130 mm), Green dots = 999 (data logged by receiver however not associated with either tag).**

### **Summary:**

- Poor results were recorded for the distance test, however need to understand the error readings (e.g. data logged as 999 by the receiver instead of unique tag identifier)
- Low power levels were recorded (weak-moderate) for tag 100 (full length antenna) and no data was recorded for the test period for tag 101 (reduce length antenna).
- Many error (999) data entries logged by the receiver (see tab Distance and Distance (all)).

### **Next steps and recommendations**

- Gain was set at 80 for the duration of the survey – Increasing gain, will increase signal sensitivity and will better enable signal detection at reception limits of the system. However, this will also amplify noise events. Increase gain to maximum (99).
- Antenna length must be retained at 180 mm for transmitters. Given the results it is recommended that the antenna length is not reduced.
- Base stations are located at intervals not greater than 1 km apart
- Increase height of base station towers. Maximising height will increase the receivers ability to detect a signal
- Testing of the base stations including similar line of sight tests undertaken during this trial study prior to tagging bats is recommended to develop the optimal base station array
- Staged approach is recommended (e.g. tag 5 bats, monitor then tag additional bats after a short monitoring period consisting of manual and base station tracking (3-4 days) before tagging additional bats)

### **Line of sight testing for base stations (June 2017)**

#### **Methods**

The position, orientation and number of antenna for each base station was considered with regard to localised physical sources of interference and previous testing (March 2017). Line of sight testing was undertaken for most of the base stations. The testing aimed to:

- Document the line of sight signal distance for the antenna's for most of the base stations
- Better understand the impedances to signal strength and direction within the study area

Testing employed a method similar to the trial study undertaken in March 2017 with some minor changes and included the following steps:

1. Place transmitter(s) at recommended test point sites
2. At each test point site record data as per data sheet
3. Ensure transmitter is held horizontal at a height of c. 2 m for a period of 2 mins, then
4. Ensure transmitter is held vertical at a height of c. 2 m for a period of 2 mins
5. Keep locations at least 200 m apart
6. Try to maintain a 2 min period at each test point site
7. Suggest taking two gps points at each test point site to mark time (at start and finish) or detailed notes regarding the location of the test point (e.g. road junction X)
8. Test point sites should include positions where the observer can see the base station tower (line of sight is unobstructed) and where the observer can't see the tower (line of sight is obstructed)

#### **Results**

Calibration tests revealed a direct line of sight detection radius of up to c. 2.2 km for the three-element antennas and up to c. 2.0 km for the six-element antennas, although based on simultaneous detections on multiple towers, we can confirm that in some cases, detections occurred at greater distances. It is important to note that similar tests have also revealed that

the six-element antenna is likely to have a greater line of sight than the three-element antenna however our testing process did not exceed 2 km.

From the line of sight testing, field observations taken from the view point of each base station and a review of google earth imagery was used to develop the estimated zone of reception (area within which a transmitter should be detected by the base station receiver) for each base station. Figure 3 displays the location of each base station, estimated range of reception and the test point sites recorded during the line of sight tests during the June 2017 survey.

# Appendix B – Bat measurements

SITE	DATE	SPECIES NAME	COMMON NAME	FATE	Time	Sex	Forearm (mm)	Weight (g)	Ear (mm)	Foot (mm)	Body length (mm)	Wing joints	Reproductive condition	Teeth	Age	Colour	Tag
Chateau Cave	13/06/2017	<i>Rhinonictoris aurantia</i>	Pilbara Leaf-nosed bat	alive	1915	Male	47.8	8.5	0	0	42.2	smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Some wear/not obvious	Sub-adult	Vibrant orange, darker brownish tips on back and back of head and neck	104
Chateau Cave	13/06/2017	<i>Rhinonictoris aurantia</i>	Pilbara Leaf-nosed bat	alive	2010	Male	46.6	8.5	0	0	40.2	smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Some wear/not obvious	Sub-adult	Vibrant orange, darker brownish tips on back and back of head and neck	105
Chateau Cave	13/06/2017	<i>Rhinonictoris aurantia</i>	Pilbara Leaf-nosed bat	alive	2127	Male	47.8	9	0	0	46.7	no obvious cartilaginous band, blood vessels not distinct		Obvious signs of wear	Adult	Pale yellow/fawn, not vibrant orange	106
Chateau Cave	13/06/2017	<i>Rhinonictoris aurantia</i>	Pilbara Leaf-nosed bat	alive													Escaped from trap no data recorded
Chateau Cave	14/06/2017	<i>Rhinonictoris aurantia</i>	Pilbara Leaf-nosed bat	alive	1842	Male	46.8	10	6.4/6.4	8.2/8.4	47.7	smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Some wear/not obvious	Adult	Vibrant orange, darker brownish tips on back and back of head and neck	107
Chateau Cave	14/06/2017	<i>Rhinonictoris aurantia</i>	Pilbara Leaf-nosed bat	alive	1946	Male	47.4	9	7.8/7.6	8.7/8.6	0	smooth with outline cartilaginous band, distinct blood vessels		Some wear/not obvious	Adult	Red-vibrant orange, darker brownish tips on back and back of head and neck area	108

Chateau Cave	14/06/2017	<i>Rhinonictis aurantia</i>	Pilbara Leaf-nosed bat	dead	2006	Male	48.3	10	6.2/6.3	8.7/8.9	0	smooth with outline cartilaginous band, distinct blood vessels	Testes not enlarged / not reproductive	Obvious signs of wear	Adult	Orange, darker brownish tips on back and back of head and neck	n/a
Joe's Cave	20/06/2017	<i>Rhinonictis aurantia</i>	Pilbara Leaf-nosed bat	alive	1920	Female	45.6	8	0	8.4	49.65	smooth with outline cartilaginous band, distinct blood vessels	Non-breeding, no wear around nipples, no obvious	No obvious wear	Sub-adult	Orange/orange-brown, darker tips on back and back of head and neck	109
Joe's Cave	20/06/2017	<i>Rhinonictis aurantia</i>	Pilbara Leaf-nosed bat	alive	1951	Female	46.1	9.5	0	8.5	0	obvious cartilaginous band/knobbly	Non-breeding, no wear around nipples, no obvious	No obvious wear	Sub-adult	Lighter yellow on belly / fawn back, neck and head. Light brownish tips on back and head.	110
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	68.5	24									
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	68	24									
Chateau Cave	13/06/2017	<i>Vespadelus finlaysoni</i>	Finlayson's Cave Bat	alive			32										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	69	23									
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	70										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	66										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	70										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	68										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	70.5										

Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	71										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	70										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	68										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	69										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	71										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	68										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive			67										
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	70.6	23									
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	70										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	65.5										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	72.6										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	32.1										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	67.5										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	71.2										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	67.2										

Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	69.2										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	68.5										
Chateau Cave	14/06/2017	<i>Vespadelus finlaysoni</i>	Finlayson's Cave Bat	alive		Male	31.3										
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male											
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male											
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive													
Chateau Cave	13/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive													
Chateau Cave	14/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive													
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	68	24.5									
Joe's Cave	20/06/2017	<i>Vespadelus finlaysoni</i>	Finlayson's Cave Bat	alive		Male	30.1	3.7									
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	70.8	27.5									
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male		23									
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	70.4	29									
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	66.9	25.5									
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	70	28									

Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Male	66.9	23									
Joe's Cave	20/06/2017	<i>Taphozous georgianus</i>	Common Sheath-tailed Bat	alive		Female	69.8	25.5									

## Appendix C – Roost search results

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Revision	Author	Reviewer		Approved for Issue		
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Rev A	C Grabham	G Gaikhorst A Holmes	-	D Farrar	-	16/08/2017
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