

**Fortescue Metals Group Ltd**  
Pilbara Leaf-nosed Bat radio tracking survey 2019-2020  
Survey report

May 2020

# Executive summary

This report presents the methods and results of the second radio-tracking study of the Pilbara Leaf-nosed Bat (PLNB) (*Rhinonicteris aurantia*) within the North Star mine study area. The trapping and radio-tracking program was developed and implemented by GHD to assist IB Operations Pty Ltd (IB Operations) with fulfilling the requirements of the condition of approval for the North Star Magnetite open cut iron ore mine.

IB Operations requested GHD develop a tracking program with the purpose of attempting to locate a natural maternity roost site for the PLNB within 30 km of Cave 13 (geographic coordinates: latitude -21.257246, longitude 119.054456). To work towards the purpose, the following objectives were determined:

- Locate and/or narrow the potential location of an alternative natural maternity roost(s) for the PLNB within a 30 km radius of Cave 13
- Locate and/or narrow the potential location of other roosts (e.g. nocturnal / temporary roosts) for the PLNB within a 30 km radius of Cave 13.

## 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 envelopes.

Field surveys were undertaken from the 6 to 10 November 2019 and 25 November to 17 December 2019 within the study area by GHD with the assistance from IB Operations and Njamal Traditional Owners.

The field survey included harp trapping, roost occupancy and ultrasonic detector 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.

Seventy one (71) bats of four species were captured during 10 nights of harp trapping at six locations. Eight PLNB including one pregnant female and one non-breeding female were captured, tagged and released from two locations, Chateau Cave and Joe's Cave.

PLNB were fitted with digitally encoded transmitters and monitored using an array of eight base stations (stationary data logging receivers) for up to 15 nights. 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 locate alternate roost habitat and assist with understanding movements of PLNB individuals from a known roost location (e.g. Chateau Cave). To supplement and validate the findings of the base stations, active searches for transmitters with handheld receivers were also completed.

## Key results

- The survey was impacted by the adverse weather conditions, which resulted in gaps in the survey data and limitations regarding the analysis of the available data, particularly for base station 2 above Joe's Cave.
- No valid first (following sunset) or last (near sunrise) tag detections were recorded by base station 1 (bs1 Rise) located 300 m from Chateau Cave) including A2 orientated at Chateau Cave. Furthermore, no other first or last detections were recorded by the nearest

base stations bs3 (OPF) or bs4 (Shariff's Pool) to indicate that tagged bats were active for any period within the area of Chateau Cave or using Chateau Cave as a roost during the survey period. The lack of data from bs1 and from manual radio-tracking surveys of Chateau cave, also indicates that none of the tagged bats were using Chateau Cave during the 2019 survey.

- Despite the absence of data indicating that tagged bats were using Chateau cave during the survey, the analysis of the ultrasonic data from detectors within the cave and data from roost occupancy surveys has unambiguously proven that PLNB were using Chateau Cave as a diurnal roost during the survey.
- It is unlikely that tagged bats occupied Cave 13 or were frequently active in the Cave 13 area during the survey, as supported by the lack of data from bs1, bs3 and bs4. Furthermore, the analysis of ultrasonic survey data did not record any calls during the one hour period following sunset for six nights during the survey.
- Given the issues interpreting signal strength and direction data from bs2, it was not possible to be definitive with regards to the direction of the tag signals. However a review of the first and last tag detection data from the nearest base station to Joe's Cave provides an indication of the location of activity during the emergence and re-entry periods in the Joe's Cave area. At least four bats carrying transmitters (Tags 19, 20, 10 and 11) were regularly active in the area of Joes Cave.
- Base stations 2 and bs4 were the only base stations to record valid first and last tag detections. The data indicates the presence of one or possibly two diurnal roosts within the reception range of bs2, most likely the area, south-east, through south-west of the base station including Joe's Cave, Zane's Gorge area.
- The analysis of data from bs2, supported by data from bs4 does indicate that Tag 11 and Tag 20 may have roosted within or in close proximity to Joe's Cave during the survey:
  - Tag 20 - Regular first detections were recorded 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 5<sup>th</sup> and 6<sup>th</sup> December 2019 by bs2, A1 (orientated west-north-west) and A4 (south-south-west at Joes Cave). The timing of the tag detections also coincides with calls recorded using ultrasonic detectors during the emergence period for Pilbara Leaf-nosed Bat during the survey period (Section 4.5).
  - Tag 11 – Regular last (near sunrise) detections were recorded 6<sup>th</sup>, 7<sup>th</sup>, 9<sup>th</sup> and 10<sup>th</sup> of December, by bs2 A1 (orientated west-north-west) and/or bs4, A4 (orientated south-south-west). Last detections were always supported by multiple consecutive detections within a 1-5 minute period the same antenna. Furthermore, multiple simultaneous detections were also recorded for two nights by bs2, A1 and bs2, A4.
- The detection data demonstrated that all tagged bats with the exception of one (Tag 22) occurred within the range of reception of the base station receivers for at least 4 survey nights. Three tags exceeded 9 nights (Tag 23, 10 non-consecutive nights; Tag 20, 14 non-consecutive nights; Tag 11, 15 consecutive nights).
- The data also revealed that tagged individuals frequently commuted beyond the range of the receivers. Although there are limitations with some of data from some nights (e.g. no data for bs1 29/11/19 and the interpretation of signal strength and direction data from bs2), the lack of detections (e.g. of 1-2 hours and whole nights for some bats), indicates that all tagged bats were most active outside the reception range of the receivers for most of the survey period. The absence of activity was more common than activity during the survey.

- The absence of detections 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, duration of the tracking survey, and manual tracking effort which should have partially overcome this potential limitation.
- The 2019 study findings coupled with information from the 2017 study provides sufficient evidence that at least one or two diurnal roosts occur within the range of reception of the receivers in addition to the known diurnal roost of Chateau Cave, Joe's Cave and Cave 13 including:
  - Potential roost location, north-east through south-west of Joe's Cave - Base stations 2 and bs4 were the only base station to record valid first and last tag detections. The data indicates the presence of a diurnal roost within the reception range of bs2, including the area, south-east, through south-west of the base station. This broad area incorporates:
    - Potential roosting habitat surveyed during manual tracking searches (ms13 and ms9 within 1 km north-east of Joes cave, Figure 4). The area east-north-east of Joe's Cave has several locations identified as potential roosting habitat (see Section 2.2 and Figure 2).
    - Zane's Gorge and the southern facing cliff face for within 4 kms west of Joe's Cave. The area west of Zane's Gorge has several locations identified as potential roosting habitat (see Section 2.2 and Figure 2).
  - Potential roost location, north-east of Joe's Cave - the timing of the last detection (4:29 am) for the morning of the 1/12/19 and first detection (7:18 pm) for the night of the 1/12/19 by bs2 – A3 (orientated east-north-east) for three and four consecutive detections then by A4 (orientated south-south-west) indicates Tag 19 was roosting in the area north-east of Joe's Cave.
  - Potential roost location, South Star Pool area - The timing of the data from bs4 for the night of the 30/11/19 indicates Tag 22 was detected in close proximity to or leaving a diurnal roost.
  - Evidence for an additional diurnal roost site is also in part supported by the lack of tag data from Chateau Cave and to a lesser extent Cave 13.
- The manual tracking and roost search survey results undertaken in the area north east of Joe's Cave during the 2017 study 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 height) 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. The findings from the 2019 study support the discussions regarding the location of potential diurnal roost habitat in the Joe's Cave and Zane's Gorge areas, and the area north-east of Joe's Cave.

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# 1. Introduction

## 1.1 Project background

IB Operations Pty Ltd (IB Operations) is the Proponent for the North Star Magnetite Project (the Project). The Project consists of an open-cut iron ore mine, and associated infrastructure, approximately 110 kilometres (km) south-south east of Port Hedland. The Project was authorised with the issue of Ministerial Statement (MS) 993 under the *Environmental Protection Act 1986*. MS 993 includes condition 10 relating to the Pilbara Leaf-nosed Bat (PLNB) (*Rhinonictus aurantia*).

Condition 10 was proposed by the Environmental Protection Authority to mitigate the potential impacts to the PLNB colony of Cave 13 due to mining activities. Condition 10 states the proponent shall implement the proposal in a manner that maintains the viability of the population of PLNB from Cave 13. The intent of conditions 10-3 to 10-11 are 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:

- 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
- Demonstrate to the satisfaction of the CEO that a viable portion of the colony of PLNB from Cave 13 has relocated and established itself in an alternative maternal roost site.

## 1.2 Scope of works

IB Operations requested GHD develop a tracking program with the purpose of attempting to locate a natural maternity roost site for the PLNB within 30 km of Cave 13 (geographic coordinates: latitude -21.257246, longitude 119.054456). The study area, as presented in Figure 1, includes the North Star mining area development envelope (MDE) and associated infrastructure develop envelope (IDE). The program used the information from the 2017 radio-tracking program to inform the proposed approach and aim to build on the existing findings and conclusions.

To work towards the purpose, the following objectives were determined:

- Locate and/or narrow the potential location of an alternative natural maternity roost(s) for the PLNB within a 30 km radius of Cave 13
- Locate and/or narrow the potential location of other roosts (e.g. nocturnal / temporary roosts) for the PLNB within a 30 km radius of Cave 13.

## 1.3 Assumptions and limitations

This report has been prepared by GHD for IB Operations and may only be used and relied on by IB Operations for the purpose agreed between GHD and IB Operations as set out in Section 1.2 of this report. GHD otherwise disclaims responsibility to any person other than IB Operations 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.

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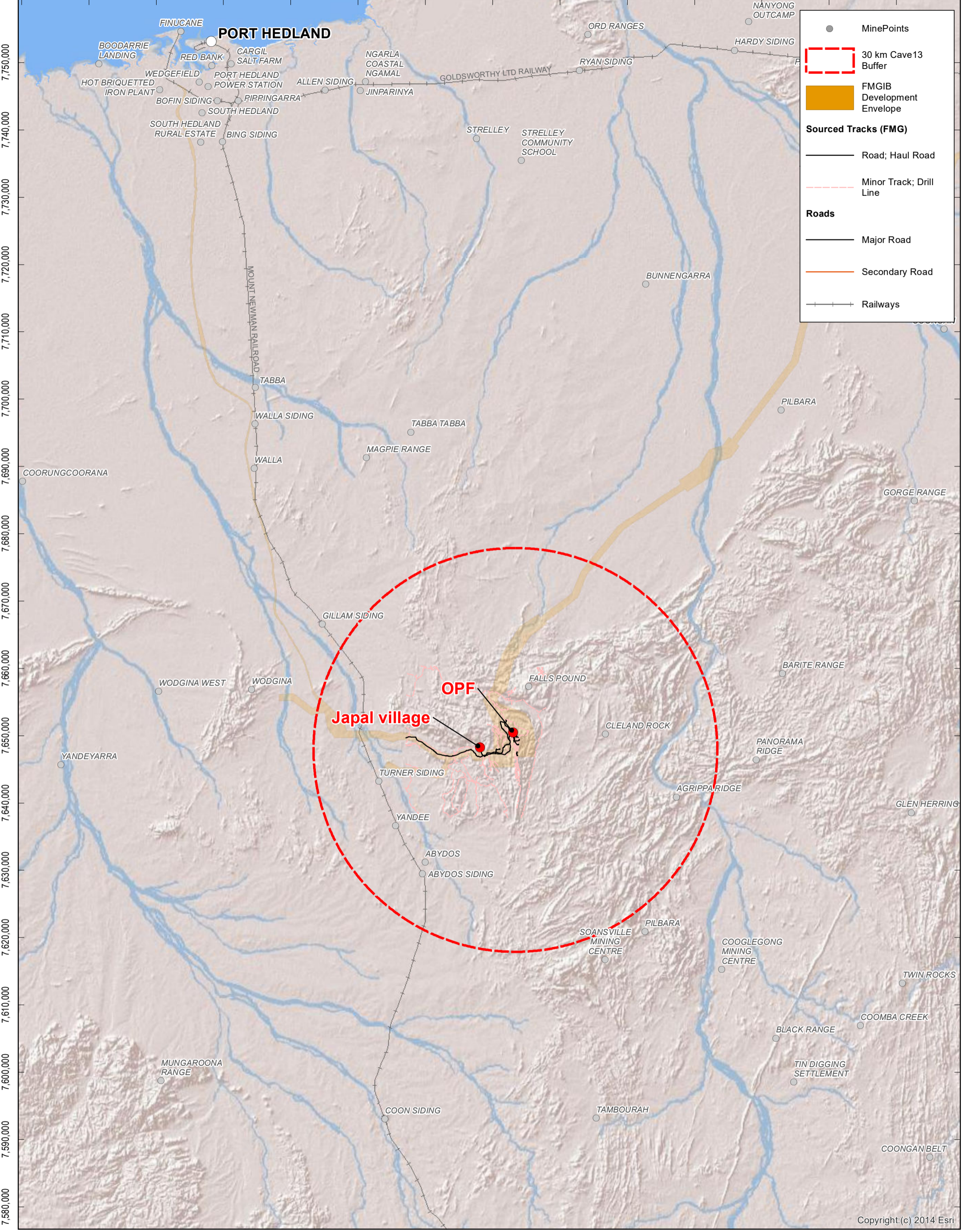
The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

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.

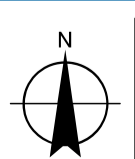
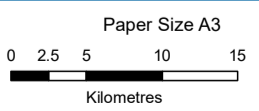
Site conditions may change after the date of this report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This assessment is based upon the study area shown in Figure 1.

640,000 650,000 660,000 670,000 680,000 690,000 700,000 710,000 720,000 730,000 740,000 750,000 760,000 770,000



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Fortescue Metals Group Ltd  
Pilbara Leaf-nosed Bat North Star Management Plan

Job Number 61-35195  
Revision 0  
Date 29 May 2020

North Star Iron Bridge study area

Figure 1

N:\AU\Geelong\Projects\3112516477\GIS\Maps\Working\3112516477\_001\_ProjectArea\_Rev0.mxd 999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au  
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Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: AF **Figure 1: Location of study area**

## 2. Review of Pilbara Leaf-nosed Bat within the North Star study area

This section provides a summary of the desktop review for the PLNB with a focus on the roosting ecology within the North Star study area.

The PLNB is listed as Vulnerable under both the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the Western Australian *Biodiversity Conservation Act 2016*. The primary consideration for this species is the protection of its roosts and breeding colonies from mining and disturbance.

The majority of the information used to develop the desktop summary was extracted from a literature review of the species completed by Specialised Zoological (2017) for IB Operations, Cramer et al. (2016) and the SPRAT profile for the PLNB (DotEE 2018). Figure 2 displays known and potential roost locations and records for the PLNB in the study area. The information provides background context to the discussion of the key outcomes resulting from survey.

### 2.1 Extent of occurrence in the study area

A review of studies supplied by IB Operations was undertaken to provide a chronological timeline of information collected regarding the occurrence of the PLNB within the study area. The following studies were reviewed:

- Atlas Iron (2016). Abydos Direct Shipping Ore (DSO) EPBC Compliance Report - Stage 2. Unpublished report by Atlas Iron Ltd. Document EPBC 2013/6985, 101-LAH-EN-REP-0014 Revision 1, 1 July 2016 URL: <http://www.atlasiron.com.au/irm/company/showpage.aspx/PDFs/5899-52902690/AbydosComplianceReport2016EPBC20136985>
- Bat Call WA 2013 (18 July 2013) Fortescue Metals Group North Star Project, Pilbara Leaf-nosed Bat colony survey April 2013
- Bat Call WA 2014 (25 May 2014) Fortescue Metals Group North Star Project, Pilbara Leaf-nosed Bat colony; Cave 13 and Fig Pool activity monitoring - March to May 2014
- ecologia environment (7 March 2012) Fortescue Metals Group North Star Project – North Star Level 2 Terrestrial Vertebrate Fauna Assessment
- GHD 2015b (2 November 2015) Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Pilbara Leaf-nosed Bat roost habitat survey
- GHD 2016a (26 July 2016), Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Cave 13 Pilbara Leaf-nosed Bat Survey
- GHD 2016b (21 September 2016), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Chateau Cave, Cave 13 and Joe's Cave - Pilbara Leaf-nosed Bat surveys including roost occupancy surveys
- GHD 2017b (17 January 2017), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Roost emergence survey and roost count for Pilbara Leaf-nosed Bat - Chateau Cave, North Star Mine 14 - 18 November 2016
- GHD 2017c (9 February 2017), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Alternate roost survey - west of Zane's Gorge from the 14 – 17 November 2016

- GHD 2017e (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Chateau Cave habitat assessment for the Pilbara Leaf-nosed Bat
- GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report
- GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat
- GHD 2020 (March 2020), Unpublished report for Fortescue Metals Group Iron Bridge – Glacier Valley and South Star Fauna Surveys: Conservation Significant Fauna Survey report results.

A summary of the key survey findings for each study is provided in Table 1.

**Table 1: Summary of surveys for Pilbara Leaf-nosed Bat and Pilbara Leaf-nosed Bat roost habitat undertaken for the North Star mine study area**

Reference	Key survey outcomes
ecologia environment (7 March 2012)	First record of PLNB at Cave 13. PLNB was recorded from 18 locations across the project area using bat detectors. Based on the analysis of the timing of call density peaks, three of these locations were considered diurnal (day) roost cave locations. The majority of records were from the North Star mining and infrastructure areas and consisted of ridge/breakaway/rocky gorge habitats with or without semipermanent water.
Bat Call WA 2013 (18 July 2013)	Targeted survey in April 2013 to confirm the general location of the day roost within the Fortescue project area and then to identify the cave(s) containing the roost considering the ecologia survey findings (2012). Surveys included the use of bat detectors and infrared video surveillance. One cave within the project area (Cave 13), was found to contain a colony of over 200 PLNBs and it was characterised as a day roost and probably a maternity roost.
Bat Call WA 2014 (25 May 2014)	Long term monitoring of the activity levels of the PLNB at Cave 13 began in early March 2014 and continued until mid-May 2014 with the aim of measuring nightly, monthly and seasonal variation of PLNB activity using SM2 bat detectors. The results of the study showed the characteristics of the PLNB colony at Cave 13 changed between March and May 2014. March activity at the cave was consistent with a primary foraging location for the species, but not a diurnal roost. During April, the activity pattern changed to one consistent with diurnally roosting bats being present at the cave in line with the results of 2013. This pattern continued into May. Data from Cave 13 suggests there is an unknown permanent diurnal roost close by (within approximately 10 km of Cave 13) and that bats from this roost are attempting to colonise Cave 13 at the end of the wet season. Additional data collected using SM2 bat detectors following the breeding season suggests Cave 13 maybe a non-permanent diurnal roost (Bat Call WA 2014) and that bats may roost in another location, at least for part of the year.
Atlas Iron 2016	Atlas Iron monitored the presence and activity of bats of conservation significance at numerous sites in the Abydos project area to document potential changes to the presence of the PLNB and their habitats during the life of the mine, and to assess the effectiveness of Atlas Iron's management commitments. The Abydos project area covers an area of upland ironstone with a northern-facing escarpment just west of Strelley Gorge. Most records of the PLNB and Ghost Bat are centred on this ironstone feature, or areas immediately adjacent. These records probably derive from bats roosting in the Abydos area itself, as well the disused Lalla Rookh mine further east on Panorama Station. Bat colonies and suspected or possible bat roosts have been monitored annually for the life of the project in a standardised programme with acoustic recorders. Monitoring focussed not only on the presence and activity of bats, but also their potential response to nearby mining activity and the structural condition of their roosts. Four caves (named as A, B, D and H) were suspected to be used as diurnal roost sites by the PLNB on the basis of the activity patterns derived from measurements of the number of echolocation call sequences made at cave entrances. A range of management measures were implemented during mining. The mine is currently in care and maintenance.
GHD 2015b (2 November 2015) Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Pilbara Leaf-nosed Bat roost habitat survey.	Surveys were undertaken by GHD to locate and describe diurnal and maternity roost sites within two pre-determined search areas: the Blue Square (see Nickos Gorge area Figure 2) and Zane's Gorge for the PLNB. Report also includes the findings of opportunistic habitat assessments completed by GHD and FMGIB during November 2014 and habitat assessments and ultrasonic surveys completed by FMGIB during March and April of 2015. In excess of 52 caves with the majority being classified as potential nocturnal roosts, were surveyed. The habitat assessment did not confirm the absence of a maternity roost within the study area however one, Joe's Cave was classified as a diurnal roost. It was also determined that the likelihood of a maternity or diurnal roost occurring within the Blue Square would be limited to the south-west portion and southern boundary of the Blue Square, including Nicko's Gorge and possibly a small area of the north-east portion of the Blue Square associated with the tributaries of Black Boy Creek. The Blue Square also contains at least three large pools which in turn support riparian vegetation which provides an important resource for the PLNB. Although not located during the field survey, the

	<p>analysis of the ultrasonic survey data revealed that there may be a diurnal roost located within or immediately adjacent Nicko's Gorge. No PLNB were observed in any of the caves surveyed during the survey period, however two other species were regularly recorded roosting within different cave habitats (<i>Taphozous georgianus</i> and <i>Vespadelus finlaysoni</i>). The Ghost Bat (<i>Macroderma gigas</i>) was recorded at two sites during the survey.</p> <p>The FMGIB surveys conducted during March and April of 2015 within the mining footprint at North Star identified one cave that may be a potential diurnal roost cave (Chateau Cave).</p>
GHD 2016a (26 July 2016), Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Cave 13 Pilbara Leaf-nosed Bat Survey.	GHD completed roost occupancy surveys for the PLNB within Cave 13, Chateau Cave and Joe's Cave during February 2016 during the breeding season. The surveys used the Roost occupancy surveys using the method described in the Survey Guidelines for Australia's Threatened Bats (DEWHA 2010); ultrasonic detection and cave habitat assessments. Temperature and humidity data was also reviewed for each of the caves. PLNB were recorded within Chateau Cave but not with Joe's Cave or Cave 13. Following a review of the results, the following categories were proposed for each site: Cave 13 - Transitory diurnal roost; Chateau Cave - Possible Non-permanent breeding roost or Permanent diurnal roost; Joe's Cave – Transitory diurnal roost.
GHD 2016b (21 September 2016), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Chateau Cave, Cave 13 and Joe's Cave - Pilbara Leaf-nosed Bat surveys including roost occupancy surveys.	GHD completed roost occupancy surveys for the PLNB within Cave 13, Chateau Cave and Joe's Cave during September February 2016 during the breeding season. The surveys used the Roost occupancy surveys using the method described in the Survey Guidelines for Australia's Threatened Bats (DEWHA 2010); ultrasonic detection and cave habitat assessments. PLNB were recorded within Chateau Cave but not with Joe's Cave or Cave 13. The results confirmed the preliminary categorisation of the caves from earlier in 2016: Cave 13 - Transitory diurnal roost; Chateau Cave - Possible Non-permanent breeding roost or Permanent diurnal roost; Joe's Cave – Transitory diurnal roost.
GHD 2017b (17 January 2017), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Roost emergence survey and roost count for Pilbara Leaf-nosed Bat - Chateau Cave, North Star Mine 14 - 18 November 2016.	GHD completed a roost emergence surveys to estimate the population size of the colony of PLNB that inhabit Chateau Cave. The roost survey was completed from the 14 – 18 November 2016 using a full spectrum ultrasonic recorder, infrared camera (IR cameras) and bat counter (the Apodemus BatCounter) with the aim of recording the ingress/egress of bats at the entrance of the main chamber of Chateau Cave during the roost emergence period from sunset for approximately one hour. The bat counter was also used to count 'passings' for the entire night. Manual observation counts of the IR camera recording and comparison with ultrasonic call data post survey were undertaken in an attempt to validate the 'passings' logged by the bat counter. The preliminary estimate of the population size of the PLNB colony occupying the main chamber of Chateau Cave during the November 2016 is up to 120 individuals. Further survey and analysis required to validate these findings.
GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report.	The trapping and radio-tracking program focussed on the area between and in the vicinity of Chateau Cave and Joe's Cave including the majority of the North Star mining development and associated infrastructure envelope during July 2017. At total of 51 bats of three species were captured including 7 PLNB which 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. Further information is provided in this report.
GHD 2019 (review of ultrasonic data from	GHD have reviewed the ultrasonic data from the SM2 unit placed within the main chamber of Chateau Cave. Between 10 – 13 July 2018 a bushfire burnt large portions of the North star area including up to the front of Chateau Cave (approximately the 10 – 11 July

Chateau Cave for the 5-17 July 2018) – data analysis (no report)

2018). Data was reviewed for a 13-day period (5 – 17 July 2018). The data analysis revealed that PLNB were present within the main chamber of the cave for the 13-day period. Furthermore, analysis revealed that PLNB were active within the main chamber for each night of the 13-day period. An analysis of the first PLNB call for each night revealed that for nine of the 12 nights (including the 9 – 13 July 2018) first calls occurred before civil twilight (e.g. before the emergence period). For the remaining three nights first calls were within 2 – 3 minutes of civil twilight. Calls recorded prior to civil twilight indicate bats were occupying the cave prior to the emergence period. An analysis of the last PLNB call for each night revealed that for nine of the 12 nights (including the 9 – 13 July 2018) the last call was past civil twilight (between 10 and 30 minutes) indicating that there was PLNB activity within the main chamber during the daylight period, which in turn confirms occupation of the main chamber by PLNB.

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

There has been a concerted effort since early 2014 to categorise known roost sites and locate additional roost sites within the North Star mine study area. The approach to locate and categorise these sites has included a combination of desktop and field survey techniques (e.g. preliminary roost habitat assessments and targeted sheeting surveys to confirm occupancy of PLNB within roost sites). Figure 2 displays the approximate extent of the area searched for roost sites considering all the surveys undertaken to date including results from 2014 – 2020. Since 2018 additional surveys have been undertaken in the South Star and Glacier Valley area generally located south and south-west of the North Star MDE.

### 2.2.1 Known diurnal roost sites

Cave occupancy surveys for the PLNB within Cave 13, Joe's Cave and Chateau Cave during February and September 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 Pilbara Leaf-nosed Bat (TSSC 2016) and the DoTE (2019). One other location within the study area is known to support diurnal roosts (Abydos mine).

**Cave 13** – Category: *Transitory diurnal roost*. The information reviewed to date suggests Cave 13 is a natural cave 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 by GHD. A recent review of long-term ultrasonic data by Specialised Zoological (2018) also supports these findings and that this cave is most likely to function as a 'nocturnal refuge' and at times a 'transitory diurnal roost' for PLNB.

**Chateau Cave** - Category: *Permanent diurnal roost*. The results from the cave occupancy surveys undertaken in February and September 2016 by GHD 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 natural 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). Furthermore, a recent review of long-term ultrasonic data by Specialised Zoological (2018) also suggests that this cave most likely functions as a 'permanent diurnal roost' that has an important role in the breeding cycle for the PLNB.

**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 that this natural 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. A recent review of long-term ultrasonic data by Specialised Zoological (2018) suggests that this cave is likely to function as a 'permanent diurnal roost' or 'non-permanent breeding roost' for the species, however the long-term monitoring data did not consider the other assessments undertaken of Joe's Cave including the occupancy surveys and habitat assessment. The categorisation of 'transitory diurnal roost' is maintained with consideration of all the information reviewed.

**Abydos Mine Project, Atlas Iron** – is located approximately 15 km north-east of Cave 13 (see Figure 1 and 2). Four caves were suspected to be used as some type of diurnal roost (not categorised) by the PLNBs. The caves were retained and excluded from the development area and buffers were established preventing any works within 50 m of the caves. Atlas Iron established a significant species management plan which included actions to monitor PLNBs within the caves.

### **2.2.2 Other roost locations**

Surveys undertaken within the North Star mine study area, outside the mining development envelope since November 2014 have identified several areas of interest, which may harbour potential roost sites. The detailed methods and results of these surveys are documented in:

- GHD 2015b (2 November 2015) Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Pilbara Leaf-nosed Bat roost habitat survey
- GHD 2016a (26 July 2016), Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Cave 13 Pilbara Leaf-nosed Bat Survey
- GHD 2016b (21 September 2016), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Chateau Cave, Cave 13 and Joe's Cave - Pilbara Leaf-nosed Bat surveys including roost occupancy surveys
- GHD 2017c (9 February 2017), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Alternate roost survey - west of Zane's Gorge from the 14 – 17 November 2016
- GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report
- GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat
- GHD 2020 (February 2020), Unpublished report for Fortescue Metals Group Iron Bridge – Glacier Valley and South Star Fauna Surveys: Fauna Survey report results

Table 2 identifies locations that could provide potential diurnal roosting of some type (including possible permanent diurnal roost, non-permanent breeding roost, or transitory diurnal roosts). The location of each roost is provided in Figure 2. Nocturnal refuge roosts have not been included as these locations are unsuitable for roost augmentation.

#### **Blue Square/ Nicko's Gorge area**

A total of 27 sites were assessed across the study area in January and February 2015 by GHD within the Blue Square and Zane's Gorge areas. Some sites consisted of a single cave, and others consisted of multiple caves, thus in excess of 52 caves with the majority being classified as potential nocturnal roosts, were surveyed.

Nicko's Gorge is a large gorge system located at the bottom of a valley in the south-west corner of the Blue Square. The gorge contains a pool and ephemeral waterfall, which in turn supports aquatic, semi-aquatic and riparian vegetation including a large stand of *Melaleuca*. The gorge is formed from very steep, sometimes sheer walls / cliffs which provides more than 30 sites (overhangs, small caves, large caves) of which at least half could not be investigated due to their location and safety constraints. The valleys and ephemeral creeks leading into and extending away from the gorge are generally well vegetated and would provide good foraging opportunities for the PLNB.

No PLNB were observed in any of the caves surveyed during the survey period, however two other species were regularly recorded roosting within different cave habitats (*Taphozous georgianus* and *Vespadelus finlaysoni*). The conservation significant Ghost Bat (*Macroderma gigas*) was recorded at two sites during the survey. Although not located during the field survey, the analysis of the ultrasonic survey data revealed that there may be a diurnal roost located within or immediately adjacent Nicko's Gorge.

Given the results of the surveys undertaken to date (GHD 2015b and GHD 2016a) it is possible that a PLNB 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 (Figure 2, Table 1). 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.

### **Joe's Cave/ Zane's Gorge area and west**

More than 50 locations have been searched within the Joe's Cave / Zane's Gorge area since November 2014 for roost sites. As part of the November 2016 surveys, 39 locations were recorded and investigated. An addition nine locations were recorded to the north-east of Joe's Cave during the radio-tracking survey undertaken in June 2017. These sites are presented in Figure 2 and Table 2. All sites were subject to a preliminary habitat assessment.

The key findings from the November 2016 field survey were:

- The preliminary habitat assessments recorded five sites that require further investigation. Three of the sites could not be appropriately accessed but appeared to contain some potential habitat (e.g. a large opening with a deep passage) for support roosting (e.g. temporary diurnal or maternity) opportunities
- Two sites – unknown cave 1 (UC1) and Bone Cave were given a preliminary categorisation of 'transitory diurnal roost' (TSSC 2016), given the architecture and potential microclimate habitat of the cave. Further survey is required to confirm this categorisation
- Ultrasonic call analysis revealed the three sites with water recorded PLNB activity within 15 minutes of civil twilight ending (18:48 +/- 5 minutes)
- 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' (TSSC 2016)
- No PLNB were recorded in roosts during the survey, although the threatened Ghost Bat was recorded at three locations via direct observation or scats during the survey
- The field assessment and review of geological information suggests the area searched has the capacity to provide roosting habitat for the PLNB.

The results of the radio-tracking surveys undertaken in June 2017 (GHD 2017f) strongly suggest other diurnal roosts likely exist 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 key findings from the June 2017 base station radio-tracking survey were:

- Tag 104 was recorded from two detections (16 and 23 June) approximately 15 minutes after civil sunrise from JJ's base station located approximately 1.5 km east of Joe's base station and 6.5 km west of Chateau Cave. Both records were from antenna 1 (orientation, north by north-west) toward an area (east of Joe's Cave/ Zane's Gorge) containing

potential diurnal roosting habitat (GHD 2017c). Given the timing of the detections it is possible the bat was flying to, and possibly in very close proximity to a diurnal roost

- Tag 106 was captured and released at Chateau Cave on the 13 June 2017 and was recorded from three detections (18, 19 and 20 June) at Joe's Cave (c. 8 km's west of Chateau Cave) and Matt's base station (c. 1 km west of Joe's Cave base station) within 5 to 10 minutes of civil sunset. The detections at Joe's Cave base station for the three nights were approximately 1-2 minutes earlier than the detections at Matt's base station. Most of the detections from Joe's Cave base station 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 base station were from Antenna 1 (orientated north-east). The number of consecutive nights (three) and the multiple detections of similar timing (+/- 5 minutes), coupled with the signal strength and antenna orientation suggests that Tag 106 was roosting within or near Joe's Cave. It is worthwhile noting that the detections at JJ's base station were at least 15 minutes past the first detection at Joe's or Matt's base station 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 minutes of civil sunrise 23 June 2017 at Joe's Cave and JJ's base station (both Antenna 1 orientated north and north by north-west). Given the timing or 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
- Tag 110 was captured and released at Joe's Cave on the 20 June 2017 and was recorded from two single detections approximately 10 mins after civil sunrise at Japal base station on 24 and 25 June 2017. Both records were from Antenna 2 (orientation, south-west). Given the timing or 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 base station 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.

Manual (hand-held) radio-tracking was also undertaken to supplement the base station survey effort. The search for potential roost sites focussed on the area north-east of Joe's Cave. Key findings include:

- Two locations were determined potential diurnal roosts (RS1 and RS4). 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 base station 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
- Two additional locations, 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.

#### **North of the ore processing facility (OPF)**

At least one of the tagged bats (Tag 107) was active outside the reception range of the receivers for large portion of the radio-tracking survey, indicating the presence of another roost location.

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. Tag 107 was also active within the reception range of the OPF base station (northern most situated base station) 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 base station (e.g. in the vicinity of the Abydos Mine area).

### **Glacier Valley and South Star area**

GHD investigated more than 40 locations (e.g. slopes, gorges and near the top of ridges and plateau's) on foot and/or by helicopter when undertaking searches for potential cave habitat. There are approximate 14 locations within the Glacier Valley MDE that have been identified as potential cave habitat; however, have not been investigated to date (e.g. not accessible), therefore the precautionary approach applies and it has been assumed that these areas may have potential for diurnal roosting habitat.

At least 13 sites (all within the proposed Glacier Valley MDE) were investigated and determined to provide potential nocturnal refuge for the PLNB, with three of these sites also providing potential temporary diurnal roosting habitat.

**Table 2: Summary of potential roosting locations recorded to date (note: known nocturnal refuge roost and locations not included)**

Location	Site name (map label)	Altitude (m)	Type of roost	Date	Tenement
Nicko's Gorge	Nicko's Gorge	Approx 250 (floor)	Multiple potential roost locations	9/1/2015	Other
Nicko's Gorge	C14BS	261	Potential nocturnal refuge and temporary diurnal roost	9/1/2015	Other
Nicko's Gorge	C19BS	292	Potential nocturnal refuge and temporary diurnal roost	9/1/2015	Other
Blue Square	C8BS	331	Potential roost location unknown type – most likely transitory diurnal or nocturnal refuge roost	9/1/2015	Other
Joe's Cave/ Zane's Gorge area	Unknown cave 1 (UC1)	-	Potential roost location unknown type – most likely transitory diurnal or nocturnal refuge roost	Nov 2016	Other
Joe's Cave/ Zane's Gorge area	UC2	-	Potential roost location unknown type	Nov 2016	Other
Joe's Cave/ Zane's Gorge area	UC3	-	Potential roost location unknown type	Nov 2016	Other
Joe's Cave/ Zane's Gorge area	Giant's Cave	-	Potential roost location unknown type	Nov 2016	Other
Joe's Cave/ Zane's Gorge area	Bone Cave	-	Potential roost location unknown type Known Ghost Bat roost	March 2015 and Nov 2016	Other
Joe's Cave/ Zane's Gorge area	Vertical cave	-	Potential roost location unknown type	March 2015	Other
Joe's Cave/ Zane's Gorge area	Cliff cave	-	Potential roost location unknown type	March 2015	Other

Joe's Cave/ Zane's Gorge area	RS1	352	Possible transitory diurnal roost	22/06/17	Other
Joe's Cave/ Zane's Gorge area	RS3	352	Potential roost location unknown type	22/06/17	Other
Joe's Cave/ Zane's Gorge area	RS4	367	Possible transitory diurnal roost	22/06/17	Other
North Star MDE or adjacent	Wallaby Cave	Approx 340	Potential roost location unknown type Known Ghost Bat roost	March 2015	FMG
North Star MDE or adjacent	Wayne Manor	313	Potential roost location unknown type	21/2/15	FMG
South of North Star MDE	Python Cave	364	Potential nocturnal refuge PLNB Known Ghost bat roost	February 2016 May 2018	FMG
South of North Star MDE	Glacier Valley MDE 12	327	Potential nocturnal refuge and temporary diurnal roost for PLNB	May 2018	FMG
South of North Star MDE	Glacier Valley MDE 16	379	Potential nocturnal refuge and temporary diurnal roost for PLNB	May 2018	FMG
South of North Star MDE	Glacier Valley MDE South Pool	Approx 320	Potential nocturnal refuge and temporary diurnal roost for PLNB Known Ghost Bat roost	May 2018	FMG

## 2.3 Understanding Pilbara Leaf-nosed Bat movements within the North Star area

GHD developed and implemented a radio-tracking program in 2017 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) (GHD 2017f).

The radio-tracking program focussed on the area between and in the vicinity of Chateau Cave and Joe's Cave (situated approximately 8 km apart) including the majority of the North Star MDE.

Seven PLNB were fitted with digitally encoded transmitters and monitored using an array of 11 base stations (stationary data logging receivers) for between seven 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 an alternate roost location. To supplement and validate the findings of the base stations, active searches for transmitters with handheld receivers were also completed.

### 2.3.1 Movement between known and alternate roost locations

The 2017 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.

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 to suggest 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 14 June 2017 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 June and 06:30, 23 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 June, 17:57-19 June, and 18:00-20 June 2017) 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 June 2017 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.

The lack of data from 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.

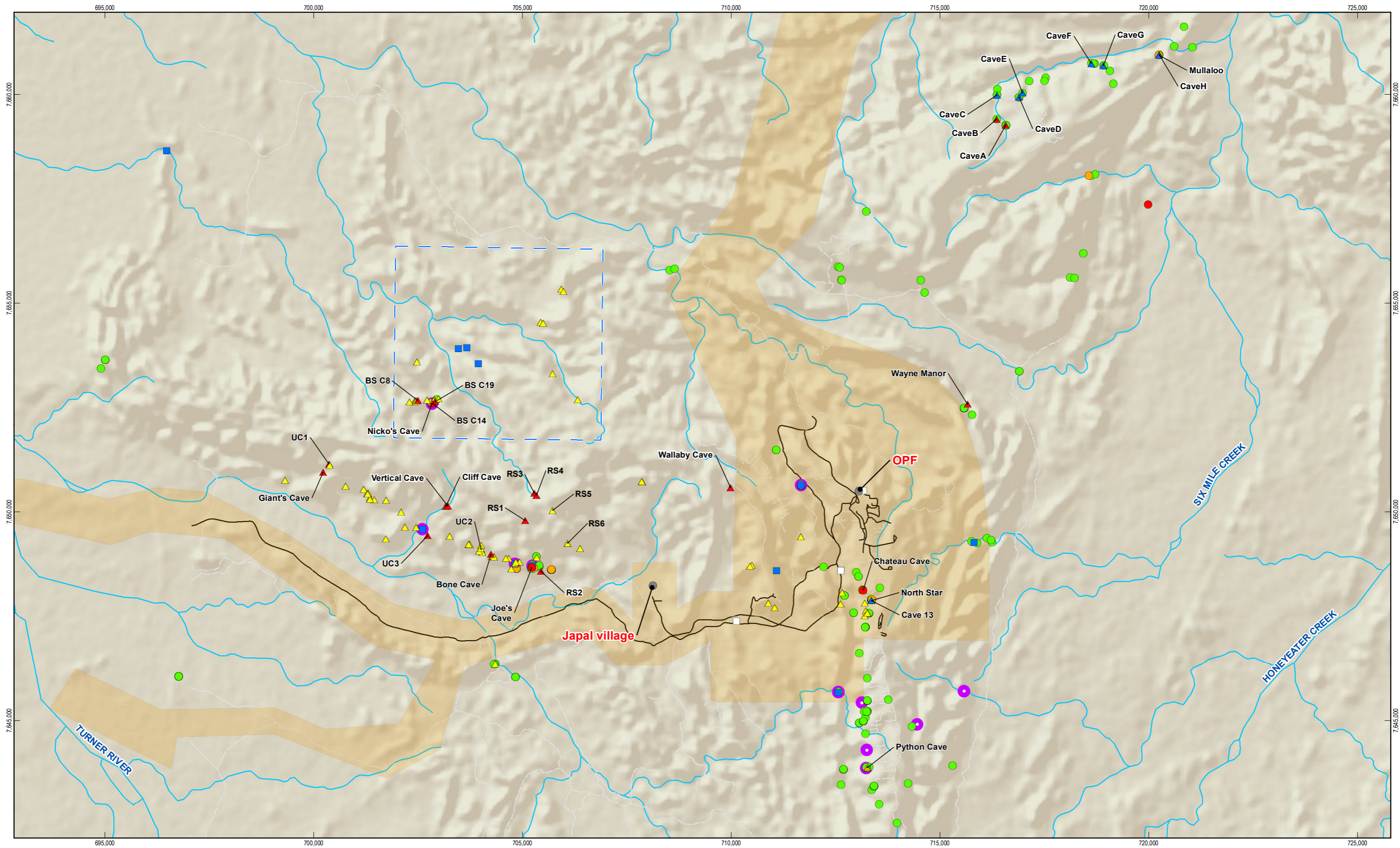
The information reviewed from the survey suggests that other roost(s) could be in the vicinity of Joe's Cave/Zane's Gorge, probably within 3-4 km of Joe's Cave/Zane's Gorge in an area spanning from the north through to north-east.

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-west of the ore processing facility (e.g. Abydos Mine area).

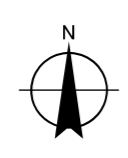
### **2.3.2 Nightly activity and inferred movement patterns**

The detection data demonstrated that all tagged bats occurred within the reception range of the base station receivers for at least five 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.



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



- ▲ Potential diurnal roost - unknown category
- ▲ Potential transitory diurnal roost
- ▲ Nocturnal refuge
- ▲ Specimen (trap or voucher)
- ▲ Observation (cave or flying at night)
- Detector record
- ▲ Transitory diurnal roost
- Specimen (trap or voucher)
- Observation (cave or flying at night)
- Detector record
- ▲ Permanent diurnal roost or Non-permanent breeding roost
- Observation (cave or flying at night)
- Detector record
- Detector record (+/- 20 min civil twilight)
- Artificial pool
- Natural pool
- FMGIB Development Envelope
- Road; Haul Road
- Minor Track; Drill Line
- Blue Box Study Area



Fortescue Metals Group Ltd  
 Review of bats for FMG operations  
 Job Number 61-37868  
 Revision 0  
 Date 29 May 2020  
**Known and potential roost locations and records for Pilbara Leaf-nosed Bat in project area**

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 Data source: Geoscience Australia: GeoData Topo 250k Series III; FMG Ltd: Study Areas - 20161028, Roads, tracks - 20170330; GHD: Pools, Bat records - 20170328; Landgate: Aerial photography (Virtual Mosaic) - 20171122. Created by:kaadams Service Layer Credits: Copyright(c) 2014 Esri

999 Hay Street, Perth WA 6000 Australia T 61 8 6222 8555 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au  
**Figure 2: Pilbara Leaf-nosed Bat roost locations and other records within the study area**

Figure 2

## 3. Methods

The field survey team comprised GHD Senior Ecologists Craig Grabham, Glen Gaikhorst, Robert Browne-Cooper, Lisa Cawthen, Brad Maryan and GHD Ecologists Madison Roberts, and Nicola Barratt. GHD was supported by FMG Environment Advisors including Shariff Zayan Jonathan Tester, Christopher Brien, Kate Thomson, and Gary Lazzaroff, and Njamal Traditional Owner, Brandon Geary.

The survey was conducted under “Licence to Take Fauna for Scientific Purposes” (Regulation 17) Licence No. BA27000181 and Animal Research Authority (Project number GHD: 12516477).

Field surveys were undertaken between 6 to 13 November and 25 November to 18 December 2019. A summary of the field survey methods is provided below, with the results of these surveys presented in Section 4.

### 3.1 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 various locations over the course of 10 nights. Sheets and other objects (e.g. large leafy branches) were used to funnel bats into the harp traps where possible. Examples of the Harp traps set-up are presented in Plates 1 - 4, with the location of each harp trap included in Figure 3. Table 3 summarises the location of each site.

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.

An EcoMeter Touch microphone (EMT, Wildlife Acoustics) 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, and species identification.

**Table 3: Harp trap locations**

Location	Latitude	Longitude	Figure 3 Map reference
Joes Cave – front of cave and cliff face	118.9776307	-21.2523	Trap 1
Jimmy’s Gap – dry creek, riparian vegetation	119.04605	-21.2513	Trap 2
Dry creek and riparian vegetation, near turkeys nest south of Joes Cave	118.967034	-21.2672	Trap 4
Shariff’s Pool on creek – pool along otherwise dry creek	118.904691	-21.2336	Trap 3
Chateau Cave - front of cave and cliff face			Trap 5
Creek and spring, near pool between base station 5 and 6	119.048132	-21.1879	Trap 6



**Plate 1: Installing harp traps at Joes Cave**



**Plate 2: Harp trap configuration and sheets – Joes Cave**



**Plate 3: Harp traps over water at Shariffs Pool – west of Joes Cave**



**Plate 4: Installing harp traps along cliff next to Chateau Cave**

## 3.2 Radio tracking

### 3.2.1 Transmitters

Eight PLNB were fitted with digitally encoded transmitters (see Plates 5 - 8). Each transmitter has a unique digital signature (code ID – see Table 4) 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-2.2 Nano Tag; 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). The transmitter was attached between the shoulder blades below the neck with degradable glue (VetBond, 3M). The transmitters have a pulse rate of 2 seconds resulting in a battery life of 18-20 days.

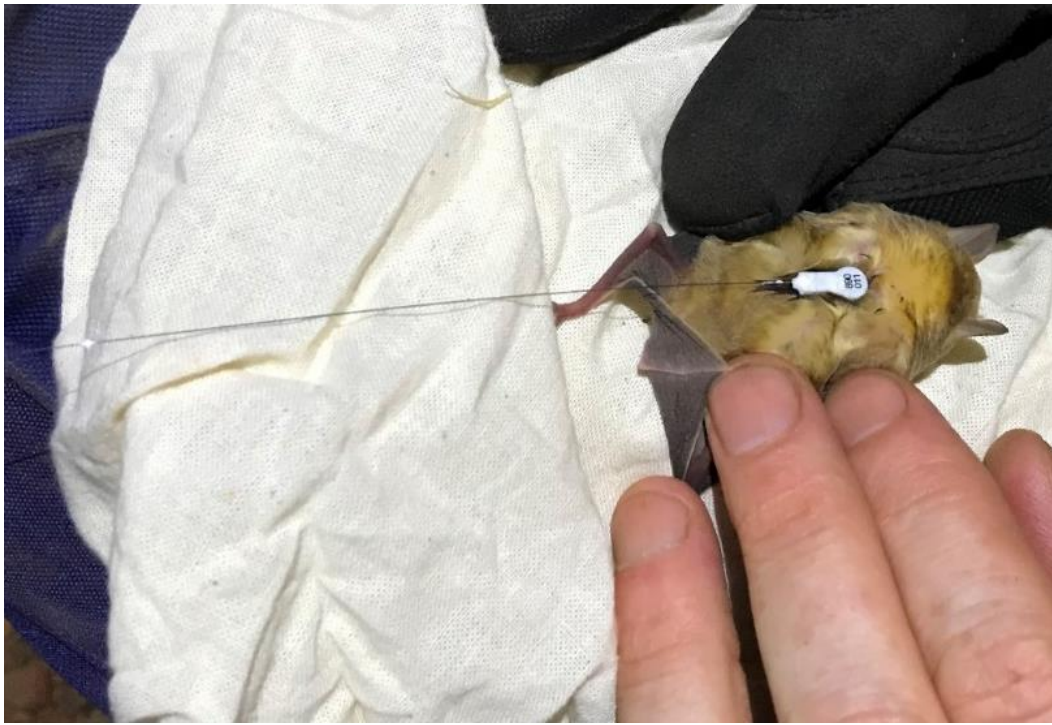
**Table 4: Transmitter (tag) details 2019**

Tag code ID	Start time/date	End time/date	Number of nights detected by base stations
19	20:10 - 29/11/19	04:20 – 10/12/19	7 of 18 nights
20	21:30 - 29/11/19	03:11 – 12/12/19	14 of 18 nights
22	20:55 - 29/11/19	19:12 – 30/11/19	1 of 18 nights
23	21:05 - 29/11/19	22:00 – 15/12/19	10 of 18 nights
24	21:40 - 29/11/19	21:30 – 15/12/19	5 of 18 nights#
25	21:55 - 29/11/19	20:58 – 15/12/19	5 of 18 nights#
10	19:45 - 2/12/19	22:10 – 07/12/19	4 of 16 nights
11	20:40 - 2/12/19	04:20 – 17/12/19	15 of 16 nights

Notes: Start time/date – approximate 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. # see limitations Section 4.2.5



**Plate 5: Application of transmitter (Tag 10)**



**Plate 6: Pilbara Leaf-nosed Bat being fitted with transmitter (Tag 11)**



**Plate 7: Pilbara Leaf-nosed Bat being fitted with transmitter (Tag)**



**Plate 8: Pilbara Leaf-nosed Bat with tag just prior to release**

### **3.2.2 Base station receivers**

After release bats were tracked using an array of 8 base stations (SRX 800-D1 stationary data logging receivers, Lotek Wireless Inc., Newmarket, Ontario, Canada) for between 1 and 18 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 any alternate roost locations. The location of each base station is displayed in Figure 3. The typical setup of the base stations is shown in Plates 9, 10 and 11.

The receiver at each base station was connected to 3 or 4 Yagi antenna (utilising either 3 or 6 elements) positioned at heights between 3.5 and 7 metres above the ground. The antenna array and orientation for each base station is detailed in Appendix A. Antennas were monitored on alternating cycles of 3-5 seconds depending the number of antenna, 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 study area, but also in some circumstances allowing for overlap.

Receivers were set to record between 16:00 and 09:00 each day 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) 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 2017) and the 2017 survey as described in Appendix A.

Tests revealed a direct LOS detection radius of at least 8.3 km for the three-element antennas and approximately 8.1 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).

**Table 5: Base station details**

Name and Figure 2 reference	Operational dates	Base station (BS) elevation, position
1. Rise	29/11/19 – 15/12/19 (14 nights)	358 m / on top of small knoll approx 300 m from Chateau Cave in valley
2. Joe's Cave	29/11/19 – 17/12/19 (18 nights)	319 m / on top of BIF, southern facing cliff edge, approximately 90 m due west of Joes Cave.
3. OPF	29/11/19 – 17/12/19 (18 nights)	381 m / On top of small BIF knoll approx 300 m from the ore processing facility.
4. South Star Pool	29/11/19 – 16/12/19 (17 nights)	381 m on top off BIF western facing cliff edge
5. North – (west)	29/11/19 – 16/12/19 (17 nights)	235 m situated in large open valley south of Abydos mine
6. North - (east)	12/12/19 – 16/12/19 (4 nights)	344 m on top off BIF southern facing cliff edge
7. Shariff's Pool	29/11/19 – 16/12/19 (17 nights)	289 m on top off BIF southern facing cliff edge
8. Wallaby	29/11/19 – 16/12/19 (17 nights)	367 m on top of BIF topographical point.

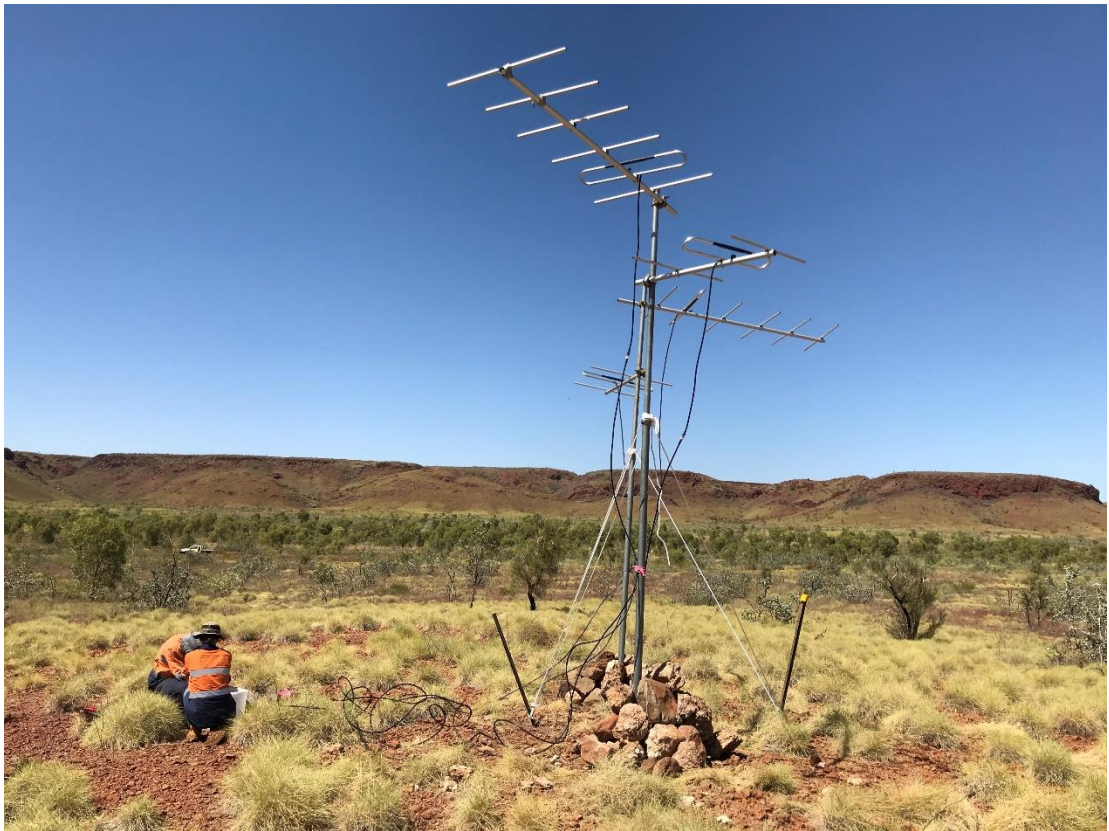
NOTE: the date range does not reflect operational effort (see Table 8).



**Plate 9: Maintenance of base station 5 north-west**



**Plate 10: Base station 2 – Joes Cave**



**Plate 11: Base station 6 – North-East**

### 3.2.3 Manual (mobile) tracking

To supplement and validate the base station data, night-time and day-time searches for transmitters were conducted with handheld receivers (SRX 800-M2 receiver, Lotek Wireless Inc) each with one three-element Yagi antenna. Figure 4 displays the search area covered by the manual tracking. Each search was undertaken by at least two people.

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. A helicopter was used to access areas north of Joes Cave and the OPF.

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 19, Section 4.2.7.



**Plate 12: GHD ecologist undertaking mobile tracking east of Joes Cave**

### 3.2.4 Data processing and analysis

#### Data processing

Data (.bin file) from each base station was downloaded via the SRX800 Host User software package (V1.2.1.1975.1). The .bin file was converted to text document using the Host User text conversion function. Text files for each base station were converted to Microsoft Excel for review and analysis.

Prior to analysing the data, tag detections for each base station were reviewed for potential errors (e.g. false detections) and outliers. These dubious detections were discarded from further analysis. Dubious detections may include:

- a. A single tag detection without consecutive detections recorded from the same tag within 60 seconds on the same base station
- b. Tag detections outside the time period when bats are active (e.g. between 6 pm and 6 am), noting that consistent detections during non-active hours may also reveal roosting bats or a dropped tag
- c. Tag detections that appear valid but are recorded following a large absence of activity and not consistent with previously recorded activity (e.g. activity following 2 or more nights without detections).
- d. Tag detections recorded at the same time on different base stations located 8 km apart or within known reception obstructions or by antenna on base stations that are not orientated toward each other.

#### Data analysis

Where possible the following was discussed for each tagged bat using the reviewed data.

First and last detection times – analysis of the timing of the first and last transmitter detections with regard to civil twilight (near sunset and sunrise) times were undertaken for each tagged bat to assist with determining 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 of tag detections from all base stations closest to civil twilight for each night for the survey period. This information is presented in table format for each tagged bat in the results section. Times highlighted in green are within 5 minutes (+/- 1 min) of civil twilight (following sunset) and before sunrise, with a theoretical flight distance of c. up to 1.8 km (e.g. the bat is capable of flying c. 1.8 km at 22 km/h within 5 mins). Times highlighted in blue are within 5-10 mins (+/- 1 min) of civil twilight (following sunset) and before sunrise, with a theoretical flight distance of between c. 3.6 km and 7.2 km. Times highlighted in yellow are from 10-20 minutes (+/- 1 min) of civil twilight (following sunset) and before sunrise, with a theoretical flight distance of at least 7.2 km. Theoretical flight distances are 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.

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. For the purpose of displaying short valid bouts of activity (e.g. 3 tag detections in one minute) that are isolated by more than 10 minutes from the next valid detection on the bar chart. The data is displayed as a minimum of 5 minute blocks of activity.

This assists with the visual tracking of the data at the scale the charts are presented, however in some cases may make the activity period appear continuous or slightly longer than it is displayed.

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.

Scatterplots were then stacked starting with Chateau Cave (for Tags 19, 20, 22, 23, 24, 25) or Joe's Cave (Tags 10 and 11) which represent the point of capture and release 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.

### **3.3 Roost searches (cave habitat assessments)**

Cave habitat assessments were undertaken in conjunction with manual tracking surveys for the purpose of locating tagged bats and identifying roosts. This process was greatly assisted by using a helicopter. Preliminary cave habitat surveys were undertaken for the PLNB according to the methods detailed in GHD 2017 (*North Star Magnetite Project – Survey Plan for Pilbara Leaf-nosed Bat*, Step 1 and Step 2. Unpublished report to Iron Bridge Pty Ltd).

When a potential roost location was identified GHD placed a full spectrum ultrasonic recorder for at least two consecutive nights to interpret patterns of activity in the context of the diurnal usage of the potential roost. Section 4.5 details the roost search effort and results.

### **3.4 Roost occupancy surveys**

A roost occupancy determination survey was undertaken of Chateau Cave using the non-invasive method described in the *Survey guidelines for Australia's threatened bats* (pp 63, DEWHA 2010) . Surveys were undertaken using a barricade (e.g. black sheet) in conjunction with full spectrum ultrasonic recorder on 16 December 2019 from 6.45 pm to approximately 8.00 pm during the maternity period for PLNB to see if the species was utilising the cave over this period. Section 4.6 details the roost occupancy survey effort and results.

### 3.5 Ultrasonic survey and bat call analysis

Bat calls were recorded during field surveys using in situ (stationary) full spectrum Song Meter (SM2 bat plus and SM4 FS, Wildlife Acoustics) and Anabat Swift detectors (Titley Scientific) at 19 locations in the study area. Section 4.7 provides a summary of the key results. Appendix D details the ultrasonic call analysis methods and results.

### 3.6 Weather and site conditions

Temperature, rainfall and humidity measured at the North Star weather station for the survey period is presented in Table 6 and Chart 1, with observational environmental data for the same period presented in Section 4.1. The sunrise and sunset times for the beginning and end of the radio tracking period are presented in Table 7.

**Table 6: Weather data for radio-tracking survey period**

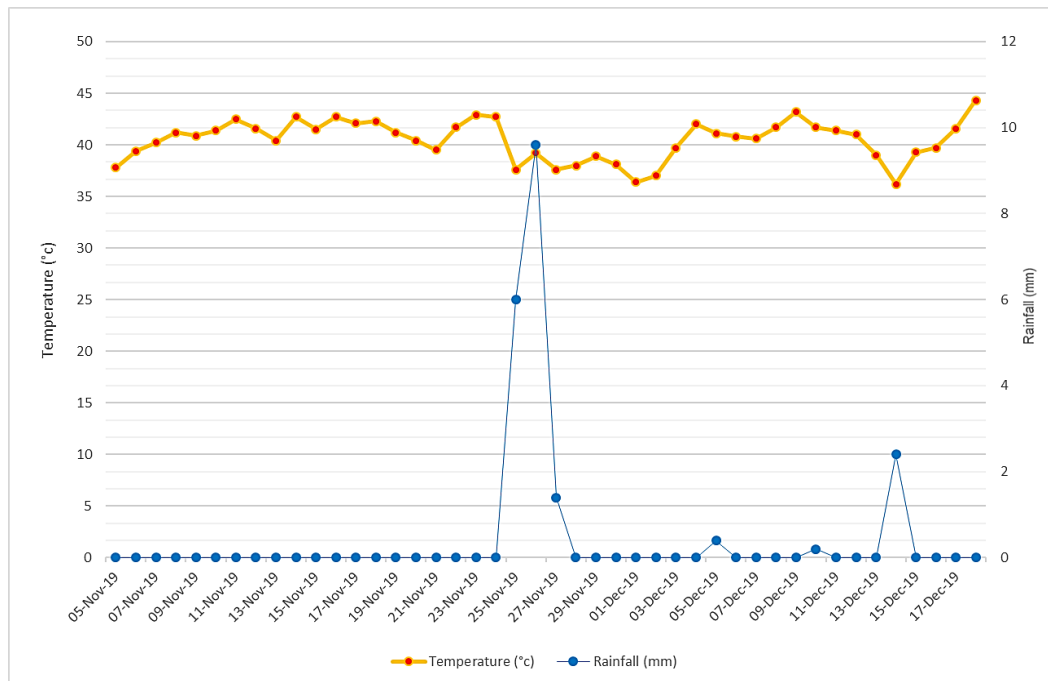
Date	Temperature (°c)		Total Rainfall (mm)
	Min	Max	
28-Nov-19	22.9	38	0
29-Nov-19	24.5	38.9	0
30-Nov-19	27.7	38.1	0
01-Dec-19	26.3	36.4	0
02-Dec-19	26.7	37	0
03-Dec-19	29.4	39.7	0
04-Dec-19	29.5	42	0
05-Dec-19	29.1	41.1	0.4
06-Dec-19	26.3	40.8	0
07-Dec-19	27	40.6	0
08-Dec-19	26.6	41.7	0
09-Dec-19	30.3	43.2	0
10-Dec-19	25.7	41.7	0.2
11-Dec-19	27.9	41.4	0
12-Dec-19	29.7	41	0
13-Dec-19	28.2	39	0
14-Dec-19	24	36.2	8.2
15-Dec-19	24	39.3	0
16-Dec-19	25.3	39.7	0
17-Dec-19	27.6	41.6	0
18-Dec-19	30.6	44.3	0

Source: weather data from Nates Tower IB operations

**Table 7: Sunrise and sunset times / Civil twilight times**

Date	Civil twilight rise	Sunrise	Sunset	Civil twilight set
28-Nov-19	4:49	05:13	18:30	18:55
29-Nov-19	4:49	05:13	18:31	18:55
30-Nov-19	4:49	05:13	18:32	18:56
01-Dec-19	4:49	05:13	18:32	18:57
02-Dec-19	4:49	05:13	18:33	18:57
03-Dec-19	4:49	05:13	18:33	18:58
04-Dec-19	4:49	05:13	18:34	18:59
05-Dec-19	4:49	05:14	18:35	18:59
06-Dec-19	4:49	05:14	18:36	19:00
07-Dec-19	4:49	05:14	18:36	19:01
08-Dec-19	4:49	05:14	18:37	19:01
09-Dec-19	4:50	05:15	18:37	19:02
10-Dec-19	4:50	05:15	18:38	19:03
11-Dec-19	4:50	05:15	18:39	19:03
12-Dec-19	4:50	05:15	18:39	19:04
13-Dec-19	4:51	05:16	18:40	19:05
14-Dec-19	4:51	05:16	18:40	19:05
15-Dec-19	4:51	05:16	18:41	19:06
16-Dec-19	4:52	05:17	18:42	19:06
17-Dec-19	4:52	05:17	18:42	19:07

Source: Australian Government –Geosciences Australia <http://www.ga.gov.au/geodesy/astro/sunrise.jsp>



**Chart 1: Daily maximum temperature (°C) and rainfall (mm) from 5 November to 18 December 2019 (source: IB Operations)**

### **Early November**

Weather experienced during the early November period was suitable for undertaking the surveys however the number of bats captured, regardless of species, was considered low given the level of survey effort and ideal location of trap sites (e.g. Joes Cave).

There are a number of plausible contributing reasons for the low number of bats captured including lack of PLNB, the main one being the bright moonlit nights (75% to 85% illumination). Other factors may include lack of post-wet rainfall in previous years, timing of survey and absence of nearby roosts.

From observations during the survey it is evident some bats could see and avoid the traps. Although the moon does not prevent PLNB from foraging (e.g. as evident from the activity recorded on handheld detectors) it possibly changes their foraging behaviour and in addition aids visual negotiation of the traps. The species may undertake shorter foraging bouts during the early evening before the moon had fully risen, and during early to late morning as the moon descends.

In the Pilbara, it is thought that breeding takes place in roosts where bats are present year-round (e.g. permanent diurnal roosts such as Chateau Cave), however some roosts (e.g. non-permanent breeding roosts) may also provide seasonal maternity habitat pending the environmental conditions (e.g. rainfall level). Given the drier conditions experienced during the post wet period it is possible that roosting opportunities for the PLNB have further reduced and the population including males and non-breeding females has contracted to roosts that provide suitable all year round microclimate conditions.

This point may be further exacerbated by reduced landscape productivity, resulting in a reduction of productive foraging habitat for the PLNB. Although difficult to gauge anecdotal observations by experienced Pilbara ecologists noted few animals active during the survey period and low insect activity, particularly flying insects (e.g. very few flying insects were encountered in the light of head torches during night surveys with the exception of Shariff's pool).

### **Late November - December**

Weather experienced during the late November through December survey period was highly variable and much less favourable for undertaking trapping and radio-tracking surveys (see Table 6 and Chart 1). Although the moon phase was probably more conducive to trapping, adverse weather conditions experienced during several nights (see Section 4.1) forced the cancellation of trapping and delayed the survey program. In addition strong winds and frequent rain impacted the performance of the base stations (see Section below).

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

## **3.7 Field survey and data limitations**

The survey was impacted by the adverse weather conditions, which resulted in gaps in the survey data and limitations regarding the analysis of the available data. The key causes of equipment failure and reduced base station performance include:

- Strong wind and/or heavy rainfall pushed over some towers. Data if available for the period the tower was down could not be relied on for accuracy regarding signal strength and direction.
- Strong wind and /or heavy rainfall caused several towers to lean, and/or swivel, impacting the reliability of the signal strength and direction component of the data.

Depending on the severity of the lean and swivel the data available for this period must be carefully interpreted and may not be relied on for accuracy.

- Rain infiltrated and filled the pole and elements of many antenna. Lotek was contacted to discuss the potential implications regarding this issue and advised that water inside antenna may impact signal direction and power, however it was unlikely to be significant. Testing was suggested to understand the extent of the potential impact, however this was not completed.

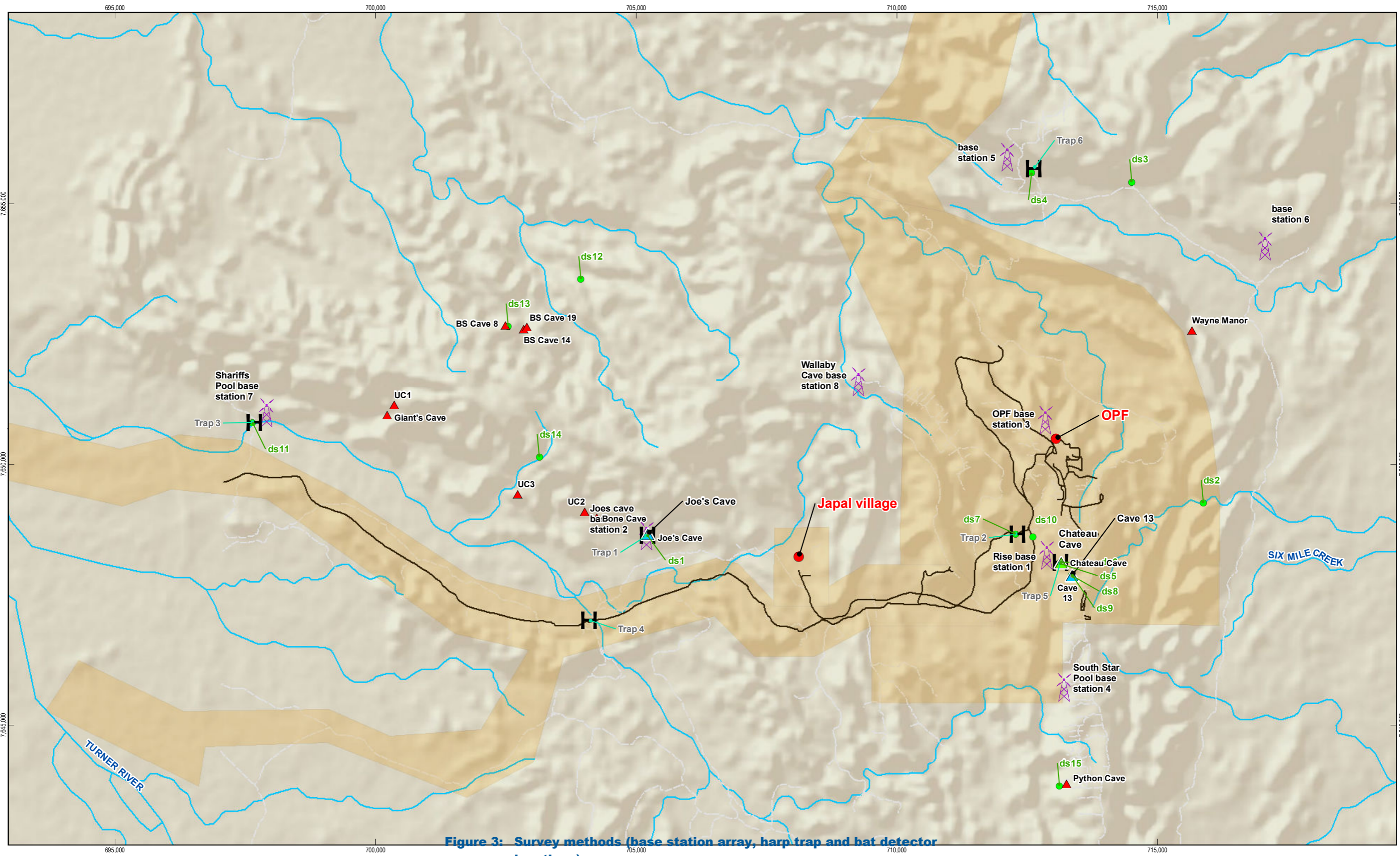
Table 8 summarises the operational issues recorded during the survey and the nights that require additional data scrutiny when interpreting the results. The line of sight testing completed during the survey (Appendix A) was used to assist with interpreting the survey data, however the testing did not always coincide with below mentioned changes to the position and orientation of the tower and therefore could not always be used to assist with interpretation of the data.

**Table 8: Operational issues – base stations**

Base station	Date of issue	Implications
1. Rise	30/11/19 approx. 8:30 am - Battery regulator flooded. Base station not operational for 2 nights (28-29 and 29-30/11/19). Repaired – 30/11/19 approx. 9 am	No data recorded for 28 and 29 /11/19.
2. Joe's Cave	a. Tower on a lean for at least 1 night, possibly 2 (29/11 and 30/11/19). Tower repositioned and re-erected with antenna at different orientation (see Appendix A). b. Minor ongoing adjustments were undertaken as tower was on slight lean and/or had swivelled (< 10 degrees) following heavy wind and/or rain despite tethering. c. During demobilisation water recorded in antenna.	Data to be carefully interpreted for the 29 and 30/11/12.  From the 2 – 17/12/19 direction and signal strength differences may occur therefore data to be carefully interpreted.
3. OPF	16/12/19 approx. 4.30 pm During demobilisation water recorded in antenna.	Signal strength and direction may be impacted, however unlikely to be significant.
4. South Star Pool	16/12/19 approx. 4.50 pm During demobilisation water recorded in antenna.	Signal strength and direction may be impacted, however unlikely to be significant.
5. North – (west)	11/12/19 Fallen base station, repositioned and re-erected 12/12/19 approximately 15 degrees off original orientation	Signal strength and direction cannot be relied on for the nights of the 10/12 and 11/12/19. From the 12/12/19 direction and signal strength differences therefore data to be carefully interpreted.
6. North - (east)	a. Fallen base station and ongoing technical issues with receiver. Receiver unit swapped and reprogrammed, new battery and new regulator installed 12/12/19. 17/12/19 approx. 3.20 pm b. During demobilisation it was noted the sunshade had been removed from the receiver (wind) exposing the unit to the sun. The receiver was flashing red (error function)	Base station was not recording data from 6-12/12/19.  No obvious data issues. Error most likely due to low battery power/issue with power supply.
7. Shariff's Pool (west of Giants Cave)	11/12/19 approx. 9:05 am. Base station found fallen after high wind during storm on previous night. Erected in original position and orientation	Signal strength and direction cannot be relied on for at least one night (10/12/19)
	17/12/19 approx. 7.50 am During demobilisation water recorded in antenna and the sunshade had been removed from the receiver (wind) exposing	Signal strength and direction may be impacted, however unlikely to be significant.

	the unit to the sun. The receiver was flashing red- error function	No obvious data issues. Error most likely due to low battery power/issue with power supply.
8. Wallaby	10/12/19. Fallen base station found and re-erected in original orientation. Approx 2 days since previous check	Signal strength and direction cannot be relied on for two nights (8/12 and 9/12/19)

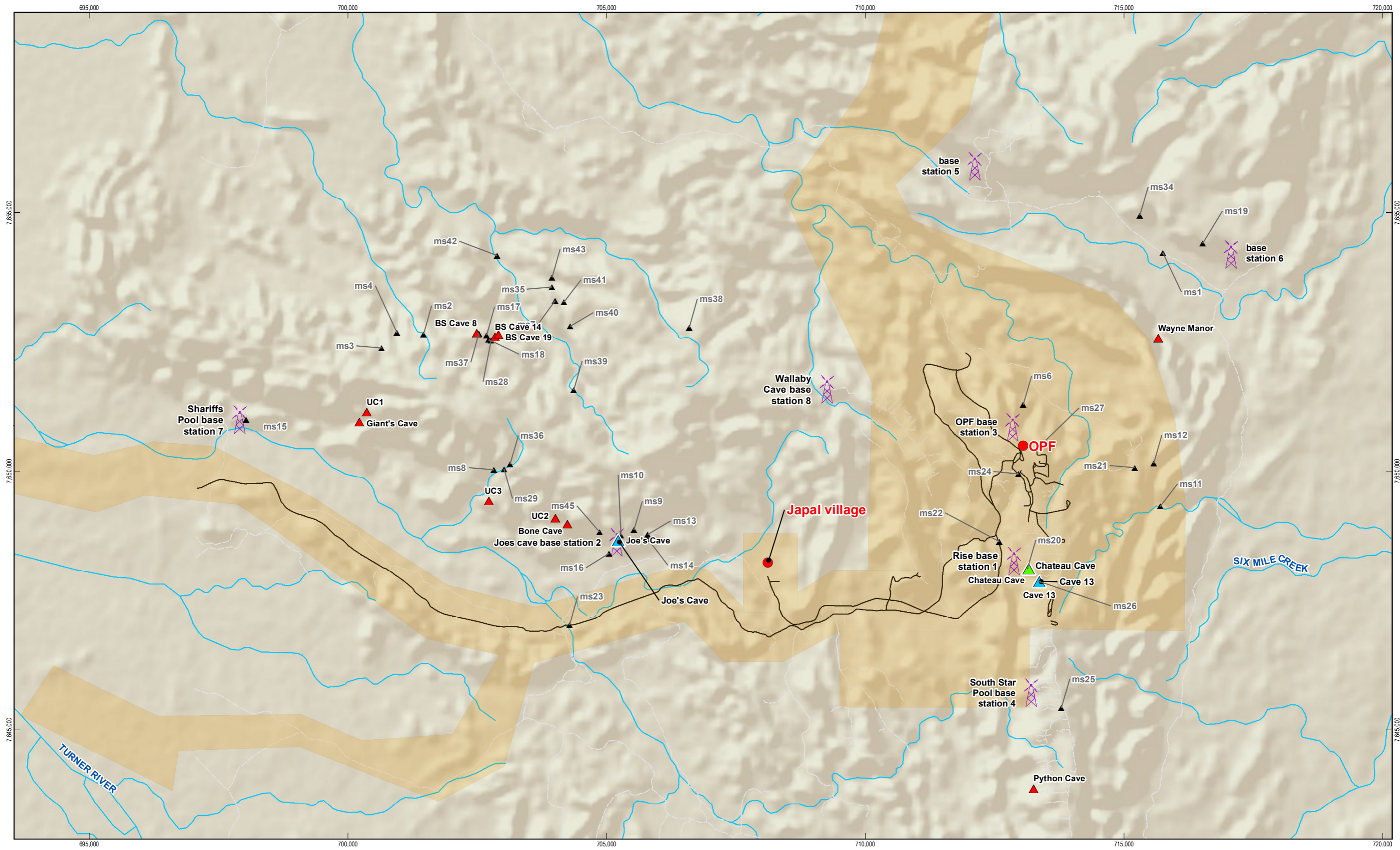
The terrain was prohibitive and it did constrain the survey design. For example, it was originally intended to place additional base stations north of the Joe's Cave/Zane's Gorge area in the blue square/Nickos Gorge area however this was not possible within the current scope of works due to the difficulties of accessing these areas (e.g. poor vehicle access 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, manual tracking with the aid of helicopter to access remote locations was undertaken in the area north-west 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.



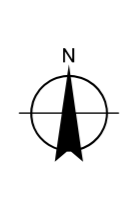
**Figure 3: Survey methods (base station array, harp trap and bat detector locations)**

<p>Paper Size A3</p> <p>Map Projection: Transverse Mercator Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 50</p>		<ul style="list-style-type: none"> <li> Bat Detector Location</li> <li> PLNB Base Station 2019</li> <li> Harp Trap Sites</li> </ul>	<ul style="list-style-type: none"> <li> FMGIB Development Envelope</li> <li> Road; Haul Road</li> <li> Minor Track; Drill Line</li> </ul>	<p><b>Bat Record</b></p> <ul style="list-style-type: none"> <li> Potential roost location unknown types (habitat assessment)</li> <li> Transitory diurnal roost</li> </ul>	<ul style="list-style-type: none"> <li> Permanent diurnal or non-permanent breeding roost</li> </ul>		<p>Fortescue Metals Group Ltd Review of bats for FMG operations</p> <p><b>Survey methods (base station array, harp trap and bat detector locations)</b></p>	<table border="0"> <tr> <td>Job Number</td> <td>61-37868</td> </tr> <tr> <td>Revision</td> <td>0</td> </tr> <tr> <td>Date</td> <td>29 May 2020</td> </tr> </table>	Job Number	61-37868	Revision	0	Date	29 May 2020
Job Number	61-37868													
Revision	0													
Date	29 May 2020													

**Figure 3: Survey methods (base station array, harp trap and bat detector locations)**



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



- ▲ Manual scan track point
- ▲ PLNB Base Station 2019
- FMGIB Development Envelope
- Road; Haul Road
- Minor Track; Drill Line
- Bat Record**
- ▲ Potential roost location unknown types (habitat assessment)
- ▲ Transitory diurnal roost
- ▲ Permanent diurnal or non-permanent breeding roost



Fortescue Metals Group Ltd  
 Review of bats for FMG operations

Job Number 61-37868  
 Revision 0  
 Date 29 May 2020

Methods (manual radio tracking)

Figure 4

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 © 2020. Whilst every care has been taken to prepare this map, GHD, FMG, GA, Landgate and Landsat make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.  
 Data source: Geoscience Australia: GeoData Topo 250k Series III; FMG Ltd: Study Areas - 20161028, Roads, tracks - 20170330; GHD: Pools, Bat records - 20170328; Landgate: Aerial photography (Virtual Mosaic) - 20171122. Created by:kaadams Service Layer Credits: Copyright(c) 2014 Esri

## 4. Survey results

### 4.1 Bat trapping

#### 4.1.1 Summary of key findings

Seventy one (71) bats of four species were captured during 10 nights of harp trapping at six locations. Eight PLNB were captured, tagged and released. Table 9 and Table 10 provides a summary of the number of species and individuals trapped at each location during each trap session (session 1, 6 to 10 November 2019 and session 2, 25 November to 2 December 2019). Key measurements taken for each of the PLNB captured and tagged during the survey are provided in Appendix B. Plates 13- 16 display Common Sheathtail Bat and PLNB during the trapping and tagging process.



**Plate 13: Common Sheathtail Bat**



**Plate 14: Pilbara Leaf-nosed Bat. Note vibrant orange fur**



**Plate 15: Pilbara Leaf-nosed Bat. Note creamy yellow fur**



**Plate 16: Pilbara Leaf-nosed Bat – pregnant (Tag 11).**



**Plate 17: Common Sheathtail Bat**

**Table 9: Summary of trap results and observations 6 to 10 November 2019**

Trap night /location	Effort	Trap results	Observations/ comments
6/11/19 Joes Cave Figure 3 – trap 1	Start c. 6:30 pm 4 harp traps x 2 hours	First bat captured 6:40 pm 9 x Common Sheathtail (6 x female, 3 x male - including 1 x pregnant female and 1 x independent juvenile) 1 x male Finalysons Cave Bat	Most trapped bats captured exiting cave. At least 8 x Common Sheathtail escaped traps Dusk at c. 6:45 pm PLNB recorded using hand held detector at c. 40 mins past dusk (2 calls for survey period) Ghost Bat heard and observed regularly from c. 35 mins past dusk Five bat species recorded on hand held detector during survey. Low- moderate activity recorded Activity decreased as moon higher and possibly due to presence of Ghost Bat. Moon c. 75% full. Slight breeze. Warm to hot (c. 32-34 dc)
7/11/19 Jimmy's Gap Dry creek/ riparian Figure 3 – trap 2	Start c. 6:30 pm 7 harp traps (3 locations) x 2.5 hours	First bat captured at 7:41 pm 1 x male Finalysons Cave Bat, 1 x male Little Broad-nosed Bat	Dusk at c. 6:45 pm No PLNB recorded using hand held detector Ghost Bat heard and observed from c. 40 mins past dusk Six bat species recorded on hand held detector during survey. Moderate activity recorded Activity decreased as moon higher and presence of Ghost Bat Moon c. 75-80% full. Moderate breeze. Warm to hot (c. 32-34 dc)
9/11/19 Shariff's Pool Large shallow pools Figure 3 – trap 3	Start c. 6:30 pm 7 harp traps (2 locations) x 3 hours	First bat captured at 6:51 pm 1 x female Finalysons Cave Bat (non-reproductive), 1 x male Little Broad-nosed Bat	Dusk at c. 6:45 pm PLNB recorded using hand held detector at 8:00 pm (3 calls for survey period) Ghost Bat heard and observed from 8:11 pm, regular activity Bats regularly observed moving across water using Infrared goggles e.g. c. 5-6 individuals observed zig zagging over/across water). Some appear to avoid traps Seven bat species recorded on hand held detector during survey. High activity levels consistently recorded for survey Activity decreased as moon higher c. 8:05 pm Moon c. 80-85% full. Moderate to strong, occasionally gusty wind. Warm to hot (c. 34 dc)
10/11/19 Dry creek / riparian Figure 3 – trap 4	Start c. 6:30 pm 7 harp traps (2 locations) x 2.5 hours	First bat captured at 7:35 pm 2 x male Little Broad-nosed Bat	Dusk at c. 6:48 pm PLNB recorded using hand held detector at 7:16 pm with multiple calls recorded on/off for c. 20 mins Ghost Bat heard and observed from 7:41 pm, regular activity Bats regularly observed flying along riparian area. Some appear to avoid traps Seven bat species recorded on hand held detector during survey. Moderate - high activity levels consistently recorded for survey Activity decreased as moon higher c. 8:10 pm Moon c. 85% full. Occasional light warm breeze. Warm to hot (c. 34 dc)

**Table 10: Summary of trap results and observations 25 November to 2 December 2019**

Trap night /location/Figure reference	Effort	Trap results	Observations/ comments
25/11/19	-	-	Trap session abandoned due to poor weather (e.g. heavy rain and lightning)
26/11/19 Chateau Cave Figure 3 – trap 5	Start c. 6:00 pm 3 harp traps x < 45 mins Note – traps placed over front of cave c. 10-15 minutes after dusk to avoid capturing all Common Sheathtail bats during emergence period	First bat captured at 6:26 pm 9 x Common Sheathtail (all female). No PLNB trapped	Approx 61 common Sheathtail observed exiting the cave between 6:26 pm and 6:50 pm (excludes trapped bats). Earlier than usual exit most likely due to pending storm activity No PLNB recorded using hand held detector Trap session abandoned early at c. 7:25 pm due to poor weather. Humid/warm with light winds building to severe storm with strong gusty winds, tropical downpour and constant lightning Moon c. <10% full
27/11/19	-	-	Trap session abandoned due to poor weather (e.g. heavy rain and lightning)
28/11/19 Chateau Cave Figure 3 – trap 5	Start c. 6:00 pm 3 harp traps x c. 2 hours Note – traps placed over front of cave c. 10-15 minutes after dusk to avoid capturing all Common Sheathtail bats during emergence period	7 x Common Sheathtail (1 x male and 6 x female) No PLNB trapped	Dusk at c. 7:05 pm PLNB calls recorded using hand held detector at 7:45 pm, then infrequently until traps closed During dusk bats regularly observed flying along cliff face (including small and large bats). Some bats appear to pass through and avoid traps including PLNB. At least two possible PLNB observed passing through trap from inside of cave. Approx 42 common Sheathtail observed exiting the cave between 6:52 pm and 7:39 pm (excludes trapped bats) Trap session abandoned early at c. 9:20 pm due to poor weather (e.g. heavy rain and lightning) Moon c. 10% full. Humid/warm with light winds building to strong gusty winds
29/11/19 Chateau Cave Figure 3 – trap 5	Start c. 6:10 pm 5 harp traps (2 x locations) x c. 3.5 hours Note – traps placed over front of cave c. 5 minutes after dusk to reduce number of Common Sheathtail Bats captured during emergence	8 x Common Sheathtail (3 x male, 2 x female, 3 unknown sex), 1 x male Finalysons Cave Bat, 6 x PLNB (5 x male and 1 x juvenile non-reproductive female)	Dusk at c. 7:05 pm PLNB recorded using hand held detector at 6:55 pm, then commonly until traps closed at 9:50 pm Bats regularly observed flying along cliff face (including small and large bats). At least 3 PLNB observed to pass through harp traps, and others observed avoiding traps. Approx 44 Common Sheathtail observed exiting the cave between 7:02 pm and 7:50 pm (excludes trapped bats) PLNB trapped between 7:54 pm and 9:41 pm All PLNB weighed, measured, tagged and released within 18 mins of capture Weather conditions favourable – warm to hot and humid, light winds. Moon c. 10-15% full
30/11/19 Jimmy's Gap Dry creek/ riparian	Start c. 6:10 pm 6 harp traps (3 locations) x c. 3.5 hours	1 x female Finalysons Cave Bat No PLNB trapped	Dusk at c. 7:05 pm PLNB recorded using hand held detector at 8:10 pm. Few calls recorded for duration of survey

Trap night /location/Figure reference	Effort	Trap results	Observations/ comments
Figure 3 – trap 2			<p>Five bat species recorded on hand held detector during survey. Moderate-high activity recorded until 8:25 pm, then low activity until traps closed at c 10:30 pm</p> <p>Bats observed flying along dry creek line and through riparian vegetation. Several bats recorded avoiding traps</p> <p>Weather conditions favourable – warm to hot and humid, light winds. Traps closed at 10:30 due to encroaching rain/lightning</p> <p>Moon c. 10-15% full</p>
1/12/19 Near base station 5 Creek/riparian with pools, base of cliff Figure 3 – trap 6	Start c. 6:10 pm 5 harp traps (3 locations) x c. 4.5 hours	1 x female Finalysons Cave Bat No PLNB trapped	<p>Dusk at c. 7:05 pm</p> <p>PLNB recorded using hand held detector at 7:23 pm. Few other calls recorded for duration of survey</p> <p>Five bat species recorded on hand held detector during survey. Low-moderate activity recorded</p> <p>Bats observed flying along creek line and through riparian vegetation. Approx 2 bats recorded avoiding traps.</p> <p>Traps closed at 10:45 pm</p> <p>Moon c. 15% full</p>
2/12/19 Joes Cave Figure 3 – trap 1	Start c. 6:20 pm 4 harp traps (2 x locations) x c. 4.5 hours	<p>First bat captured at 6:40 pm</p> <p>18 x Common Sheathtail (5 x female, 13 x male)</p> <p>2 x Finalysons Cave Bat (1 x female and 1 x unknown sex)</p> <p>2 x PLNB (1 x male and 1 x pregnant female)</p>	<p>Dusk at c. 7:05 pm</p> <p>Most trapped bats captured exiting cave.</p> <p>At least 10 x Common Sheathtail escaped traps.</p> <p>Five bat species recorded on hand held detector during survey. Moderate activity recorded</p> <p>Bats observed flying around front of cave and attempting to enter cave. Also along cliff either side of cave entrance. Two PLNB noted to fly into traps then fly out again, and at least 3 small bats recorded avoiding traps</p> <p>PLNB trapped at 7:40 pm and 8:24 pm</p> <p>Both PLNB weighed, measured, tagged and released within 17 mins of capture.</p> <p>Traps closed at 9:25 pm</p> <p>Moon c. 15% full</p> <p>Following closure of the traps the cave was investigated with a red light torch as several PLNB were noted to fly into the rear main chamber. Upon further investigation two small bats (probably Finlaysons Cave Bat) were recorded flying into one of the small sub-chambers/cavities off the rear of main chamber. Based on previous cave searches this cavity was thought to be shallow, however upon further inspection the cavity is a small floor level passage (c. 1.5-2 m long, &lt; 1 m wide, &lt; 1 m high) with a near right angle bend that leads into a another smaller chamber (c. 3-4 m deep, 3-4 m wide, &lt; 1 m high) with multiple narrow floor-ceiling columns throughout the chamber. Two small bats (probably Finlaysons Cave Bat) were observed flying in the chamber.</p>

## 4.2 Radio-tracking – tag analysis

### 4.2.1 Transmitter 19

Tag 19 was recorded for seven non-consecutive nights during the survey (Table 11 and Chart 2). It was captured and released at Chateau Cave, however it did not return to the Chateau Cave area for 4 nights (Scatterplot 1). It was regularly active within the range of the receivers from the 29/11/19 – 3/12/19, however from the AM period of the night of the 3/12/19 through the AM period of the night of the 8/12/19 the tag was absent from the range of the receivers. Following this absence, it was recorded by bs1 (near Chateau Cave) for three nights, however tag detections were limited to short bouts of less than 1 minutes each night (e.g. maximum of 6 consecutive detections within the same minute by one or two antenna). Given the absence of tag detections from antenna orientated toward the Chateau Cave area (e.g. bs8 and bs4) for the same period the detections may be dubious.

Of the 1692 valid detections recorded during the survey period from four base stations, c. 51% were recorded by bs4 (n = 848, located above South Star Pool, of which 527 detections are from antenna 3 (A3) orientated west-south-west at Joes Cave) and c. 35% (n = 597) bs2. The remaining 14% of detections were from bs8 and bs1.

First (within 20 minutes of civil twilight following sunset) and last detections (near sunrise) were recorded by bs2 for Tag 20, and both early in the evening and late in the morning for several nights (Table 11).

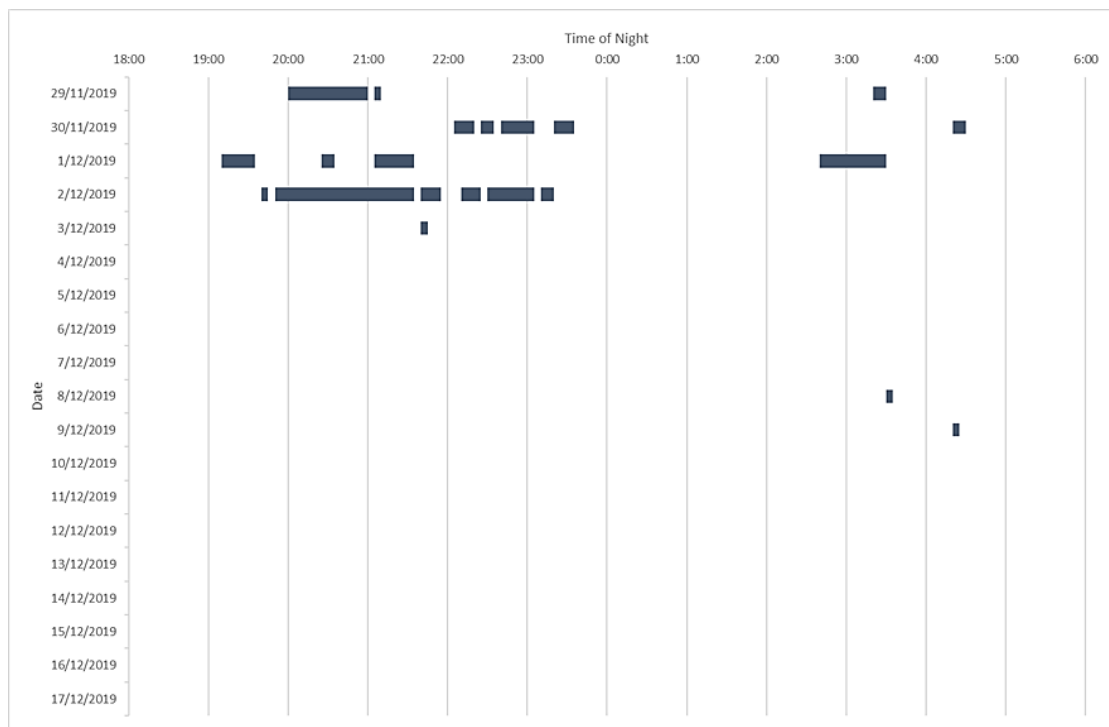
Data for the nights of the 29/11/19 – 2/12/19 provide the most useful information containing 98% of the tag detections, indicating that this tag was most active in the vicinity of bs2, Joes Cave area (Scatter plot 1 and Scatter plot 2). This outcome is also supported by many near simultaneous tag detections recorded by A3 (orientated west-north-west at Joes Cave) on bs4, and some detections recorded by A2 (orientated west-south-west, above the area of Joes Cave) on bs8 (see Scatter plot 1). Multiple near or near simultaneous tag detections recorded by bs4, A3 can be confidently used to support activity results from bs2 as it was proven during tag testing and prior to the release of the tagged bats that the reception range of A3, bs4 extends to Joe's Cave (see Appendix A).

Although there are limitations with some of data from some nights (e.g. no data for bs1 29/11/19 and the interpretation of signal direction data from bs2), the lack of and random frequency of detections indicates, particularly from the night of the 3/12/19 onwards suggests that bat was most active outside the reception range of the receivers for most of the survey period.

**Table 11: Summary of first and last tag detections each night Tag 19**

Night	Time first detection	Base station (antenna and orientation)	Time last detection	Base station (antenna and orientation)
29/11/2019	20:11 (released Chateau Cave)	Bs8 - A3 / SSE and Bs4 – A2 / N	03:29	Bs2 – A2 / WNW, A3 / N* and Bs4 – A3 / WNW
30/11/2019	22:10	Bs2 – A3 / ENE	04:29	Bs2 – A3 / ENE (4 consecutive detections)
1/12/2019	19:18	Bs2 – A3 / ENE and A4 / SSW (15 consecutive detections between 19:18 and 19:22)	03:28	Bs2 – A3 / ENE and Bs4 – A3
2/12/2019	19:49	Bs8 – A2 / WSW	01:58	Bs2 – A3 / ENE, A4 / SSW and Bs4 – A3
3/12/2019	21:47##	Bs1 – A3 / NNE		-
8/12/2019	-	-	3:33##	Bs1 - A1 / SW, A2 / SE
9/12/19	-	-	4:20##	Bs1 – A1 / SW

NOTE: \* Orientation of antenna for Bs2 Joes Cave not accurate as tower was on a lean for the night of the 29-30/11/19. ## - data may be outlier. Times highlighted in green are within 5 mins (+/- 1 min) of civil twilight. Times highlighted in blue are within 5-10 mins (+/- 1 min) of of civil twilight. Times highlighted in yellow are 10-20 mins (+/- 1 min) after civil twilight.



**Chart 2: Nightly activity patterns for Tag 19**

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 or roosting.



### Scatter plot 1: Base station detections for Tag 19

Notes: No or few valid tag detections for base stations 3, 5, 6, 7. 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 base station 1 (Rise opposite point of capture at Chateau Cave), then 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.



**Scatter plot 2: Base station detections for Tag 19 – base station 2, night by night 6 am 6 pm, 30/11 – 2/12/19**

Scatter plot 2 displays the activity pattern for Tag 19 during this period as recorded by bs2. During the PM period the tag was most in the area south-south-west of bs2 as detected by A4 (orientated south-south-west toward Joes Cave) and around the immediate area of the base station (e.g. within 200 m of the tower) as indicated by high, then low signal strength across multiple antenna over a short period of time. There is a notable absence in activity between the PM activity then the AM activity, which appeared to be within the area of the base station.



### Scatter plot 3: Base station detections for Tag 19 – 6 am – 6 pm 2-3/12/2019

The scatterplot displays the movement of Tag 19 for the night of the 2/12/19 from the area south through south-east of bs2 to the immediate area of bs2, then to the South Star Pool area, then to the Chateau Cave area during the PM period. Tag 19 then appears to return to the Joes Cave area during the AM period after being absent from the range of the receivers for a period of c. 2.5 hours. Tag 19 was most likely visiting the South Star Pool and Chateau Cave as indicated by the high then low signal strength from all antenna at bs4 and bs1. It appears that Tag 19 was active in the Joes Cave area between between 1:30 am and 2:15 am indicated by the by the high then low signal strength from all antenna, and few detections also received by A3 bs4. The straight line distance between Chateau Cave and Joe's Cave is c. 8 km, therefore when Tag 19 moved between the Joe's Cave, South Star Pool, Chateau Cave areas and return

the straight line distance travelled would have exceeded 16 km. This estimate does not consider all commuting events, foraging and roosting events during the course of the night.

#### **4.2.2 Transmitter 20**

Tag 20 was recorded for 13 consecutive nights during the survey (Table 12 and Chart 3). It was captured and released at Chateau Cave on the night of the 29/11/19, however it did not return to the Chateau Cave area for 10 nights, noting the limitations with bs1 (Scatter plot 4). It was regularly active within the range of the receivers, particularly bs2 for the period it was detected.

Of the 2746 valid detections recorded during the survey period from five base stations, c. 66% bs2 (n=1808) and c. 30% (n=819) bs4, of which 90% of detections were from A3 orientated west-south-west at Joes Cave. The remaining 4 % of detections were recorded from bs4, bs7 and bs8.

Data indicates Tag 20 was most active in the vicinity of Joes Cave area (bs2), with occasional activity at other base stations including bs7 (Shariff's Pool) and bs4. (Scatter plot 4). This outcome is also supported by many near simultaneous tag detections recorded by A3 (orientated west-north-west at Joes Cave) on bs4, and some detections recorded by A2 (orientated west-south-west, above the area of Joes Cave) on bs8 (see Plot 1).

Regular first detection were recorded for between the 1-7/12/19 for 5 nights (Table 12) by bs2, A1 (orientated west-north-west, at bs7), and A4, b2 (south-south-west at Joes Cave). For the night of the 5/12/19 early detections were also recorded by bs4, A3, however no other detections were recorded within 30 minutes of civil twilight by other base stations. Early detections were also recorded for other nights

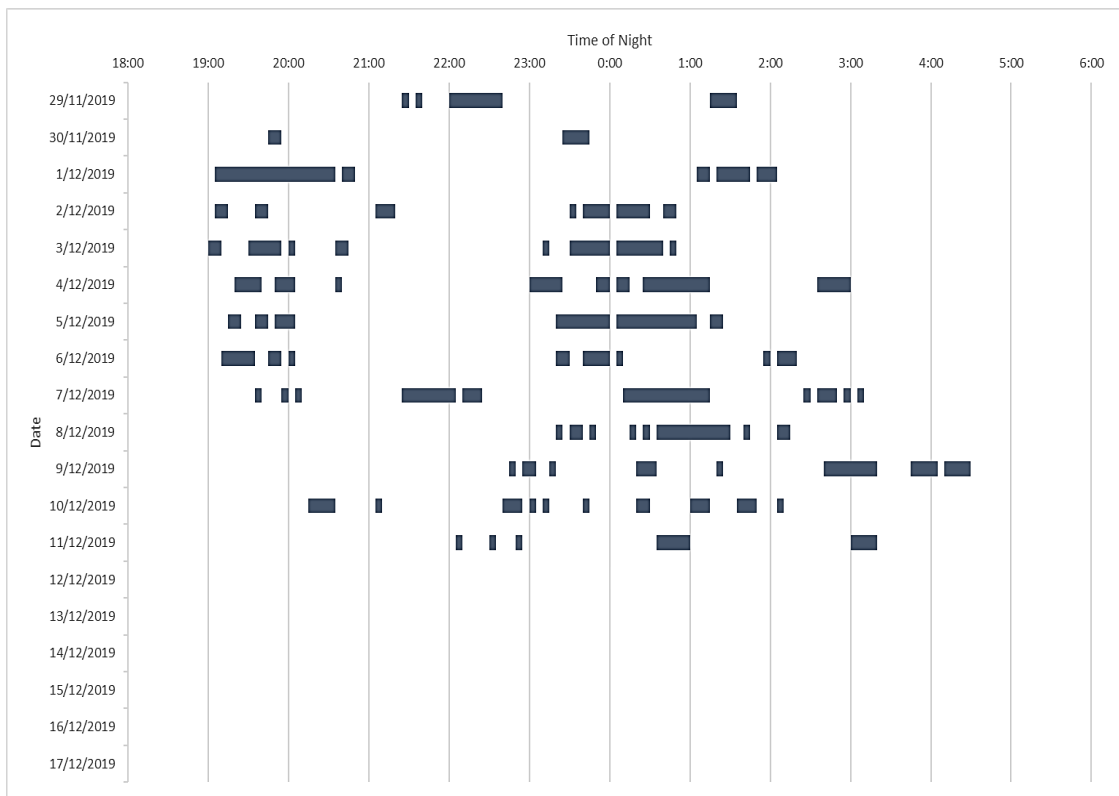
The regular timing of first and early detections from the same antenna (A1 or A4) on the same base station (bs2) indicates that Tag 20 was probably roosting in close proximity to bs2 (Joes Cave, Zane's Gorge area) during the 1-7/12/19. However the lack of first detections from the 8/12/19 for the remainder of the survey indicates a change in the roosting behaviour of Tag 20.

Although there are limitations with some of data from some nights (e.g. no data for bs1 29/11/19 and 30/11/19 and the interpretation of signal direction data from bs2), there were large periods of time that Tag 20 was not recorded by any of the base stations (Chart 3, Scatter plot 4 and 5). The data indicates that for most nights Tag 20 was active during the early PM period, however was absent between 9 pm and 11 pm from the range of the receivers for most nights (Scatter plot 4). Activity peaked between the hours of 11 pm and 2 am, before it again reduced and was absent.

**Table 12: Summary of first and last detections each night Tag 20**

Night	Time first detection	Base station (antenna and orientation)	Time last detection	Base station (antenna and orientation)
29/11/2019	21:35 (following release Chateau Cave)	Bs8 – A3 / SSE	01:26	Bs2 – A4 / E*
30/11/2019	19:46	Bs2 – A4 / SSW	23:40	Bs2 – A2 / NNW
1/12/2019	19:05	Bs2 – A4 / SSW (4 consecutive detections within 60 seconds)	01:55	Bs2 – A4 / SSW
2/12/2019	19:07	Bs2 – A1 / WNW (3 consecutive detections within 60 seconds)	00:40	Bs2 – A1 / WNW
3/12/2019	19:04	Bs2 – A1 / WNW (5 consecutive detections within 60 seconds)	00:43	Bs2 – A1 / WNW
4/12/2019	19:23	Bs2 – A1 / WNW	02:51	Bs2 – A1 / WNW
5/12/2019	19:15	Bs2 – A1 / WNW (2 consecutive detections within 60 seconds) and Bs4 - A3 / WNW (2 consecutive detections within 60 seconds)	01:17	Bs2 – A1 / WNW
6/12/2019	19:14	Bs2 – A1 / WNW (4 consecutive detections within 60 seconds)	02:12	Bs2 – A1 / WNW
7/12/2019	19:35	Bs2 – A1 / WNW, A4 / SSW	03:00	Bs2 – A1 / WNW
8/12/2019	23:22	Bs2 – A1 / WNW	02:07	Bs2 – A1 / WNW
9/12/2019	22:47	Bs2 – A1 / WNW	04:20	Bs2 – A1 / WNW
10/12/2019	20:17	Bs2 – A1 / WNW	03:11	Bs2 – A1 / WNW
11/12/19	22:06	Bs2 – A1 / WNW	03:11	Bs2 – A1 / WNW

NOTE: \*Orientation of antenna for Bs2 Joes Cave not accurate as tower was on a lean for the night of the 29-30/11/19. Bs1 – Rise not operational 29/11/12. Times highlighted in green are within 5 mins (+/- 1 min) of civil twilight. Times highlighted in blue are within 5-10 mins (+/- 1 min) of civil twilight. Times highlighted in yellow are 10-20 mins (+/- 1 min) after civil twilight.



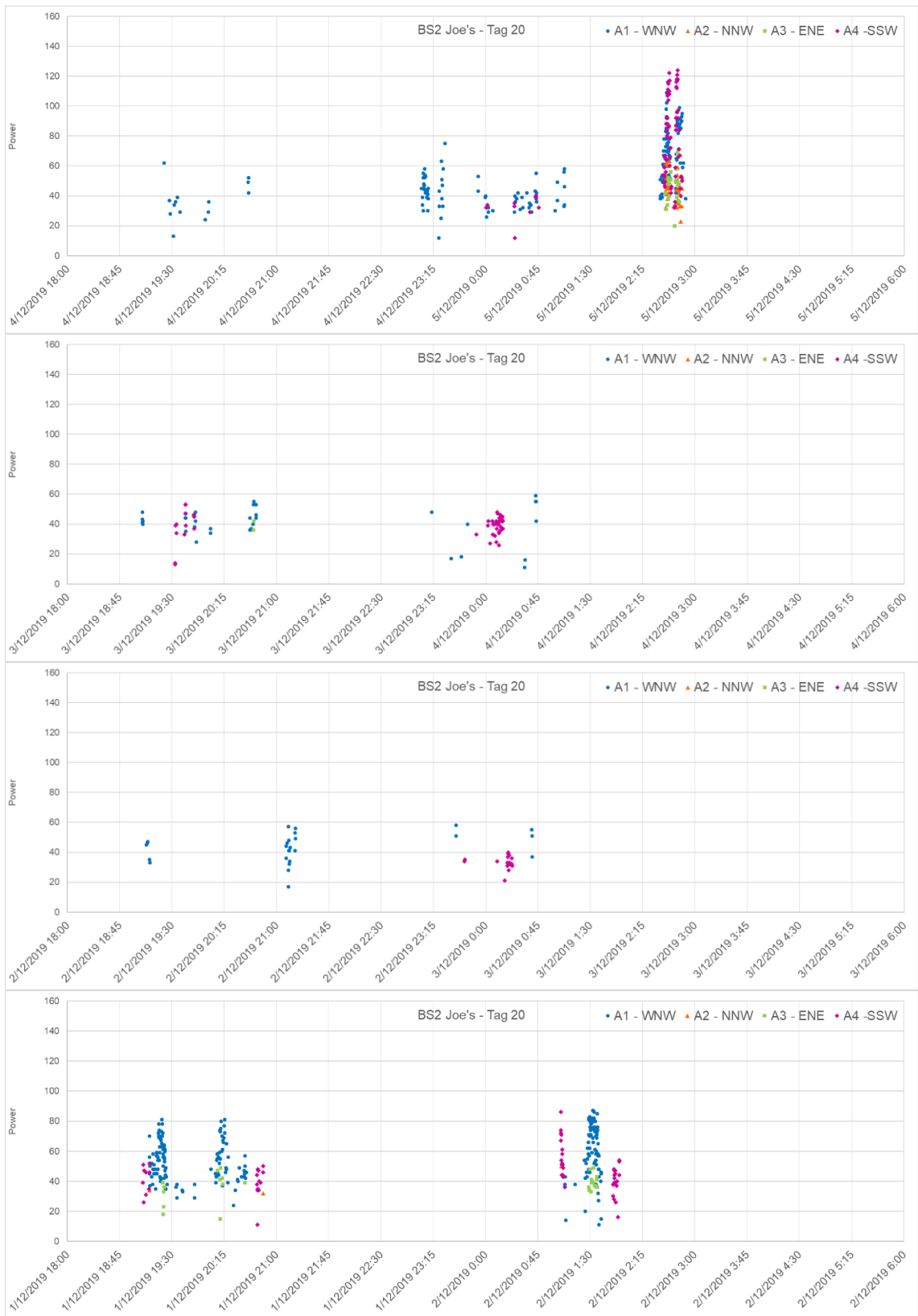
**Chart 3: Nightly activity patterns for Tag 20**

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.



**Scatter plot 4: Base station detections for Tag 20**

Notes: No valid detection data for base stations 3, 5 and 6. 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 base station 1 (Rise opposite point of capture at Chateau Cave), then 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.



**Scatter plot 5: Base station detections for Tag 20 – base station 2, night by night 6 am 6 pm, 1-4/12/19**

Scatter plot 5 displays the typical activity patterns for Tag 20 during this period as recorded by bs2. Tag 20 was most active during the early PM, late PM and early AM periods in the area west and south west of bs2, immediate area of the base station (e.g. within 200 m of the tower, as indicated by high, then low signal strength across multiple antenna over a short period of time), through to the east and north-east of Joes Cave.

There is a notable absence of detections from A2 (orientated north-north-west), indicating Tag 20 was not active north of bs2 within the range of the receivers during the survey.

#### 4.2.3 Transmitter 22

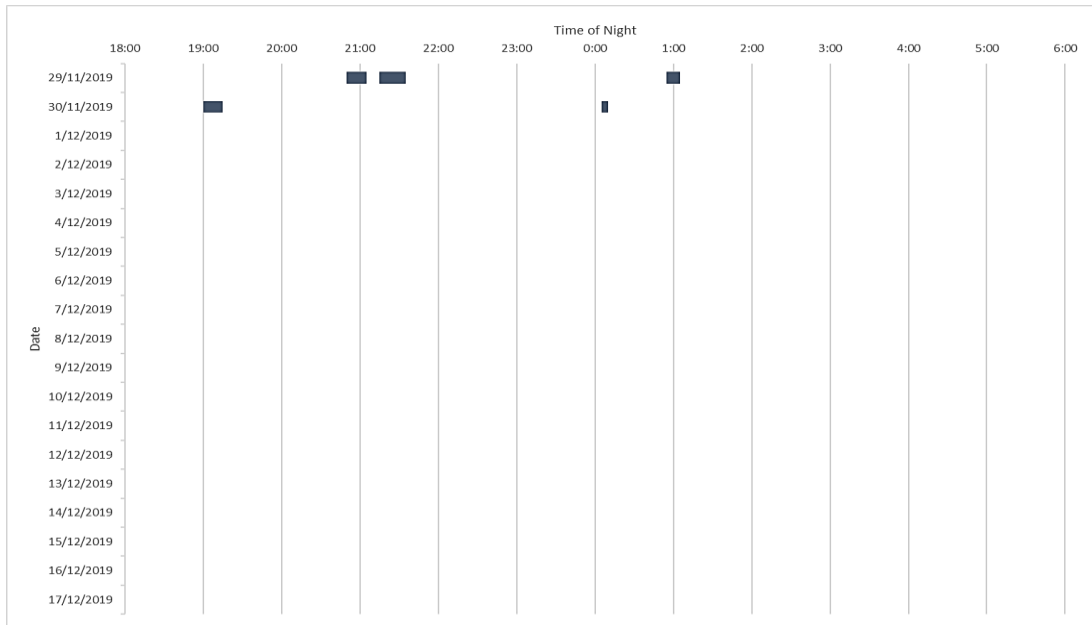
Tag 22 was recorded for one night during the survey (Table 13 and Chart 4). It was captured and released at Chateau Cave on the night of the 29/11/19. Given the lack of data (115 valid tag detections) over 1 night, it is most likely that the bat discarded the tag early the evening of the 30/11/19 or it never returned. It was therefore difficult to analyse activity and movement. Furthermore, the data recorded by bs2 consisted of infrequent and mostly weak signal detections (Chart 4 and Scatter plot 6).

The limited data available indicates following release Tag 22 flew to the vicinity of bs4 (South Star Pool) with all detections from A1 (orientated south-west, south of South Star pool). The timing of the data from the night of the 30/11/19 indicates Tag 22 was detected in close proximity to or leaving a diurnal roost. Following the first detection by A1 at 7:01 pm, 74 consecutive detections were recorded by A1 for an 11 minute period from 7:01 – 7:12 pm, with 7:12 pm being the last valid detection recorded. No other detections were recorded by bs4 or other base stations within 20 minutes of civil twilight.

**Table 13: Summary of first and last detections each night Tag 22**

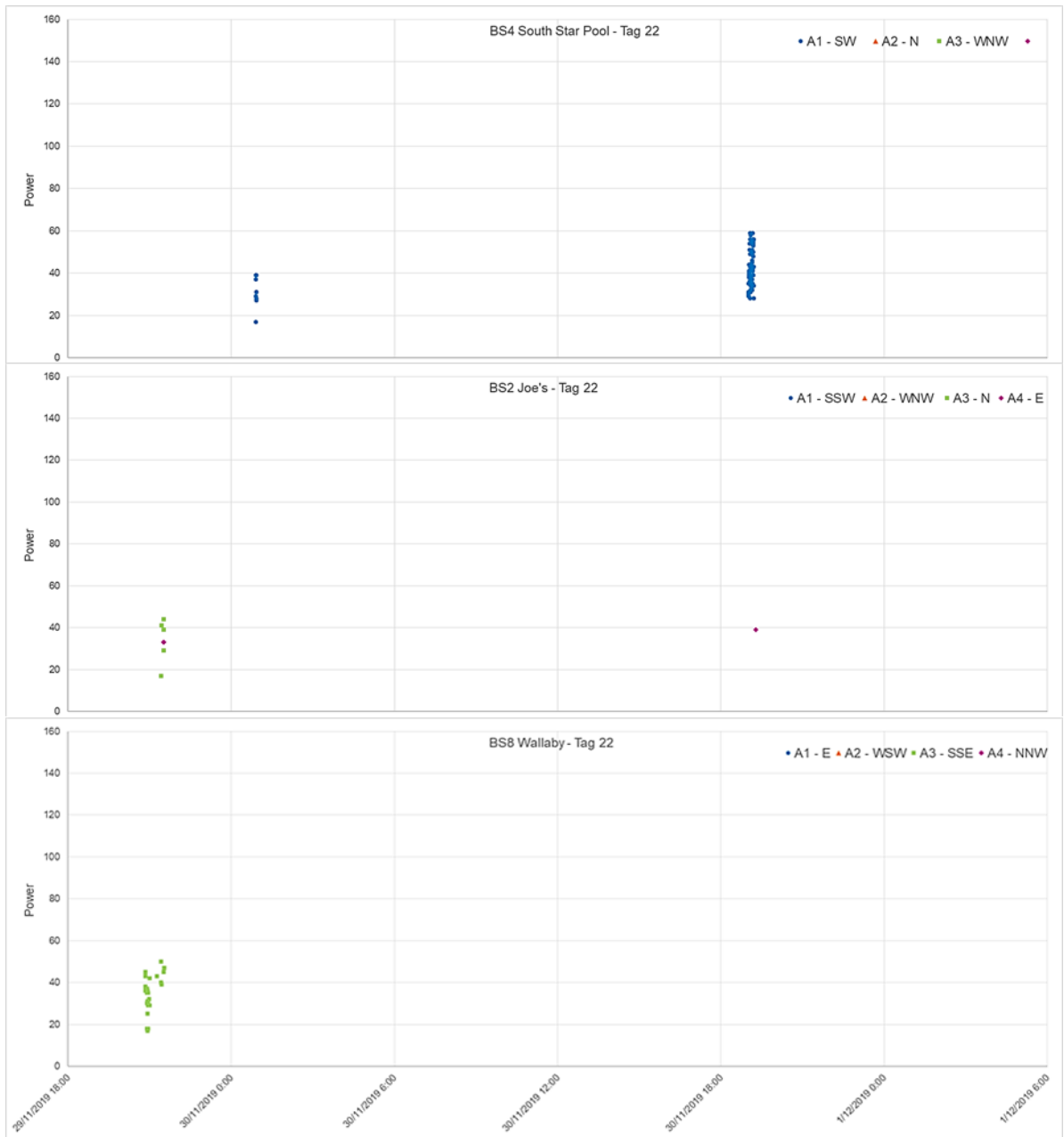
Night	Time first detection	Base station (antenna and orientation)	Time last detection	Base station (antenna and orientation)
29/11/2019	20:55 (following release Chateau Cave)	Bs8 – A3 / SSE	00:55	Bs4 – A1 / SW
30/11/2019	19:01	Bs4 – A1 / SW (74 consecutive detections between 19:01 – 19:12)	19:12	Bs4 – A1 / SW

NOTE: Times highlighted in green are within 5 mins (+/- 1 min) of civil twilight. Times highlighted in blue are within 5-10 mins (+/- 1 min) of of civil twilight. Times highlighted in yellow are 10-20 mins (+/- 1 min) after civil twilight.



**Chart 4: Nightly activity patterns for Tag 22**

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.



### Scatter plot 6: Base station detections for Tag 22

Notes: No valid detection data for base stations 1, 5, 6, 7. Detections for bs2 (Joes Cave) should not be relied on for directional information. 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 base station 1 (Rise opposite point of capture at Chateau Cave), then 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.

#### 4.2.4 Transmitter 23

Tag 23 was recorded for 10 non-consecutive nights during the survey (Table 12 and Chart 5). It was captured and released at Chateau Cave, however it did not return to the Chateau Cave area during the survey (Scatterplot 7). Although active within the range of the receivers most nights, detection data consisted of infrequent and short bouts of activity of weak signal strength. The short bouts of activity were often isolated by many hours or occasionally nights without any activity.

Few valid detections (n = 88) were recorded during the survey period from five base stations, c. 48% bs8 and c. 39% bs5 (north-west, near Abydos mine site). The remaining detections (13%) were from bs3 and bs4 (see Scatter plot 7). The majority of activity, although infrequent was during the PM period of each night with very little or no activity during the AM period of each night (Chart 5).

Analysis of data to date suggests that this tag was active in the area north and east of bs8 and around bs5 (toward Abydos), however data consisted of infrequent and mostly weak signal detection making it difficult to infer signal direction and source. The absence of data from other base stations, particularly bs1, bs2 and bs4 also supports this outcome.

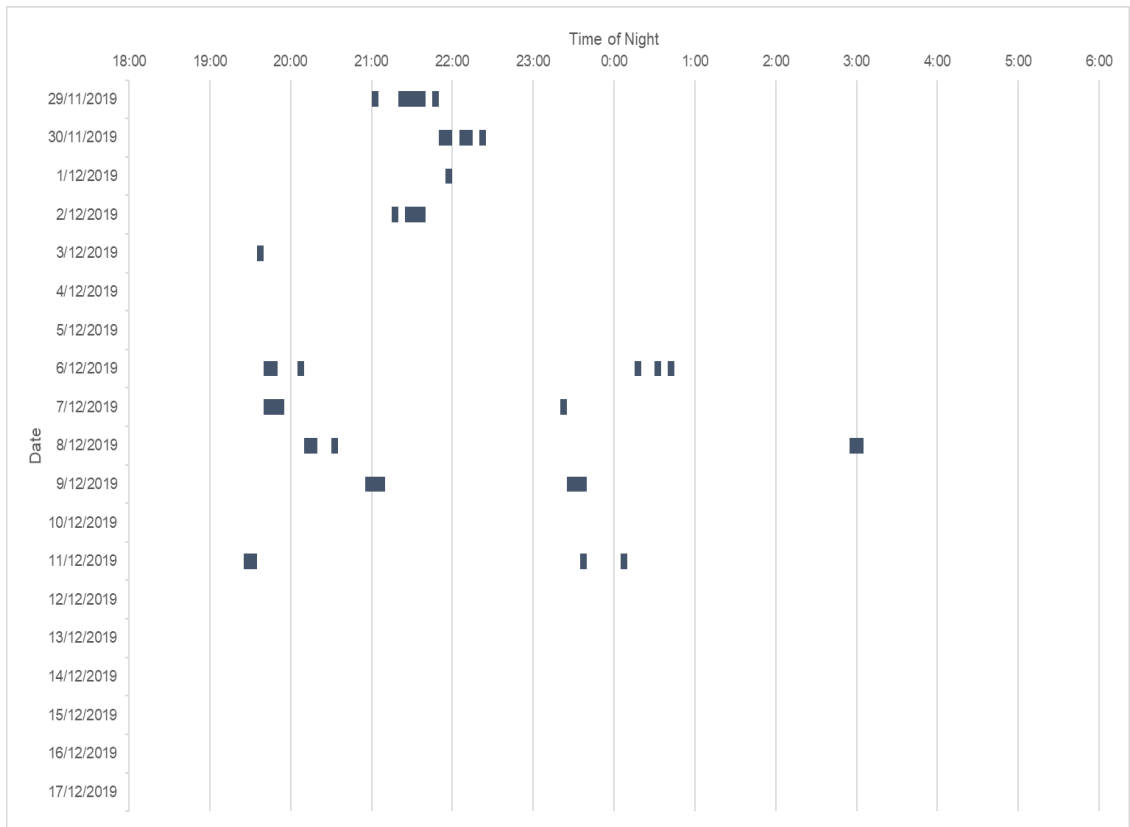
No first or last detections were recorded for Tag 23, however the tag was recorded early in the evening for four nights (Table 11) by bs5 and bs8.

Although there are limitations with some of data from some nights (e.g. no data for bs1 29 and 30 November 2019 and the interpretation of signal direction data from bs8 for the 11/12/19), the lack of and random frequency of detections indicates that Tag 23 was most active outside the reception range of the receivers for most of the survey period.

**Table 14: Summary of first and last detections each night Tag 23**

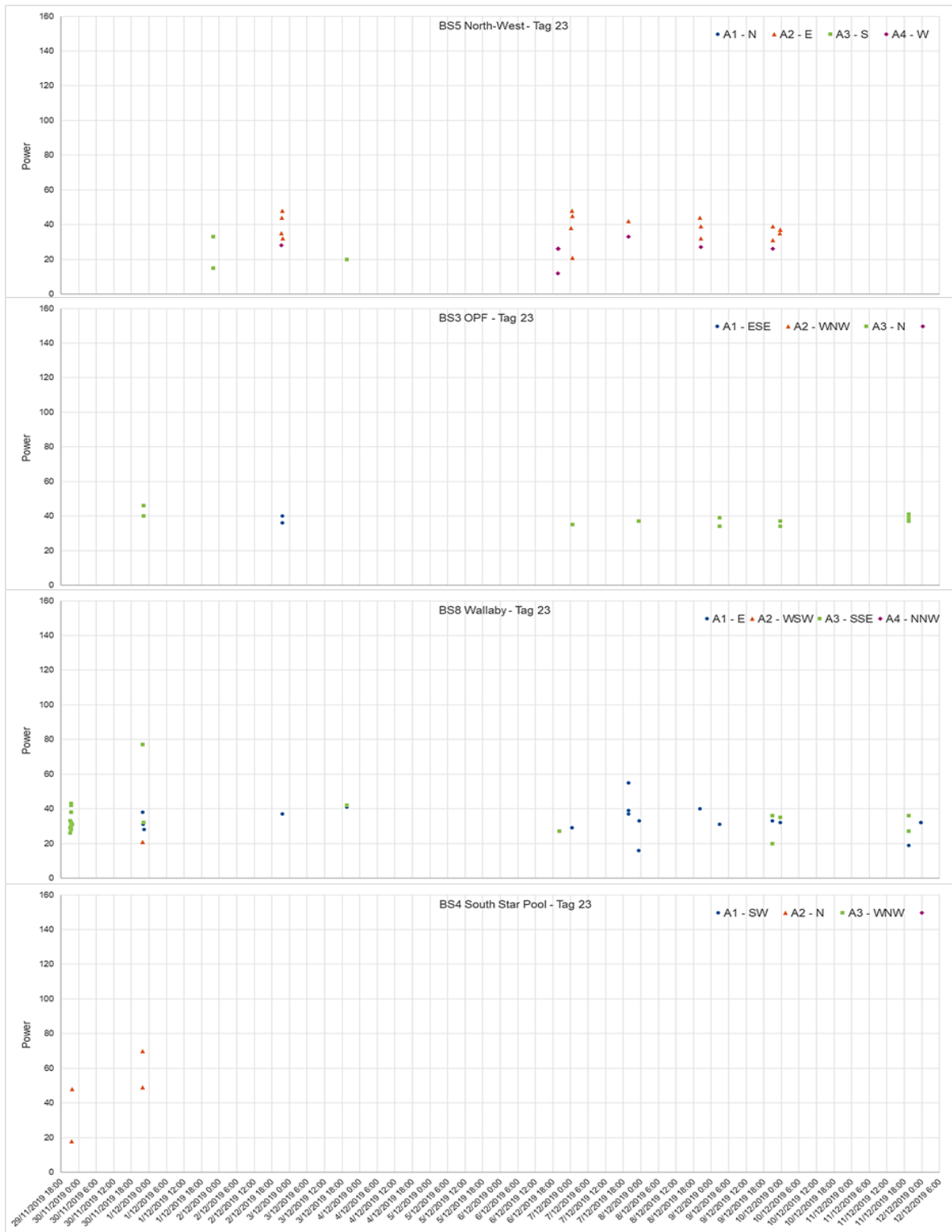
Night	Time first detection	Base station (antenna and orientation)	Time last detection	Base station (antenna and orientation)
29/11/2019	21:22 (following release Chateau Cave)	Bs8 – A3 / SSE	21:49	Bs4 – A2 / WNW
30/11/2019	21:51	Bs8 – A2 / WSW and Bs4 – A2 / N	22:20	Bs8 – A1 / E
1/12/2019	21:57	Bs5 – A3 / S	-	-
2/12/2019	21:17	Bs5 – A2 / E, A4 / W	21:34	Bs5 – A2 / E and Bs3 – A1 / ENE
3/12/2019	19:38	Bs8 – A3 / SSE and Bs5 – A3 / S	-	-
6/12/19	19:45	Bs5 – A4 / W	00:35	Bs5 – A2 / E and Bs3 – A3 / N
7/12/2019	19:44	Bs8 – A1 / E	23:20	Bs3 – A3 / N and Bs8 – A1 / E
8/12/2019	20:31	Bs5 – A2 / E, A4 / W	02:54	Bs3 – A3 / N and Bs8 – A1 / E
9/12/2019	20:55	Bs8 – A1 / E, A3 / SSE	23:38	Bs5 – A2 / E
11/12/19	19:29	Bs8 - A1 / E and Bs3 – A3 / N	23:35	Bs8 A1 / E

NOTE: Times highlighted in green are within 5 mins (+/- 1 min) of civil twilight. Times highlighted in blue are within 5-10 mins (+/- 1 min) of civil twilight. Times highlighted in yellow are 10-20 mins (+/- 1 min) after civil twilight.



**Chart 5: Nightly activity patterns for Tag 23**

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.



### Scatter plot 7: Base station detections for Tag 23

Notes: No valid detections for base stations 1, 2, 6, 7. 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 base station 1 (Rise opposite point of capture at Chateau Cave), then 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.

#### 4.2.5 Transmitter 10

Tag 10 was recorded for 5 non- consecutive nights during the survey (Table 15 and Chart 6). It was captured and released at Joes Cave on the night of the 2/12/19. The majority of the detection data consisted of infrequent and short bouts of activity of weak signal strength. The short bouts of activity were often isolated by many hours or sometimes nights without any activity (Chart 6 and Scatter plot 8).

Of the 553 valid detections recorded during the survey period from four base stations, c. 52% bs2 (n=286) and c. 39% bs7 (n=216). The remaining 9% of detections were recorded from bs4 and bs8.

Data indicates Tag 10 was most active in the vicinity of bs2 (Joes Cave area), the area south-west of Joes Cave and within the immediate area of bs7 (Shariff's Pool) whilst active within the range of the receivers. This outcome is also supported by some near simultaneous tag detections recorded by A3 (orientated west-north-west at Joes Cave) on bs4 (Scatter plot 8).

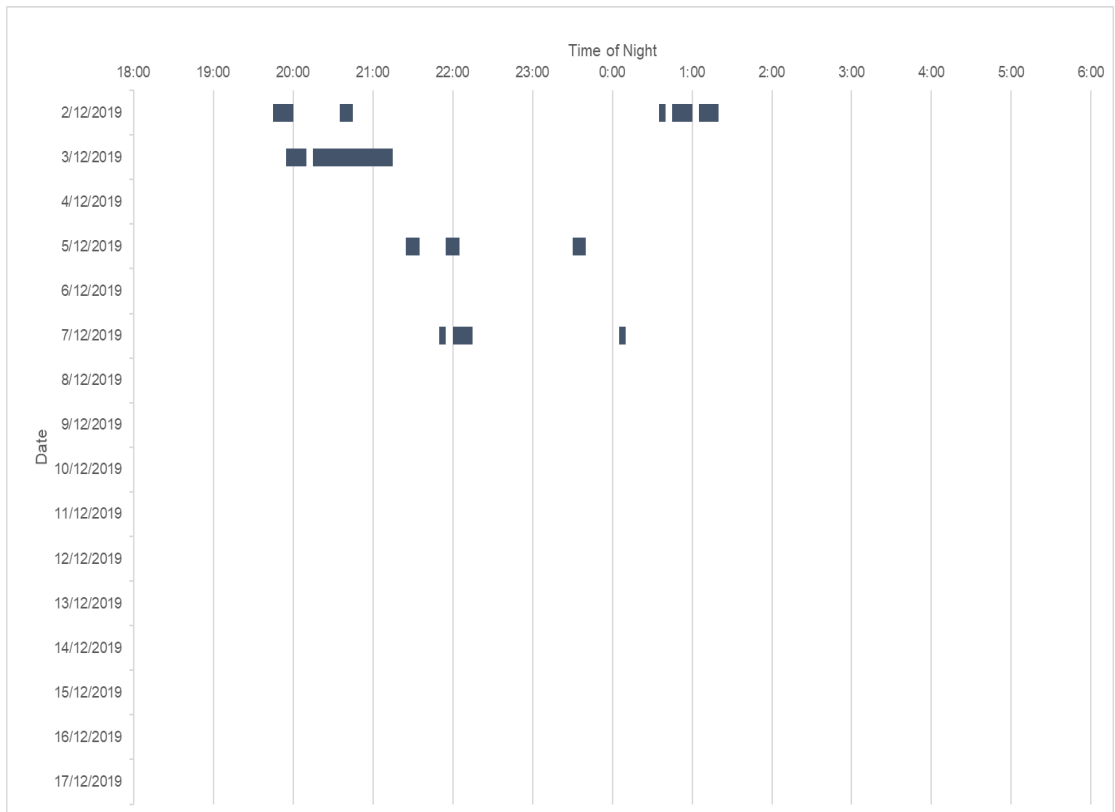
No first or last detections were recorded, nor any early in the evening or late in the morning for Tag 10.

Although there are limitations with some of data from some nights, particularly the interpretation of signal direction and strength from bs2, there were large periods of time that Tag 10 was not recorded by any of the base stations (Chart 6). The data indicates that for most nights Tag 10 was active during the PM period, however was absent for the AM period from the range of the receivers for most nights (Chart 6 and Scatter plot 8). Tag 10 was probably active outside the reception range of the receivers for most of the survey period.

**Table 15: Summary of first and last detections each night Tag 10**

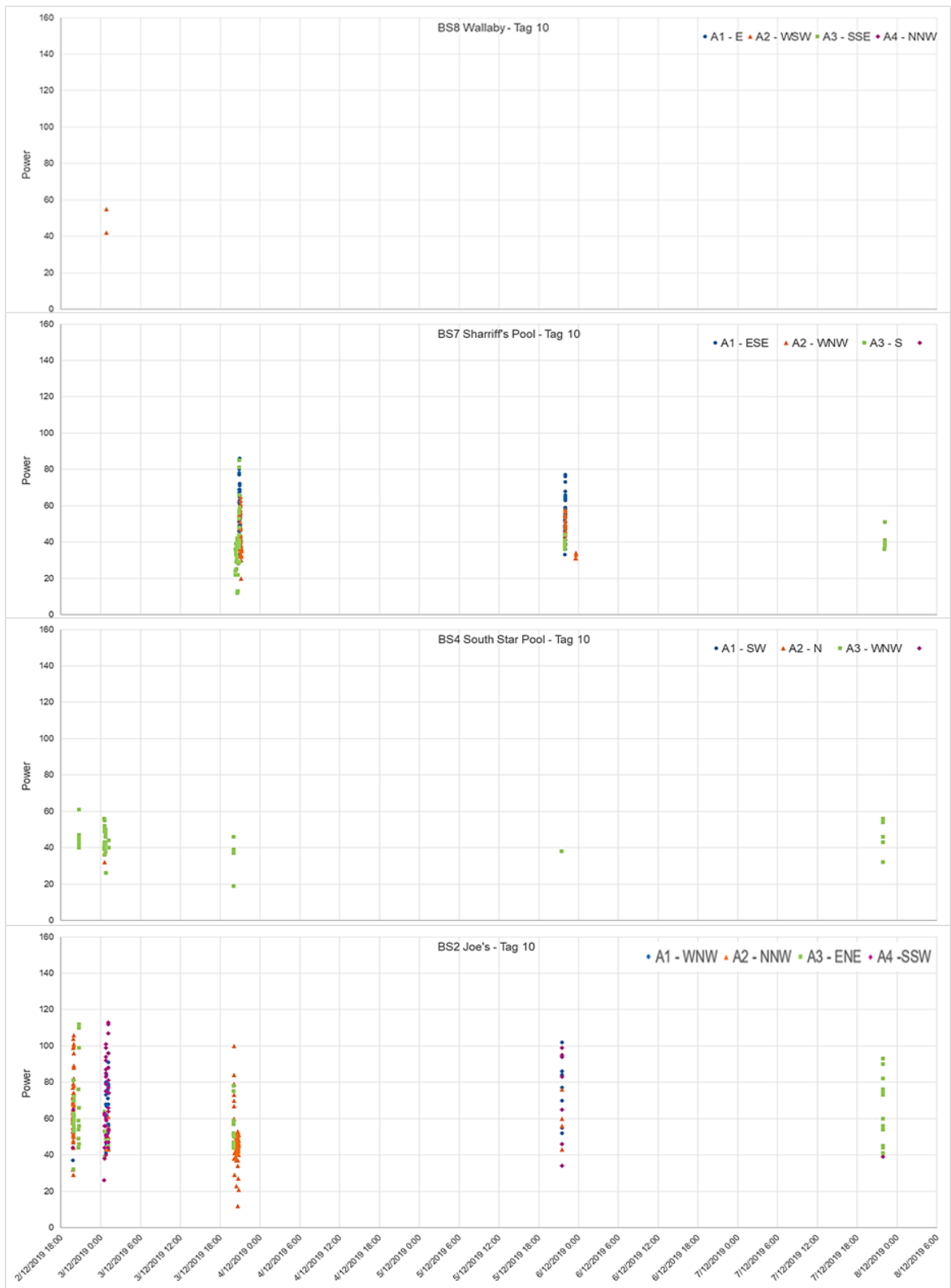
Date	Time first detection	Base station (antenna and orientation)	Time last detection	Base station (antenna and orientation)
2/12/2019	19:55 (released Joes Cave)	Bs2 – A2 NNW, A3 / ENE	01:12	Bs4 – A3 / WNW
3/12/2019	19:59	Bs4 – A3 / WNW	21:10	Bs7 – A2 / S
4/12/2019	No data	-	No data	-
5/12/2019	21:28	Bs2 - A1 WNW, A4 / SSW	23:35	Bs7 – A2 / S
6/12/2019	No data	-	No data	-
7/12/2019	21:51	Bs4 – A3 / WNW	22:10	Bs7 – A3 / WNW

NOTE: Times highlighted in green are within 5 mins (+/- 1 min) of civil twilight. Times highlighted in blue are within 5-10 mins (+/- 1 min) of of civil twilight. Times highlighted in yellow are 10-20 mins (+/- 1 min) after civil twilight.



**Chart 6: Nightly activity patterns for Tag 10**

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.



### Scatter plot 8: Base station detections for Tag 10

Notes: No valid detection data for base stations 1, 3, 5, 6. 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 Joes Cave (point of capture), then 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.

#### 4.2.6 Transmitter 11

Tag 11 was recorded for 15 consecutive nights during the survey (Table 12 and Chart 3). It was captured and released at Joes Cave on the night of the 2/12/19, and continued to be active within the Joes Cave area for the entire survey period. No valid detections were recorded for base stations 1, 3, 5 and 6 during the survey.

Of the 4361 valid detections recorded during the survey period from four base stations, c. 74% bs2 (n=3208), c. 13% (n = 574) bs7 and c. 11% (n = 520) bs4 (of which 97% of detections were from A3 orientated west-south-west at Joes Cave). The remaining 2% of detections were recorded from bs8.

Data indicates Tag 11 was consistently active each night in the vicinity of Joes Cave area (bs2), and for many nights in the vicinity of bs7 (Shariff's Pool) (Scatter plot 9). This outcome is also supported by many near simultaneous tag detections recorded by A3 (orientated west-north-west at Joes Cave) on bs4, and some detections recorded by A2 (orientated west-south-west, above the area of Joes Cave) on bs8 (see Scatter plot 9).

No first detections were recorded however four last (near sunrise) detections were recorded for the mornings of the 6<sup>th</sup>, 7<sup>th</sup>, 9<sup>th</sup> and 10<sup>th</sup> of December, by bs2 and bs4. Last detections were always supported by multiple consecutive detections within a 1-5 minute period by the same antenna (Table 16). Simultaneous detections were also recorded on bs2 A1 (orientated west-north-west) the 6/12/19 (Scatter plot 10) and bs2 A4 (orientated south-south-west) the 10/12/19.

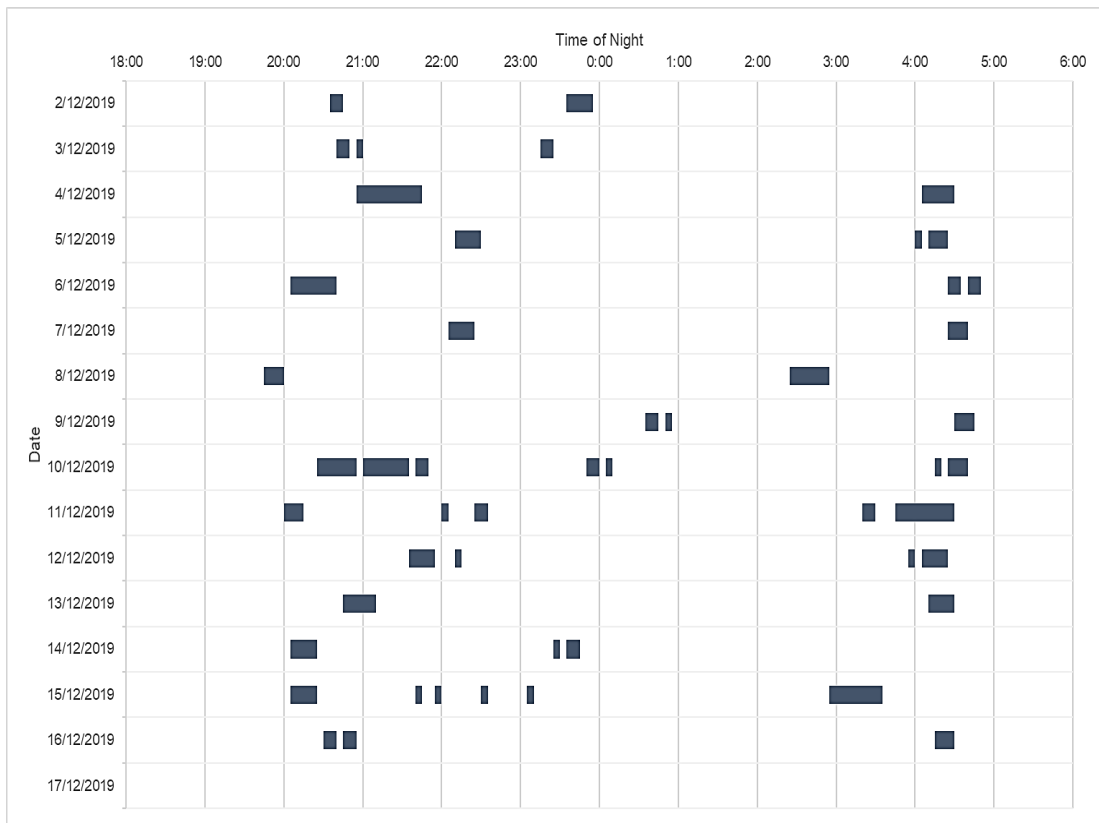
Late morning detections were also recorded for 6 other nights (e.g. between 4:10 and 4:30 am). The regular and consistently high number of detections near sunrise indicates that Tag 11 was in transit to or arriving at a roost in close proximity to the area west through south west of bs2 (e.g. the Joes Cave/Zane's Gorge area and area further west).

As previously mentioned there are limitations with data from some nights (e.g. no data for bs1 29/11/19 and 30/11/19), particularly the interpretation of signal direction data from bs2 and to a lesser extent bs8. Despite these limitations there were clearly large periods of time that Tag 11 was not recorded by any of the base stations. The data indicates that Tag 11 was active during the PM period within the receiver range of reception, however was absent most nights between approximately midnights and 2:30 am from the range of the receivers (Chart 7, Scatter plot 10 and 11). Activity peaked again between the hours of 3 am and 4:30 am, before it again reduced and was absent.

**Table 16: Summary of first and last detections each night Tag 11**

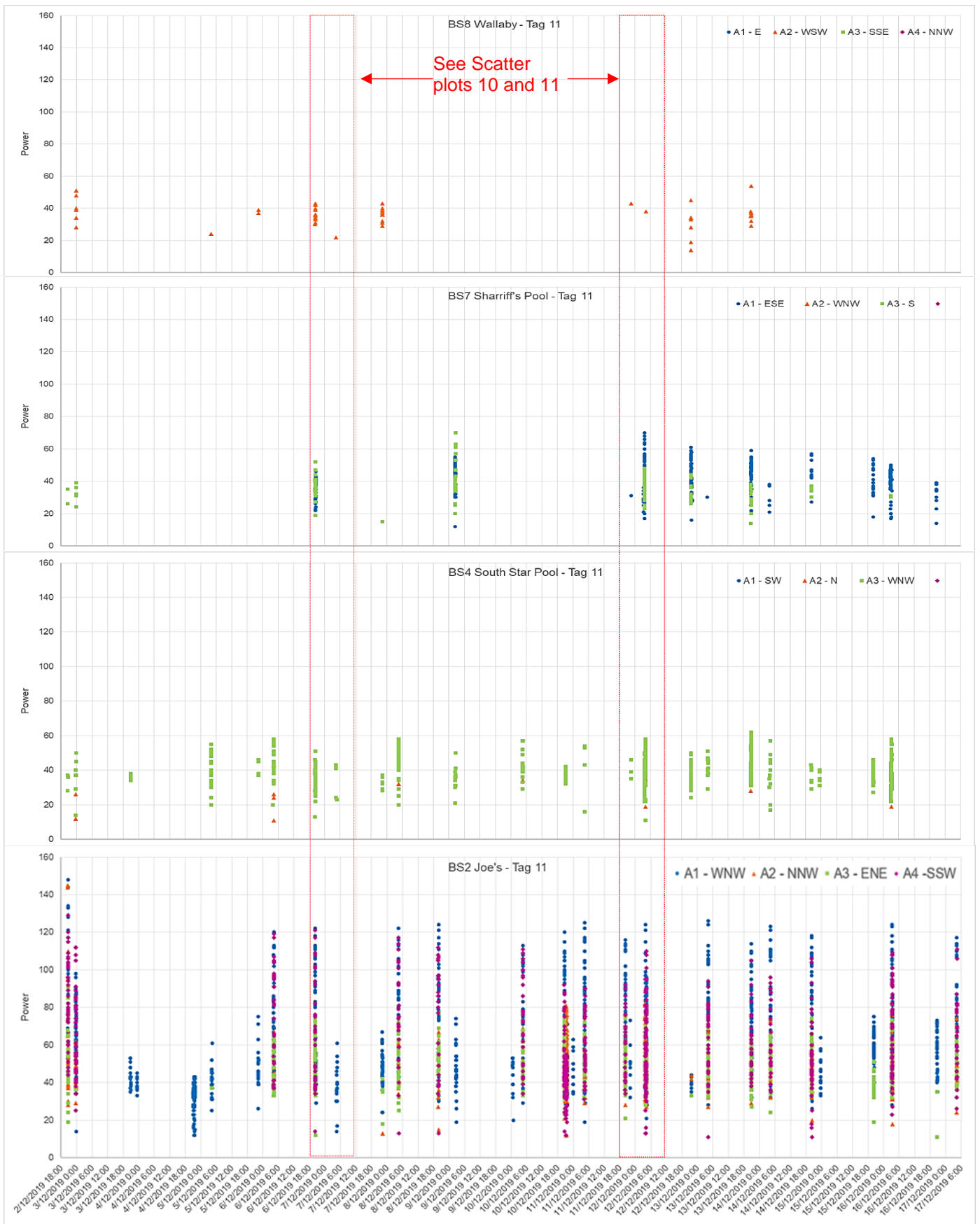
Night	Time first detection	Base station (antenna and orientation)	Time last detection	Base station (antenna and orientation)
2/12/2019	20:40 (released Joes Cave)	Bs2 – A1 / WNW, A4 / SSW	23:52	Bs2 – A1 / WNW
3/12/2019	20:43	Bs2 – A1 / WNW	23:22	Bs2 – A1 / WNW
4/12/2019	20:57	Bs2 – A1 / WNW	04:20	Bs2 – A1 / WNW
5/12/2019	22:12	Bs2 – A1 / WNW	04:16	Bs4 – A3 / WNW, A2 / N
6/12/2019	20:08	Bs2 – A4 / SSW and Bs4 – A3 / WNW	04:41	Bs2 – A1 / WNW and Bs4 – A3 / WNW (1 detection). Note: 11 consecutive detections between 04:35 – 04:41 by Bs2, A1
7/12/2019	22:06	Bs2 – A1 / WNW	04:34	Bs4 – A3 / WNW (27 consecutive detections between 04:30 – 04:34) Note: 9 consecutive detections between 04:30 – 04:32 Bs2 – A3 and A4)
8/12/2019	19:49	Bs2 – A3 / ENE, A4 / SSW	02:47	Bs2 – A1 / WNW
9/12/2019	10/12 – 00:31	Bs2 – A1 / WNW	04:37	Bs4 – A3 / WNW (19 consecutive detections between 04:34 – 04:37). Note: 67 consecutive detections between 04:30 – 04:35 Bs2 – A1, A2, A3, A4
10/12/2019	20:29	Bs2 – A4 / SSW	04:32	Bs2 – A4 / SSW and Bs4 – A3 / WNW (4 consecutive detections within 50 seconds). Note: 31 consecutive detections between 04:30 – 04:32 – Bs2, A1, A2, A3, A4.
11/12/2019	20:01	Bs2 – A4 / SSW	04:23	Bs2 – A1 / WNW
12/12/2019	21:35	Bs2 – A1 / WNW	04:15	Bs4 – A3 / WNW
13/12/2019	20:46	Bs2 – A4 / SSW	04:20	Bs4 – A3 / WNW
14/12/2019	20:06	Bs2 – A4 / SSW	23:42	Bs2 – A1 / WNW
15/12/2019	20:06	Bs2 – A1 / WNW	03:29	Bs2 – A1 / WNW
16/12/2019	20:33	Bs2 – A1 / WNW	04:20	Bs2 – A4 / SSW

NOTE: Times highlighted in green are within 5 mins (+/- 1 min) of civil twilight Times highlighted in blue are within 5-10 mins (+/- 1 min). Times highlighted in yellow are 10-20 mins (+/- 1 min) after civil twilight



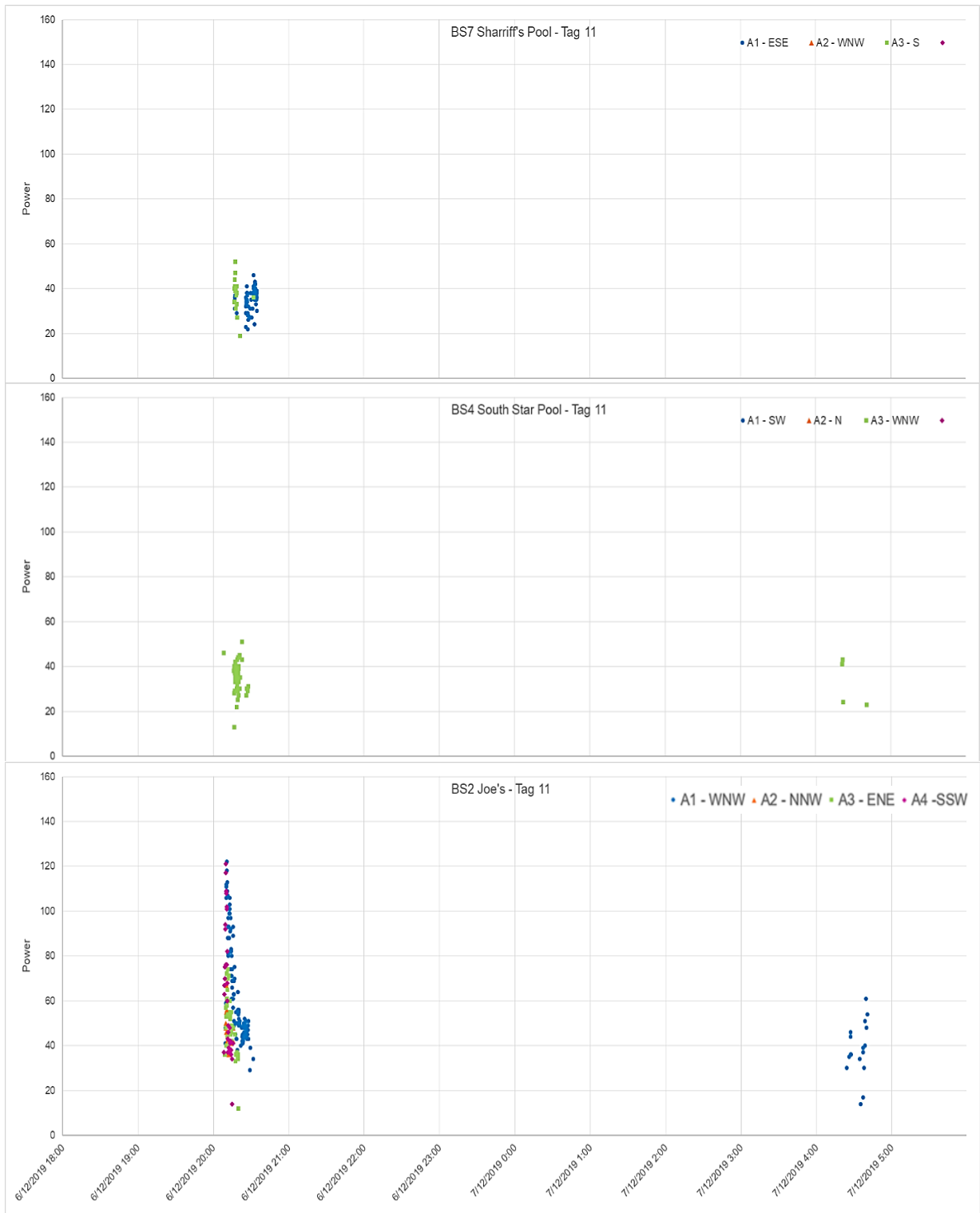
**Chart 7: Nightly activity patterns for Tag 11**

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.



### Scatter plot 9: Base station detections for Tag 11

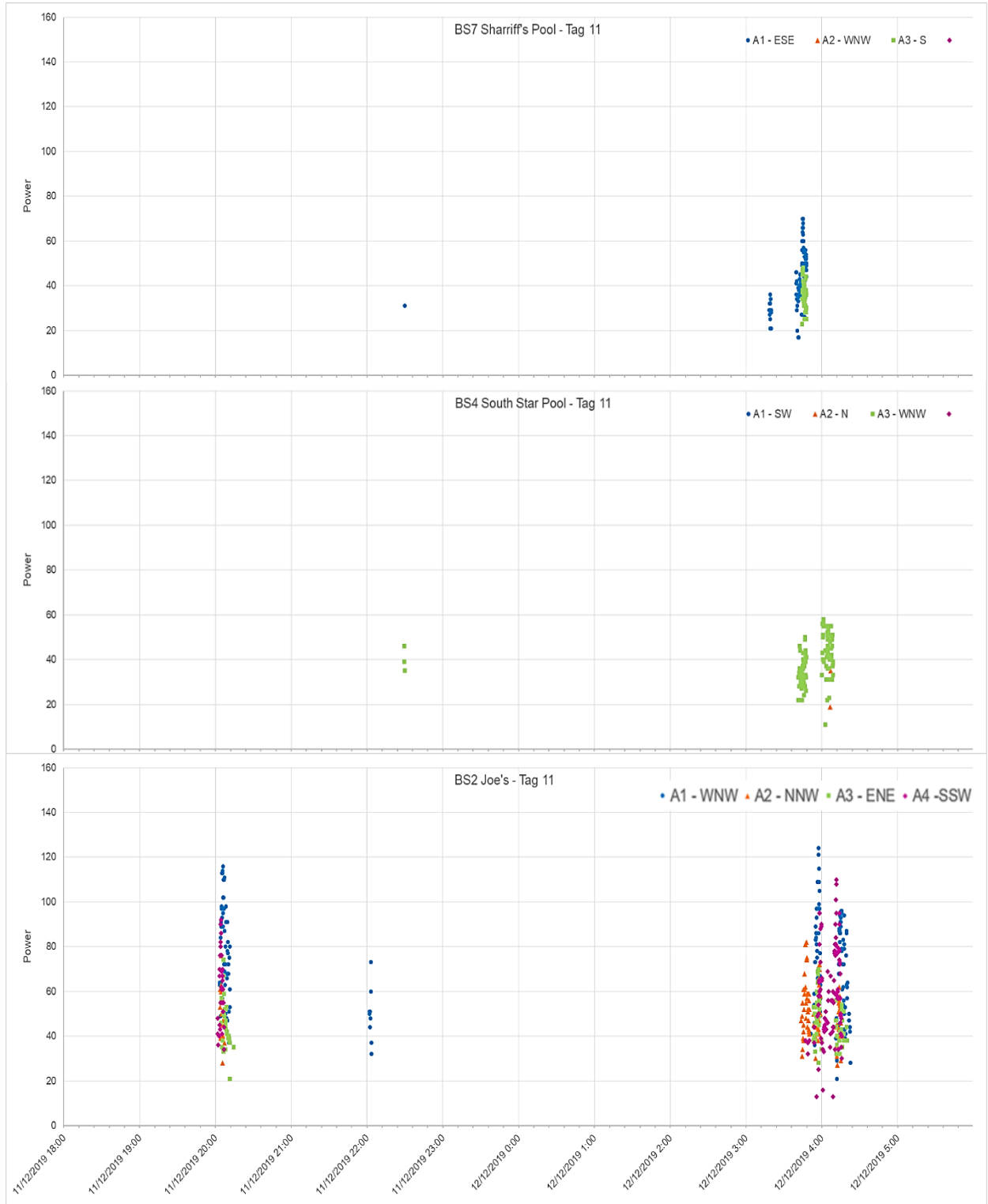
Notes: No valid detections for base station 1, 3, 5, and 6. Detections represented as the power (signal strength) plotted on the x axis, over time on the y axis for each antenna for each base station. Scatterplots are stacked starting with Joes Cave (point of capture), then to demonstrate detections over time and infer movement and direction via visual comparison of the detections (signal strength) over time for each of the base stations.



**Scatter plot 10: Base station detections for Tag 11 – 6 pm 6/12 to 6 am 7/12/2019**

Scatter plot 10 displays the activity pattern for Tag 11 during the night of the 7/12/2019. Activity from c. 8:00 – 8:40 pm started in the immediate area of bs2 (e.g. within 200 m of the tower, as indicated by high, then low signal strength across multiple antenna over a short period of time).

Tag 11 then appeared to move south, south-west as indicated by the declining signal strength over time from bs2, A1 (orientated west-south-west) and bs4, A3 and the increasing signal strength recorded on bs7, A3 (orientated south), then activity recorded by A1, bs7 (orientated east-south-east). From c. 9:00 pm – 4:00 am Tag 11 was absent from the range of the receivers until it was recorded by A1, bs2 and A3, bs4 at c. 4:10 am, most likely in the area south-west of bs2.



**Scatter plot 11: Base station detections for Tag 11 – 6 pm 11/12 to 6 am 12/12/2019**

Scatter plot 11 displays the activity pattern for Tag 11 during the night of the 12/12/12. Activity from c. 8:00 – 8:20 pm started in the immediate area of bs2 (e.g. within 200 m of the tower, as indicated by high, then low signal strength across multiple antennas over a short period of time).

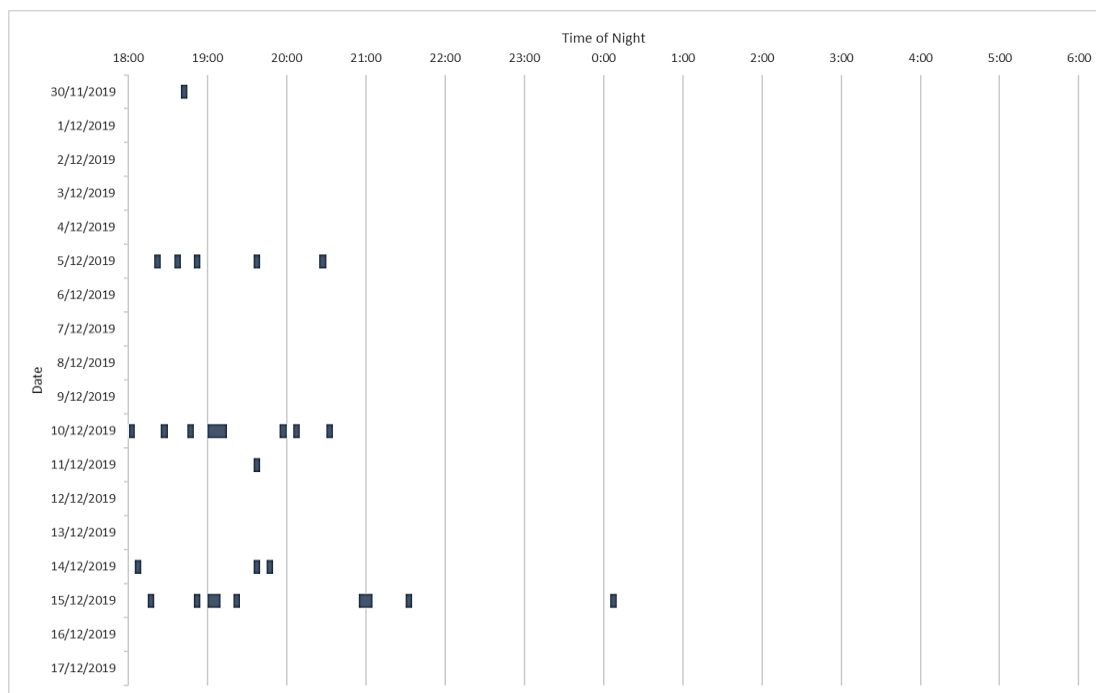
Tag 11 was then absent from the range of the receivers until near 10:00 pm when it was recorded by A1, bs2 and A3, bs4 for a short period. It was then again absent from the range of the receivers for more than 5.5 hours until it was recorded by A1, bs7 (orientated east-south-east) and then soon after by mutipl antenna on bs2 and A3, bs4.

#### 4.2.7 Transmitter 24 and 25

Few valid tag detections were recorded for Tags 24 (n = 34) and 25 (n = 23) (see charts 8 and 9). Although both tags were received by the base station network for up to 15 non-consecutive nights the records consisted of often random, isolated detections (e.g. 2-3 consecutive detections within 1 minute, then no other detection for at least 5 minutes, in most cases more than 30 minutes from the same base station) each night. Near simultaneous detections from two base stations were also occasionally recorded, however in all circumstances the base stations were too far apart with line of sight obstructions, or the antenna were not orientated favourably.

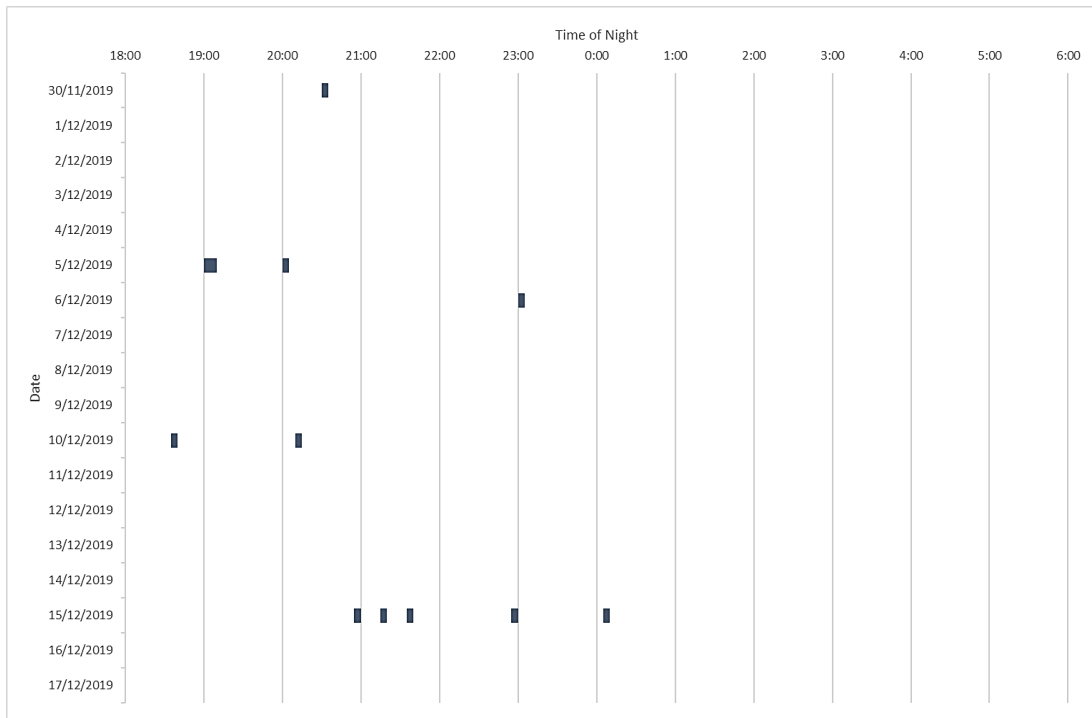
The lack of and random frequency of detections suggests that both bats may have been active outside the reception range of the receivers for the majority of the survey period. This is also partially supported by the lack of data for many of the survey nights. It is possible that some of the bat activity 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.

Alternatively the detections may have been all false positives, however this is unlikely given the successful number of detections recorded for all other tags. The most plausible explanation is that the tagged bats were most active outside the reception range of the receivers.



**Chart 8: Nightly activity patterns for Tag 24**

NOTE: data presented contains dubious dections and is presented to display the lack of and frequency of data.



**Chart 9: Nightly activity patterns for Tag 25**

NOTE: data presented contains dubious detections and is presented to display the lack of and frequency of data.

### 4.3 Radio-tracking – base station analysis

#### 4.3.1 Activity between base stations

The number of valid tag detections (9579) recorded from each base station was analysed to understand the level of activity (e.g. valid detections for the survey period) for each base station and provide a basis to compare the level of activity between base stations. Detection data for tags 24 and 25 have been excluded from the analysis as the majority of detections were considered dubious.

Table 17 provides a summary of the number of valid detections recorded by each base station (all antenna combined) and the number of tags detected by each base station for the duration of the survey. The majority of detections were from three base stations: bs2 (62%); bs4 (24%) bs7 (9%), with base stations (1, 3 and 5) accounting for the remaining 4% of detections. The composition of the detections for bs1, bs2 and bs4 is discussed below.

**Table 17: Summary of detection data for each base station**

Base station	Number valid detections	Number tags detected
Bs1	174	19, 20
Bs2	5906	10, 11, 19, 20, 22
BS3	18	11, 23
Bs4	2322	10, 11, 19, 20, 22, 23
BS5	34	23
Bs6	None	None
Bs7	883	10, 11, 20
Bs8	242	10, 11, 19, 20, 22, 23

Note: detection data for tags 24 and 25 excluded

### **Base station 1 (Rise)**

Base station 1 was located c. 358 m elevation on top of small knoll approximately 300 m west from Chateau Cave. The primary purpose of bs1 was to record activity from tagged bats using Chateau Cave and within the area of Chateau Cave. With the exception of the 28/11/19 and 29/11/19 the base station was operational without any recorded issues.

Of the 174 detections c. 48% recorded by A1 (n=87, orientated south-west), c. 36% recorded by A2 (n=65, orientated south-east at Chateau Cave), c. 12 % recorded by A3 (n=22, orientated north-north-east at the OPF).

### **Base station 2 (above Joes Cave)**

Base station 2 was located at c. 319 m elevation on top of southern facing cliff edge, approximately 90 m east of Joes Cave. There were many operation issues over the course of the survey, therefore it was difficult to rely on the accuracy of the signal direction and strength data recorded by bs2 (see Section 3.7). A breakdown of the 5906 detections per antenna considering the changes to antenna orientation during the survey is provided in Table 18.

### **Base station 4 (above South Star Pool)**

Base station 4 was located at c. 381 m elevation on top off a western facing cliff edge, approximately 600 m east of South Star Pool. Of the 2322 valid detections c. 5% by A1 (n=117, orientated south-west), c. 16% recorded by A2 (n=375, orientated north at Chateau Cave), c. 79% recorded by A3 (n=1830, orientated west-north-west over South Star Pool at Joes Cave).

**Table 18: Summary of detection data for Joe's base station**

Aerial / orientation	Date	Number valid detections	% of detections recorded by bs2 for date period#
A1 – SSW at Joes Cave	29-30/11/19	11	4
A2 – WNW at Shariff's Pool	29-30/11/19	39	16
A3 – N	29-30/11/19	71	28
A4 – E – at Chateau Cave	29-30/11/19	130	52
A1 – WNW at Shariff's Pool	30/11/12 –	2561	45
A2 – NNW	30/11/12 –	832	15
A3- ENE – at Chateau Cave	30/11/12 –	741	13
A4- SSW - at Joes Cave	30/11/12 –	1521	27

Note: #29-30/12/19 total n= 252, and 30/11/19-17/12/19 total n= 5906

### **4.3.2 First and last detection times**

First and last detections with regard to civil twilight times (near sunset and sunrise) were analysed for each base station to assist with determining if bats were roosting in Chateau Cave or Joe's Cave, and to refine the location of other potential roost sites. Summary of first and last detections for each base station:

- Bs1 – No first detections, only last detections for the night of the 9/12/19 for Tag 19 (see Section 4.2 and limitations of data)
- Bs2 - a total of 243 valid detections (125 first and 118 last) from three tags (11, 19 and 20 - see Section 4.2) from the 2/12/19-11/12/19. Detections were recorded on A1 (43%), A4 (25%), A3 (12%) and A2 (6%)
- Bs4 - a total of 132 valid detections (79 first and 53 last) from four tags (11, 19, 20 and 22 - see Section 4.2) from the 30/11/19-11/12/19. Detections were recorded on A1 (55%), A3 (42%) and A2 (2%)
- Bs3, Bs5, Bs6, Bs7, Bs8 - No valid first or last detections.

#### 4.4 Radio-tracking - manual (mobile) tracking data

Manual radio tracking using hand held receivers was also undertaken from between the 30 November to 17 December 2019 including day-time searches for diurnal roosts and tags and night-time searches to track foraging and commuting activity of tagged bats.

Table 19 summarises the survey effort and results. Figure 4 displays the location of the manual tracking searches and key results. No tags were detected with the exception of Tag 11 which was recorded on one occasion very briefly in an area approximately 400 m east of Joe's Cave. However the results should be viewed carefully as the detection period was very brief (e.g. approximately 3 seconds) and despite targeted survey effort in the area no additional detections were recorded. NOTE: the manual detections were recorded at 9:13 am therefore unlikely to correlate with base station tower of operation (4 pm-9 am).

**Table 19: Summary of effort and results for manual (hand held) radio-tracking**

Date	Track and search description	Results / Figure 3 reference
30/11/2019	Jimmy's Gap during trap session at 6:30 pm for approximately 2 hours (not continuous)	No tags detected
30/11/2019	Scan within Chateau Cave for approximately 10 mins	No tags detected
1/12/2019	Trap site 6 during trap session at 6:30 pm for approximately 2 hours (not continuous)	No tags detected
1/12/2019	Scan within Chateau Cave for approximately 10 mins	No tags detected
2/12/19	Scan out front of Joes Cave during trap session at 6:30 pm for approximately 2 hours (not continuous). Scan within Joes Cave at end of trap session for 10 mins	No tags detected in cave. Tags 10 and 11 detected following release
6/12/2019	Scan approximately 400 m north-east Joe's cave base station 2 at 9:13 am for 10 min. This was from top of plateau / breakaway directed east towards rocky gully	Tag 11 detected for approximately 3 seconds – signal strength c. 27 north-east of Joes Cave.
6/12/2019	Scan approximately 160 m north-east Joe's cave base station 2 at 10:32 am for 10 min. This was from top of plateau / breakaway	No tags detected.
6/12/2019	Scan approximately at Pool 12 at 7:10 pm for 10 min	No tags detected
6/12/2019	Scan approximately 800 metres north of Pool 12 at 7:58 pm for 10 min	No tags detected
7/12/2019	Scan approximately 620 m east-north-east of Joe's cave base station 2 at 9:00 am for 10 min. This was at base of breakaway to try to triangulate location of tag 11 detected on previous morning in this approximate location	No tags detected
7/12/2019	Scan near base station 7 at 9:55 am for 10 min	No tags detected
7/12/2019	Scan approximately 580 m east of Joe's cave base station 2 at 8:40 am for 10 min. This was near base of breakaway to try to triangulate location of tag 11 detected on previous morning in this approximate location	No tags detected
9/12/2019	Scan approximately 400 m west-south-west of Nicko's Gorge at 11:18 am for 10 min	No tags detected
9/12/2019	Scan approximately 370 m south-west of Nicko's Gorge at 1:25 pm for 10 min	No tags detected
9/12/2019	Cliff Cave or cave nearby located and scanned c. 2.5 km north-west of Joe's Cave at 2:28 pm for 10 min. No tags detected	No tags detected. Cave habitat assessment completed - potential PLNB roost cave
9/12/2019	Scan approximately 11 km west-north-west of OPF at 1:25 pm for 10 min	No tags detected
10/12/2019	Scan approximately 750 m NNW of base station 6 at 10:42 am for 10 min	No tags detected
11/12/2019	Scan within Joe's cave at 10:50 am for 10 min	No tags detected
11/12/2019	Scan within Chateau cave at 11:57 am for 10 min	No tags detected
16/12/2019	Scan within Chateau cave during roost occupancy surveys	No tags detected

Date	Track and search description	Results / Figure 3 reference
17/12/2019	Scan within Joe's cave at 5:15 pm for 15 min	No tags detected

## 4.5 Roost searches

The search for alternative roost site(s) focussed on the area north and north-east of Joe's Cave base station number 2 and the area around base station 6. The survey three potential roost sites of which all were subject to a preliminary habitat assessment (sites ms19, ms36 and ms37, Figure 4). Full spectrum SM4 bat detectors were placed at each location for a period of two consecutive nights. No PLNB were recorded during the hour following sunset at any site. The location and description of each site is provided in Appendix C. A summary of the survey findings is provided below:

- Site ms19 near bs6 – located close to Abydos mine. Although no evidence was recorded during the survey to suggest occupation by PLNB the structure of the roost is similar to other known transitory and non-permanent breeding roosts (e.g. large front chamber , with a passage of 5 or more metres leading to a rear chamber with smaller sub-chambers in the ceiling). The site is considered a 'potential transitory diurnal roost'
- Site ms36 – located north-west of bs2 (Joes Cave) and east of bs7. This cave has been previously surveyed (Cliff Cave) and was labelled as an unknown potential roost location. Although no evidence was recorded during the survey to suggest occupation by PLNB the structure of the roost is similar to other known transitory and non-permanent breeding roosts (e.g. large front entrance chamber, with two smaller but deeper chambers off the rear of the main chamber, evidence of bats). The site is considered a 'potential transitory diurnal roost'
- Site ms37 – located near Nicko's Gorge. This cave has been previously surveyed (Cave 8) and was labelled as an unknown potential roost location. Although no evidence was recorded during the survey to suggest occupation by PLNB the structure of the roost is similar to other known transitory and non-permanent breeding roosts (e.g. large front entrance chamber, with a smaller chamber off the rear of the main chamber, evidence of bats). The site is considered a 'potential transitory diurnal roost'.

## 4.6 Roost occupancy surveys

Chateau Cave was surveyed using the non-invasive sheeting method on the 16 December 2019 from 6.45 pm to approximately 8.00 pm to determine the presence of PLNB within the main chamber during the survey period and the documented maternity period for PLNB. The following observations were recorded:

- Prior to sheeting the cave (day light period) a hand held receiver (SRX 800-M2) was deployed within the entrance of the main chamber of Chateau Cave for 10 min at 6:30 pm, no tagged bats were detected
- A visual inspection of the main chamber was undertaken (behind the sheet) and at least 5 PLNBs were recorded flying around in the main chamber
- At approximately 7.15 pm a handheld receiver was deployed within the main chamber of Chateau Cave for 10 min, no tagged bats were detected
- At approximately 7.45 pm a hand held receiver was deployed within the main chamber of Chateau Cave for 10 min, no tagged bats were detected
- Sheeting assessment completed by just after 8.00 pm
- Both Common Sheathtail Bat and Finalyson's Cave Bat were recorded from the inside the main chamber and from the second chamber of the cave during the sheeting survey.

## 4.7 Bat call analysis results

Data from 16 sites for 66 nights was recorded using full spectrum Song Meter (SM2 bat plus and SM4 FS), Anabat Swift and AudioMoth detectors. The location of each ultrasonic detector site is displayed on Figure 3. Appendix D consolidates the survey findings for each night and site. A summary of key survey results, includes:

- At least five species of bat were identified with Common Sheath-tail Bat (*Taphazous georgianus*) and Finlayson's Cave Bat (*Vespadelus finlaysoni*) most commonly recorded
- PLNB was recorded for 41 of the 66 nights and from 6 of the 16 sites. Appendix D provides a summary of the PLNB calls detected at each site for the first hour of each night of the survey
- PLNB calls were recorded within 20 mins of civil twilight (+/- 1 min) for 21 nights at four locations. The majority of records are from Chateau Cave (site ds6 = 14 nights during November and December), Joes Cave (site ds1 = 3 nights, 13th, 15th and 16th December 2019), a site near Python Cave (ds5 = 1 night, 1/12/19) and Pool 12 (site ds2 = 1 night, 12/11/19).

Analysis of the data for Chateau Cave revealed the PLNB is utilising the cave as a diurnal roost (e.g. PLNB calls were recorded from the main chamber at least 20 minutes prior to dusk, meaning the species was inside the cave during daylight).

## 5. Discussion

This report presents the methods and results of the second radio-tracking study of the Pilbara Leaf-nosed Bat within the North Star mine study area. The trapping and radio-tracking program was developed and implemented by GHD to assist IB Operations with fulfilling the requirements of the condition of approval for the North Star Magnetite open cut iron ore mine.

When comparing data from the 2017 and 2019 surveys there are several key differences that must be noted. Although the study aims and objectives were similar the study design and field conditions experienced during the surveys were considerably different. The 2019 survey design deliberately expanded on the 2017 survey, with the 2019 base station array covering a much larger area (e.g. greatest distance between base stations - bs7 and bs4 at c. 16.4 km) compared to the 2017 array (e.g. 9.7 km being the greatest distance between base stations). Although two base stations, bs1 (Rise) and bs3 (OPF) shared the same location (within 2 m accuracy) as the 2017 study, the antenna array (number, element and orientation) differed enough to prevent an accurate comparison of the data.

In addition to the base station array, the timing of the surveys (e.g. mid-year June 2017 compared to late year, November-December 2019), and the weather conditions associated with these periods was significantly different. The 2019 survey was impacted by adverse weather conditions resulting in data gaps for several nights for four towers and limitations regarding the analysis of the available data, particularly for bs2. During the 2017 survey conditions were near optimal and with no obvious effect on the performance of the base stations, therefore the signal direction and signal strength data could be relied on and used to infer distance and movement patterns. The signal direction and strength data collected during the 2019 surveys was difficult to interpret, therefore a greater reliance on the analysis of activity data (e.g. comparing all data from one base station to another base station over the course of the night for each tag) was required.

### 5.1 Activity at known roost sites

To understand the roosting behaviour of the PLNB within the study area, the study attempted to capture and track bats from two of the three known diurnal roost locations (Chateau Cave and Joe's Cave). Chateau Cave, Joes Cave and Cave 13 are all recognised PLNB diurnal roosts (see Section 2.2).

All PLNB bats were trapped and tagged at either Chateau Cave (tags 19, 20, 22, 23, 24 and 25) or Joes Cave (tags 10 and 11). Given the location (e.g. known roost), timing and number of bats trapped and observed exiting Chateau Cave we assumed that one or more tagged bats originated from within Chateau Cave. PLNB trapped and tagged at Joes Cave were also assumed to have originated from within or in close proximity to the cave.

To understand usage of the known roost sites, analysis of the timing of the first and last detections with regard to civil twilight times was undertaken for each of base stations located in close proximity to each roost. Base station 1 was positioned to record tagged bats entering/exiting Chateau Cave and activity in the area of Chateau Cave. Base station 2 was positioned to record activity from Joe's Cave and the area surrounding Joes Cave.

#### **Chateau Cave**

There was little evidence to suggest that any of the tagged bats were roosting in Chateau Cave during the survey. A very similar outcome was recorded for Chateau Cave during the 2019 survey as no valid first or last detections were recorded by bs1 including A2 orientated at Chateau Cave. Furthermore, no other first or last detections were recorded by the nearest base stations bs3 (OPF) or bs4 (Shariff's Pool) to indicate that tagged bats were active for any period

within the area of Chateau Cave or using Chateau Cave as a roost during the survey period. The lack of data from bs1 and from manual radio-tracking surveys of Chateau cave, also indicates that none of the tagged bats were using Chateau Cave during the 2019 survey. Despite the absence of data from bs1 for the first night of the surveys, the base station was operational for the remainder of the survey period.

Despite the absence of data indicating that tagged bats were using Chateau cave during the survey, the analysis of the ultrasonic data from detectors within the cave and data from roost occupancy surveys has unambiguously proven that PLNB were using Chateau Cave as a diurnal roost during the survey.

### **Cave 13**

It is unlikely that tagged bats occupied Cave 13 or were frequently active in the Cave 13 area during the survey, as supported by the lack of data from bs1, bs3 and bs4. Furthermore, the analysis of ultrasonic survey data did not record any calls during the one hour period following sunset for six nights during the survey.

### **Joe's Cave**

Given the issues interpreting signal strength and direction data from bs2, it was not possible to be definitive with regard to the source of the tag signals. However a review of the first and last tag detection data from the nearest base station provides an indication of the location of activity during the emergence and re-entry periods in the Joe's Cave area.

Base stations 2 and bs4 were the only base stations to record valid first and last tag detections. The majority of detections from bs2 from the 2/12/19 onwards were recorded on A1 (43%, orientated west-north-west toward Shariff's Pool), then A4 (25%, orientated, south-south-west at Joe's Cave), A3 (12%, orientated east-north-east) and A2 (6%, orientated north-north-west). The data indicates the presence of one or possibly two diurnal roosts within the reception range of bs2, most likely the area, south-east, through south-west of the base station including Joe's Cave, Zane's Gorge area. It is important to note that many (42%) of the detections from bs4 were recorded by A3 (orientated west-north-west at Joe's Cave) and were either simultaneous or near-simultaneous with detections from bs2 or within 1-2 minutes of detections from bs2. Such detections provide supporting evidence for a diurnal roost site at Joe's Cave or within close proximity to Joe's Cave given the orientation of the antenna and line of sight testing results (Appendix A).

The analysis of data from bs2, supported by data from bs4 does indicate that Tag 11 and Tag 20 may have roosted within or in close proximity to Joe's Cave during the survey:

- Tag 20 - Regular first detections were recorded 1st, 2nd, 3rd, 5th and 6th December 2019 by bs2, A1 (orientated west-north-west) and A4 (south-south-west at Joes Cave). The timing of the tag detections also coincides with calls recorded using ultrasonic detectors during the emergence period for Pilbara Leaf-nosed Bat during the survey period (Section 4.5). No corresponding last detections were recorded for the same nights by any base station indicating that Tag 20 was returning to its roost prior to sunrise via a route not within the reception range of the receivers (e.g. along Zane's Gorge, parts of which are a 'blind spot') and/or for some nights it was entering the roost earlier than expected.

- Tag 11 – Regular last (near sunrise) detections were recorded 6th, 7th, 9th and 10th of December), by bs2 A1 (orientated west-north-west) and/or bs4, A4 (orientated south-south-west). Last detections were always supported by multiple consecutive detections within a 1-5 minute period the same antenna. Furthermore, multiple simultaneous detections were also recorded for two nights by bs2, A1 and bs2, A4. Late morning detections were also recorded for 6 other nights (e.g. between 4:10 and 4:30 am). No corresponding first detections were recorded for the same nights by any base station indicating that Tag 20 was leaving its roost via a route not within the reception range of the receivers and/or its was delaying its emergence.

During the current and 2017 study none of the bats trapped and tagged at Chateau Cave were detected using Chateau Cave as a roost. It is important to raise the possibility that the capture and tagging of bats may alter their behaviour. Due to the disturbance (e.g. several nights of trapping and handling/tagging of individuals) individuals may abandon the roost for the duration of the survey period, and possibly longer therefore influencing the ability of the survey to track the movements of the individual. This behavioural response ay account for the lack of tagged bats utilising Chateau Cave during both surveys.

## 5.2 Nightly activity

In addition to locating roost sites the study also aimed to understand the nightly activity patterns of the tagged PLNB within the range of reception of the receivers.

The detection data demonstrated that all tagged bats with the exception of one (Tag 22) occurred within the range of reception of the base station receivers for at least 4 survey nights. Three tags exceeded 9 nights (Tag 23, 10 non-consecutive nights; Tag 20, 14 non-consecutive nights; Tag 11, 15 consecutive nights).

The majority of detections were from three base stations: bs2 (62%); bs4 (24%) bs7 (9%), with base stations (1, 3 and 5) accounting for the remaining 4% of detections. Activity was often characterised by c. 3 consecutive detections followed by large gaps of zero activity and short bouts of isolated activity (e.g. 3 or more consecutive detections each minute for 1-5 minutes). Three tagged bats (19, 20 and 11) recorded regular bouts of moderate activity (e.g. 3 or more consecutive detections each minute for more than 5 minutes).

The data also revealed that tagged individuals frequently commuted beyond the range of the receivers. Although there are limitations with some of data from some nights (e.g. no data for bs1 29/11/19 and the interpretation of signal strength and direction data from bs2), the lack of detections (e.g. of 1-2 hours and whole nights for some bats), indicates that all tagged bats were most active outside the reception range of the receivers for most of the survey period. The absence of activity was more common than activity during the survey. For example there were clearly large periods of time that Tag 11 was not recorded by any of the base stations. The data indicates that Tag 11 was active during the PM period within the receiver range of reception, however was absent most nights between approximately midnight and 2:30 am from the range of the receivers. Activity peaked again between the hours of 3 am and 4:30 am, before it again reduced and was absent, assuming the bat had returned to roost.

The 2017 study revealed similar findings regarding nightly activity patterns of tagged bats. The data from 2017 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. 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 both the 2017 and 2019 surveys 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, duration of the tracking survey, and manual tracking effort which should have partially overcome this potential limitation.

### 5.3 Alternate roost locations

The main purpose of the survey was to locate and/or narrow the potential location of an alternative natural maternity roost site(s) for the PLNB within the study area

The 2019 study findings coupled with information from the 2017 study provides sufficient evidence that at least one or two diurnal roosts occur within the range of reception of the receivers in addition to the known diurnal roost of Chateau Cave and Cave 13. There is evidence to suggest that Joe's Cave may have been used as a diurnal roost during the survey by Tag 11 and/or 20 however as indicated by the data, it is unlikely that either bat consistently used Joe's Cave for every night of the survey period.

- Potential roost location, north-east through south-west of Joe's Cave - Base stations 2 and bs4 were the only base station to record valid first and last tag detections. As previously discussed the data indicates the presence of a diurnal roost within the reception range of bs2, including the area, south-east, through south-west of the base station. This broad area incorporates:
  - Potential roosting habitat surveyed during manual tracking searches (ms13 and ms9 within 1 km north-east of Joes cave, Figure 4). The area east-north-east of Joe's Cave has several locations identified as potential roosting habitat (see Section 2.2 and Figure 2).
  - Zane's Gorge and the southern facing cliff face for within 4 kms west of Joe's Cave. The area west of Zane's Gorge has several locations identified as potential roosting habitat (see Section 2.2 and Figure 2).
- Potential roost location, north-east of Joe's Cave - the timing of the last detection (4:29 am) for the morning of the 1/12/19 and first detection (7:18 pm) for the night of the 1/12/19 by bs2 – A3 (orientated east-north-east) for three and four consecutive detections then by A4 (orientated south-south-west) indicates Tag 19 was roosting in the area north-east of Joe's Cave. Potential roosting habitat surveyed during manual tracking searches (ms13 and ms9 within 1 km north-east of Joes cave, Figure 4). The area east-north-east of Joe's Cave has several locations identified as potential roosting habitat (see Section 2.2 and Figure 2).
- Potential roost location, South Star Pool area - The timing of the data from bs4 for the night of the 30/11/19 indicates Tag 22 was detected in close proximity to or leaving a diurnal roost. Following the first detection by bs4, A1 (orientated south-west, south of South Star pool) at 7:01 pm, 74 consecutive detections were recorded by A1 for an 11 minute period from 7:01 – 7:12 pm, with 7:12 pm being the last valid detection recorded. No other detections were recorded by bs4 or other base stations within 20 minutes of civil twilight.
- Evidence for an additional diurnal roost site is also in part supported by the lack of data from Chateau Cave and to a lesser extent Cave 13 as discussed in Sections 5.1 and 5.2.
- Other diurnal roosts may also exist in areas outside the reception range of the base stations, as indicated by the 2017 study however, particular the Abydos Mine area however insufficient data was collected during the 2019 study to add to the 2017 findings.

- The manual tracking and roost search survey results undertaken in the area north east of Joe's Cave during the 2017 study 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 height) 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. The findings from the 2019 study support the discussions regarding the location of potential diurnal roost habitat in the Joe's Cave and Zane's Gorge areas, and the area north-east of Joe's Cave.

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# Appendices

# Appendix A - Line of sight testing and theoretical zone of reception

## *Line of sight testing and outputs*

The position, orientation and number of antenna for each base station was considered with regard to localised physical sources of interference and previous testing (June 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 and survey during June 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. Record two gps points at each test point site to mark time (at start and finish) and 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).

These tests revealed a direct line of sight detection radius of up to 8.3 km for the three-element antennas and up to 8.1 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 8.1 km for the six element antenna.

To gain a better understanding of the reception range of each base station we also reviewed the line of site and approximate zone of reception with consideration to the topography which was most likely the biggest source of signal impediment, field observations taken from the view point of each base station, review of google earth imagery (3D view shed), and elevation modelling using the elevation of each base station plus 1 m. The theoretical zone of reception is considered to be the area within which a transmitter should be detected by the base station receiver for each base station. This process does not account for areas where gaps in the reception range occur (e.g. 'black spots' which may prevent signal transmission or reception), thus it is likely to over estimate the reception area for each base station.

Figure 5 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 2019 survey.

**Table 20: Antenna array (orientation and type) for each base station**

Base station	Antenna number (bearing degree's and orientation / element type)			
	1	2	3	4
1. Rise	220 - SW / 3	131 – SE / 3	20 – NNE / 3	-
2. Joe's Cave (28-29/11/19) approximate orientation	SSW / 3	WNW / 6	N / 3	E / 6
2. Joe's Cave (30/11/12 onwards) approximate orientations	WNW – 280 / 3	NNW – 350 / 6	60 – ENE / 3	185 – SSW / 6
3. OPF	109 - ESE / 6	302 – WNW / 6	357 - N / 3	-
4. South Star Pool	225 – SW / 6	1 – N / 6	285 – WNW / 3	-
5. North – (west)	350 - N / 6	85 -E / 3	185 - S / 3	265 - W / 3
6. North - (east)/ twin towers	340 – NNW / 3	190 - S / 6	85 - E / 3	285 – WNW / 6
7. Shariffs Pool (west of Giants Cave)	116 - ESE / 3	297 – WNW / 6	187 – S / 3	-
8. Wallaby	88 - E / 6	248 – WSW / 3	149 – SSE / 3	339 – NNW / 6

**Summary of LOS testing results using tags just prior to release****Tag 19**

Between 20:00 and 20:09 prior to releasing the tagged bat at 20:10 at Chateau Cave Tag 19 was recorded at three base stations: c. 8 km west at bs2 Joes Cave (antenna 4, 6 element (ele) orientated east); c. 4.9 km north-west at bs 8 Wallaby (antenna 3, 3 ele orientated south-south-east); 2.3 km south at bs 4 South Star Pool (antenna 2, 6 ele orientated north).

**Tag 20**

Tag 20 was recorded c. 4.9 km north-west at bs 8 Wallaby at 20:43 and 21:29 (antenna 3, 3 ele orientated south-south-east) prior to releasing the tagged bat at 21:35 at Chateau Cave

**Tag 22**

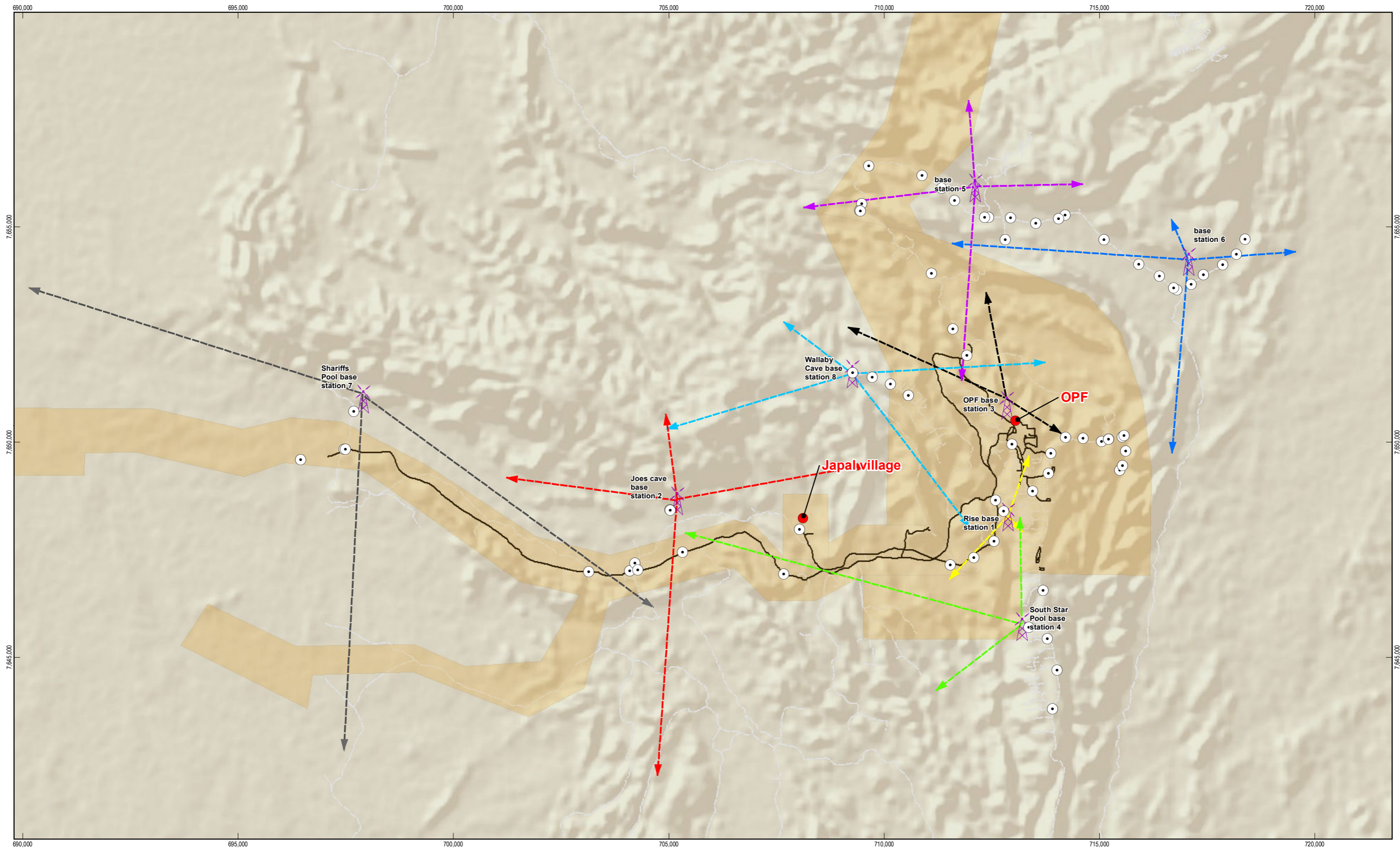
Tag 22 was recorded c. 4.9 km north-west at bs 8 Wallaby at 20:50 (antenna 3, 3 ele orientated south-south-east) prior to releasing the tagged bat at 20:55 at Chateau Cave.

**Tag 23**

Tag 23 was recorded c. 4.9 km north-west at bs 8 Wallaby at 21:02 (antenna 3, 3 ele orientated south-south-east) prior to releasing the tagged bat at 21:20 at Chateau Cave.

**Tag 11**

Prior to release (c. 20:40) at Joes Cave Tag 11 was recorded simultaneously at 20:35 c. 8.3 km south-east at bs 4 South Star Pool (antenna 3, 3 ele orientated west-north-west) and c. 7.7 km north-west at bs7 Shariffs Pool (antenna 3, 3 ele orientated east-south-east).



<p>Paper Size A3</p> <p>Map Projection: Transverse Mercator Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 50</p>		<ul style="list-style-type: none"> <li> line of site test points</li> <li> PLNB Base Station 2019</li> <li> FMGIB Development Envelope</li> </ul>	<ul style="list-style-type: none"> <li> Road; Haul Road</li> <li> Minor Track; Drill Line</li> </ul> <p><b>BaseStation</b></p> <ul style="list-style-type: none"> <li> 1. Rise</li> <li> 2. Joe's Cave</li> <li> 3. OPF</li> </ul>	<ul style="list-style-type: none"> <li> 4. South Start Pool</li> <li> 5. North (West)</li> <li> 6. North (east) Twin Towers</li> <li> 7. Shariffs Pool (West of Giants Cave)</li> </ul>	<ul style="list-style-type: none"> <li> 8. Wallaby</li> </ul>		<p>Fortescue Metals Group Ltd Review of bats for FMG operations</p> <p><b>Base station line of sight and zone of reception</b></p>	<table border="0"> <tr> <td>Job Number</td> <td>61-37868</td> </tr> <tr> <td>Revision</td> <td>0</td> </tr> <tr> <td>Date</td> <td>29 May 2020</td> </tr> </table>	Job Number	61-37868	Revision	0	Date	29 May 2020
Job Number	61-37868													
Revision	0													
Date	29 May 2020													

# **Appendix B** - Trap data sheet

LOCATION	SITE	DATUM	LATITUDE	LONGITUDE	ACCURACY	DATE	NAME_ID	SPECIES_NAME	COMMON_NAME	SPECIES_GROUP	COUNT	IDENTIFIER	CERTAINTY	METHOD	FATE	TRANSMITTER
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Jimmy's Gap, dry Creek	GDA94	-21.2513	119.04605	100	7/11/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Jimmy's Gap, dry Creek	GDA94	-21.2513	119.04605	100	7/11/2019	24200	Scotorepens greyii	Little Broad-nosed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Shariffs Pool	GDA94	-21.2672	118.904691	100	9/11/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Shariffs Pool	GDA94	-21.2672	118.904691	100	9/11/2019	24200	Scotorepens greyii	Little Broad-nosed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	

North Star Mine Site	dry Creek	GDA94	-21.2672	118.967034	100	10/11/2019	24200	Scotorepens greyii	Little Broad-nosed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	dry Creek	GDA94	-21.2672	118.967034	100	10/11/2019	24200	Scotorepens greyii	Little Broad-nosed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94			100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	

North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	28/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	24205	Vespadelus finlaysoni	Finalyson's Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags

North Star Mine Site	Chateau Cave	GDA94			100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags
North Star Mine Site	Chateau Cave	GDA94			100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags
North Star Mine Site	Chateau Cave	GDA94			100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags
North Star Mine Site	Chateau Cave	GDA94			100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags
North Star Mine Site	Jimmy's Gap, dry Creek	GDA94	-21.2513	119.04605	100	30/11/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	creek, pools	GDA94	-21.1879	119.048132	100	1/12/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	

North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24175	Taphozous georgianus	Common Sheath-tailed Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24205	Vespadelus finlaysoni	Finalysons Cave Bat	Mammal	1	Craig Grabham	3	Harp trap	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	43368	Rhinonicteris aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2

																Nano Tags
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Harp trap	alive	Lotek NTQB -2.2 Nano Tags
North Star Mine Site	Chateau Cave	GDA94			100	6/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - Anabat Swift and AudioMoth	alive	
North Star Mine Site	Chateau Cave	GDA94			100	7/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - Anabat Swift and AudioMoth	alive	
North Star Mine Site	Chateau Cave	GDA94			100	13/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Chateau Cave	GDA94			100	14/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Chateau Cave	GDA94			100	15/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Chateau Cave	GDA94			100	16/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder -	alive	

														SongMet er4bat		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	17/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	18/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	19/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	20/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	21/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	22/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	23/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder -	alive		

														SongMet er4bat		
North Star Mine Site	Chateau Cave	GDA94		100	24/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94		100	25/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Chateau Cave	GDA94		100	26/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat and Anabat Swift	alive		
North Star Mine Site	Chateau Cave	GDA94		100	27/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat and Anabat Swift	alive		
North Star Mine Site	Chateau Cave	GDA94		100	28/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat and Anabat Swift	alive		

North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat and Anabat Swift	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	30/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat and Anabat Swift	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	1/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat and Anabat Swift	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	2/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat and Anabat Swift	alive	
North Star Mine Site	Chateau Cave	GDA94	[REDACTED]	100	3/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat and Anabat Swift	alive	

North Star Mine Site	Cave 13		-21.258338	119.055878	100	28/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - AudioMoth	alive	
North Star Mine Site	Cave 13		-21.258338	119.055878	100	29/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - AudioMoth	alive	
North Star Mine Site	Cave 13		-21.258338	119.055878	100	1/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Cave 13		-21.258338	119.055878	100	2/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Cave 13		-21.258338	119.055878	100	3/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Cave 13		-21.258338	119.055878	100	4/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	9/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - Anabat Swift	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	10/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - Anabat Swift	alive	

North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	11/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - Anabat Swift	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	12/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	13/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	14/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	15/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	16/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	Cow Pool	GDA95	-21.252201	119.034387	100	11/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMeter4bat	alive	
North Star Mine Site	dry creek	GDA96	-21.191008	119.049871	100	12/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder -	alive	

															SongMet er4bat		
North Star Mine Site	Python Cave	GDA97	-21.294584	119.055767	100	1/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Python Cave	GDA98	-21.294584	119.055767	100	2/12/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - SongMet er4bat	alive		
North Star Mine Site	Pool 12	GDA99	-21.245479	119.080453	100	10/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - AudioMoth	alive		
North Star Mine Site	Pool 12	GDA100	-21.245479	119.080453	100	12/11/2019	43368	Rhinonictis aurantia	Pilbara Leaf-nosed bat	Mammal	1	Craig Grabham	3	Ultrasonic recorder - AudioMoth	alive		
North Star Mine Site	Joe's Cave	GDA94	-21.25215397	118.9777	100	6/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive		
North Star Mine Site	Jimmy's Gap, dry Creek	GDA94	-21.2513	119.04605	100	7/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive		
North Star Mine Site	Shariffs Pool	GDA94	-21.2672	118.904691	100	9/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive		
North Star Mine Site	Chateau Cave	GDA94			100	26/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive		
North Star Mine Site	Chateau Cave	GDA94			100	27/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive		

North Star Mine Site	Chateau Cave	GDA94			100	29/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive	
North Star Mine Site	Jimmy's Gap, dry Creek	GDA94	-21.2513	119.04605	100	30/11/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive	
North Star Mine Site	creek, pools	GDA94	-21.1879	119.048132	100	1/12/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive	
North Star Mine Site	Joe's Cave	GDA94	-21.2523	118.9776307	100	2/12/2019	24180	Macroderma gigas	Ghost Bat	Mammal	2	Craig Grabham	3	Observation - in flight	alive	

## **Appendix C** - Cave habitat assessment results

# Appendix D - Bat detector survey methods and results

## Bat call analysis and limitations

Call identification was assisted by consulting distribution information for potential species (Armstrong 2011 and McKenzie et al various dates; Churchill 2008; Van Dyck et al. 2013) and records from NatureMap (2019). No reference calls were collected during the survey.

Data was processed and analysed using a combination of manual review and automated processes using Kaleidoscope Pro (Wildlife Acoustic, version 5.1.8) and Anabat Insight (Titly Scientific, version 1.8.3) using the following process:

- Files were downloaded from the units and saved to a computer hard drive and external hard drive (back up copy) following the survey for later processing and analysis
- For compressed WAV and WAC files (full spectrum) collected using the Song Meter units, files were converted to standard WAV using the conversion function in Kaleidoscope Pro
- For each night data was manually reviewed for bat calls using Kaleidoscope Pro or Anabat Insight from sunset onwards for approximately 1 hour by visually comparing the time-frequency graph and call characteristics (e.g. peak frequency, characteristic frequency and call shape) with species call descriptions from published guidelines (e.g. Armstrong and Cole 2007; McKenzie and Bullen 2009 and 2012).
- Data was then filtered using Wildlife Acoustic Kaleidoscope signal parameter batch processing. Further manual data review was also completed for validation purposes which was repeated several times to accurately identify species.
- Data was then processed using the Wildlife Acoustic Kaleidoscope cluster analysis function to provide information regarding Pilbara Leaf-nosed Bat call activity patterns for each night.

A call (pass) was defined as a sequence of three or more consecutive pulses of similar frequency and shape with the exception of the Pilbara Leaf-nosed Bat where at least two clear pulses was acceptable. Calls with less than three defined consecutive pulses of similar frequency and shape were not unambiguously identified to a species but may be used as part of the activity count for the survey area. Due to variability in the quality of calls and the difficulty in distinguishing some species the identification of each call was assigned a confidence rating (see Mills et al. 1996 & Duffy et al. 2000) during the manual validation process as summarised in the table below.

## Confidence ratings applied to calls

Identification	Description
D - Definite	Species identification not in doubt.
PR - Probable	Call most likely to represent a particular species, but there exists a low probability of confusion with species of similar call type or call lacks sufficient detail.
SG - Species Group	Call made by one of two or more species. Call characteristics overlap, particularly poor quality calls or mixed species calls making it difficult to distinguish between species e.g. <i>Taphozous georianus</i> / <i>Taphozous hilli</i> <i>Nyctophilus</i> sp. The calls of <i>Nyctophilus geoffroyi</i> / <i>daedalus</i> / <i>arnhemensis</i> .

The semi-automated analysis process does not always capture all 'softer' Pilbara Leaf-nosed Bat (those calls with a lower amplitude) and Ghost Bat calls and sometimes calls with few pulses. Noting these limitations the manual review of all files for the first hour of the analysis process each night ensured no emergence calls were missed. Furthermore random manual checking of data revealed that few if any Pilbara Leaf-nosed Bat calls were missed for the majority of the nights. Having said that both the Pilbara Leaf-nosed Bat and Ghost Bat need to be in close proximity to the bat detector to be recorded. The Ghost Bat call in particular is of low intensity making it difficult to detect with a bat detector therefore ultrasonic surveys should not be the primary means of surveying for this species.

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**Sunrise, sunset and civil twilight times during survey period.**

Date	Sunrise	Sunset	Civil twilight rise	Civil twilight set
28/11/2019	5:14	18:24	4:50	18:48
17/12/2019	5:17	18:43	4:53	19:08

Source: BOM

## Summary of results to date

Unit	Figure no	Site	Night	Time 1st bat call	Species	Time 1st PLNB call
sm4 u5	ds5	Chateau Cave (inside cave)	13/11/2019	18:31	<i>T.georgianus</i>	19:01
sm4 u5	ds5	Chateau Cave (inside cave)	14/11/2019	18:32	<i>T.georgianus</i>	19:46
sm4 u5	ds5	Chateau Cave (inside cave)	15/11/2019	18:31	<i>T.georgianus</i>	18:46
sm4 u5	ds5	Chateau Cave (inside cave)	16/11/2019	18:32	<i>T.georgianus</i>	19:31
sm4 u5	ds5	Chateau Cave (inside cave)	17/11/2019	18:34	<i>T.georgianus</i>	19:48
sm4 u5	ds5	Chateau Cave (inside cave)	18/11/2019	18:38	<i>T.georgianus</i>	20:05
sm4 u5	ds5	Chateau Cave (inside cave)	19/11/2019	18:48	<i>T.georgianus</i>	19:51
sm4 u5	ds5	Chateau Cave (inside cave)	20/11/2019	18:34	<i>T.georgianus</i>	19:21
sm4 u5	ds5	Chateau Cave (inside cave)	21/11/2019	18:35	<i>T.georgianus</i>	19:32
sm4 u5	ds5	Chateau Cave (inside cave)	22/11/2019	18:35	<i>T.georgianus</i>	20:03
sm4 u5	ds5	Chateau Cave (inside cave)	23/11/2019	18:36	<i>T.georgianus</i>	19:31
sm4 u5	ds5	Chateau Cave (inside cave)	24/11/2019	17:30	<i>T.georgianus</i>	18:19
sm4 u5	ds5	Chateau Cave (inside cave)	25/11/2019	17:30	<i>T.georgianus</i>	19:40
sm4 u5	ds5	Chateau Cave (inside cave)	26/11/2019	17:38	<i>T.georgianus</i>	20:26
sm4 u5	ds5	Chateau Cave (inside cave)	27/11/2019	17:35	<i>T.georgianus</i>	19:44
sm4 u5	ds5	Chateau Cave (inside cave)	28/11/2019	17:30	<i>T.georgianus</i>	19:08
sm4 u5	ds5	Chateau Cave (inside cave)	29/11/2019	17:34	<i>T.georgianus</i>	18:52
sm4 u5	ds5	Chateau Cave (inside cave)	30/11/2019	17:31	<i>T.georgianus</i>	19:30
sm4 u5	ds5	Chateau Cave (inside cave)	1/12/2019	17:30	<i>T.georgianus</i>	19:14
sm4 u5	ds5	Chateau Cave (inside cave)	2/12/2019	17:30	<i>T.georgianus</i>	20:00
sm4 u5	ds5	Chateau Cave (inside cave)	3/12/2019	17:30	<i>T.georgianus</i>	19:52
sm4 u2	ds8	Cave 13	1/12/2019	18:33	<i>V finlaysoni</i>	.
sm4 u2	ds8	Cave 13	2/12/2019	17:55	<i>T.georgianus</i>	.
sm4 u2	ds8	Cave 13	3/12/2019	18:34	<i>V finlaysoni</i>	.
sm4 u2	ds8	Cave 13	4/12/2019	18:27	<i>T.georgianus</i>	.
sm4 u5	.	Cow Pool	10/11/2019	18:30	<i>S. greyii</i>	.
sm4 u5	.	Cow Pool	11/11/2019	18:42	<i>V. finlaysoni</i>	19:25
sm4 u1	ds4	bs5	11/11/2019	18:43	<i>V. finlaysoni</i>	.
sm4 u1	ds4	bs5	12/11/2019	18:42	<i>S. greyii</i>	19:29
sm4 u1	ds7	Jimmys Gap	27/11/2019	19:03	<i>V. finlaysoni</i>	.
sm4 u1	ds7	Jimmys Gap	28/11/2019	18:55	<i>V. finlaysoni</i>	.
sm4 u1	ds15	python cave	30/11/2019	18:49	<i>V. finlaysoni</i>	.
sm4 u1	ds15	python cave	1/12/2019	18:37	<i>unsure</i>	19:21
sm4 u1	ds15	python cave	2/12/2019	18:47	<i>V. finlaysoni</i>	19:13
sm4 u2	.	bs5 and bs6	27/11/2019	18:53	<i>T.georgianus</i>	.
sm4 u2	.	bs5 and bs6	28/11/2019	19:04	<i>T.georgianus</i>	.
swift	ds5	Chateau Cave (inside cave)	6/11/2019	18:15	<i>T. georgianus</i>	18:15
swift	ds5	Chateau Cave (inside cave)	7/11/2019	18:15	<i>T. georgianus</i>	18:16
swift	ds6	Chateau Cave (outside)	26/11/2019	18:27	<i>T. georgianus</i>	.
swift	ds6	Chateau Cave (outside)	27/11/2019	18:57	<i>T. georgianus</i>	20:13
swift	ds6	Chateau Cave (outside)	28/11/2019	18:52	<i>T. georgianus</i>	19:15
swift	ds6	Chateau Cave (outside)	29/11/2019	18:50	<i>T. georgianus</i>	19:27
swift	ds6	Chateau Cave (outside)	30/11/2019	18:23	<i>T. georgianus</i>	19:30
swift	ds6	Chateau Cave (outside)	1/12/2019	18:16	<i>T. georgianus</i>	19:13
swift	ds6	Chateau Cave (outside)	2/12/2019	18:23	<i>T. georgianus</i>	19:58
swift	ds6	Chateau Cave (outside)	3/12/2019	18:25	<i>T. georgianus</i>	19:04
swift	ds1	Joes Cave	9/11/2019	18:36	<i>V. finlaysoni</i>	.
swift	ds1	Joes Cave	10/11/2019	18:42	<i>V. finlaysoni</i>	19:33

swift	ds1	Joes Cave	11/11/2019	18:16	<i>T. georgianus</i>	19:16
AM1	ds2	pool 12	10/11/2019	18:05	<i>T. georgianus</i>	.
AM1	ds2	pool 12	11/11/2019	18:39	<i>V. finlaysoni</i>	.
AM1	ds2	pool 12	12/11/2019	18:07	<i>T. georgianus</i>	19:04
AM4	ds2	pool 12	10/11/2012	18:27	<i>T. georgianus</i>	18:35
AM4	ds2	pool 12	11/11/2012	18:39	<i>C. gouldii</i>	.
AM2	ds3	spring below bs6	11/11/2019	19:02	<i>V. finlaysoni</i>	.
AM2	ds3	spring below bs6	12/11/2019	19:07	<i>V. finlaysoni</i>	.
AM2	ds10	turkeys nest	27/11/2019	.	.	.
AM2	ds10	turkeys nest	28/11/2019	19:18	<i>V. finlaysoni</i>	.
AM2	ds10	turkeys nest	29/11/2019	19:08	<i>V. finlaysoni</i>	.
AM2	ds10	turkeys nest	30/11/2019	19:03	<i>T. georgianus</i>	.
AM4	ds11	shariffs pool	27/11/2019	.	.	.
AM1	ds8	Cave 13	28/11/2019	18:44	<i>V. finlaysoni</i>	.
AM1	ds8	Cave 13	29/11/2019	18:45	<i>V. finlaysoni</i>	.
AM1	ds5	Chateua cave (inside)	6/11/2019	18:16	<i>T. georgianus</i>	18:47
AM1	ds5	Chateua cave (inside)	7/11/2019	18:16	<i>T. georgianus</i>	18:47
sm4 u1	ds12	Chopper 1	9/12/2019	19:05	<i>C. gouldii</i>	.
sm4 u1	ds12	Chopper 1	10/12/2019	.	.	.
sm4 u2	ds13	Chopper 1	9/12/2019	18:41	<i>M. gigas</i>	.
sm4 u2	ds13	Chopper 1	10/12/2019	17:50	<i>T. georgianus</i>	.
sm4 u5	ds14	Chopper 3	9/12/2019	19:01	<i>T. georgianus</i>	
sm4 u5	ds14	Chopper 3	10/12/2019	18:50	<i>V. finlaysoni</i>	
sm4 u5	ds1	Joes cave	12/12/2019	18:28	<i>T. georgianus</i>	19:22
sm4 u5	ds1	Joes cave	13/12/2019	18:03	<i>T. georgianus</i>	19:10
sm4 u5	ds1	Joes cave	14/12/2012	18:01	<i>T. georgianus</i>	19:51
sm4 u5	ds1	Joes cave	15/12/2019	18:02	<i>T. georgianus</i>	19:05
sm4 u5	ds1	Joes cave	16/12/2012	18:09	<i>T. georgianus</i>	19:13

NOTE: Table represents manual analysis for the first hour of survey for each night.

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