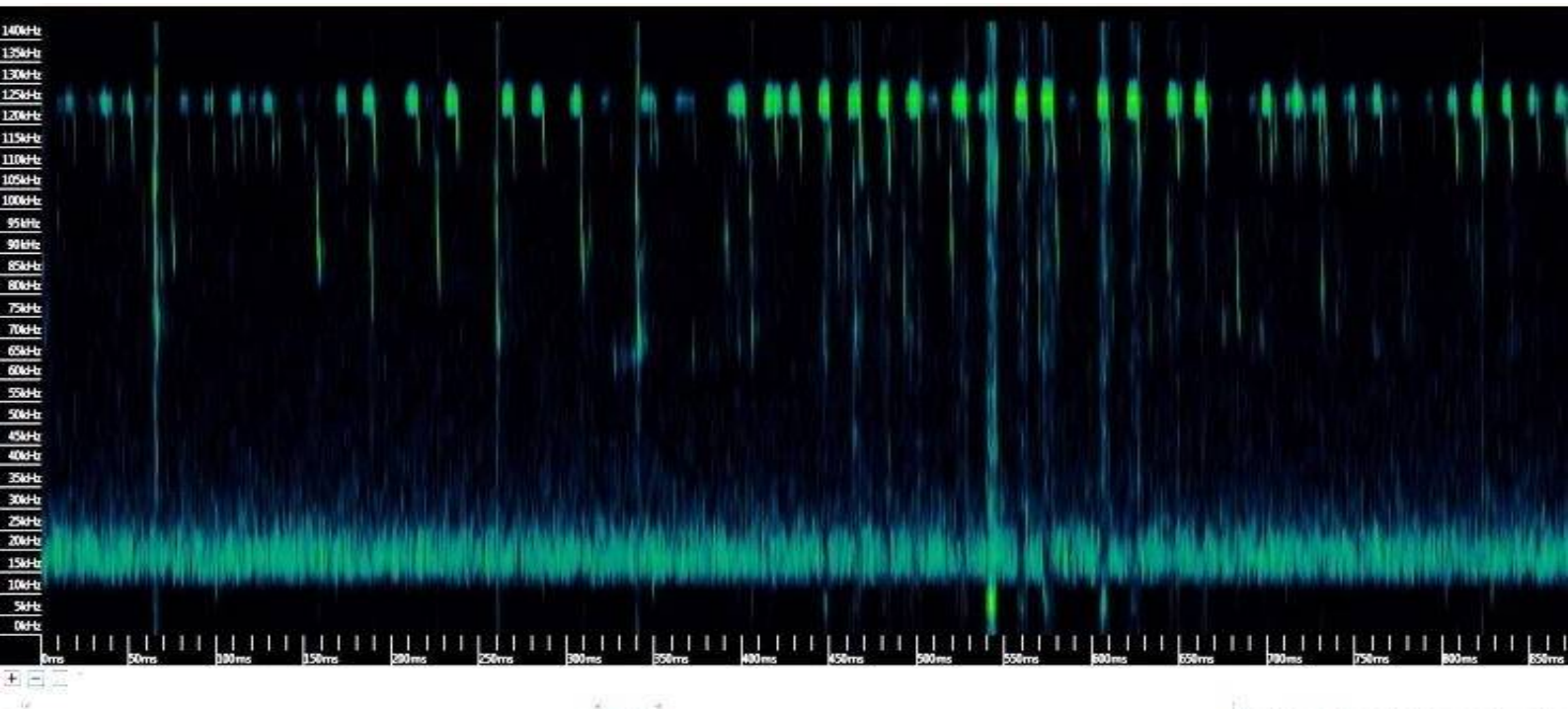

FMG Iron Bridge Pty Ltd

North Star Magnetite Project

Cave 13 Pilbara Leaf-nosed Bat Survey

July 2016

Executive summary

FMG Iron Bridge Pty Ltd (FMGIB) has been granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure, 110 kilometres (km) south-east of Port Hedland. Condition 10 of the *Environmental Protection Act 1986* Ministerial Statement 993 details the specific measures that FMGIB must implement to mitigate the impacts of the development to the Pilbara Leaf-nosed Bat (PLNB) colony located in Cave 13 due to mining activities.

GHD Pty Ltd (GHD) was engaged by FMGIB to undertake surveys for the PLNB within Cave 13, Chateau Cave and Joe's Cave during February 2016. This report has been prepared by GHD for FMGIB based on the assumptions and limitations outlined in Section 1.4 and may only be used and relied on by FMGIB for the purpose agreed between GHD and FMGIB as set out in Section 1.2 of this report.

Methods

Field surveys were undertaken 8-12 February 2016 to determine the occupancy of Cave 13, Chateau Cave and Joe's Cave by the PLNB during the breeding season. The following surveys were completed for Cave 13, Chateau Cave and Joe's Cave:

- Roost occupancy surveys using the method described in the Survey Guidelines for Australia's Threatened Bats (DEWHA 2010)
- Ultrasonic detection surveys
- Cave habitat assessment.

Temperature and humidity was recorded for each cave using a handheld temperature and humidity reader and iButton temperature/humidity loggers.

This report also considers the results of surveys undertaken to date of Cave 13 by GHD and other consultants. The information from the GHD 2016 surveys and review of existing information was used to discuss the roost categorisation (i.e. the type of roost) of Cave 13, Chateau Cave and Joe's Cave.

Key outcomes

GHD proposes the following categories 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.

Cave 13

Analysis of the temperature and humidity data from the cave for two sampling periods (23/02-16/05/2015 and 09/02-02/05/2016) suggests that whilst providing optimal temperatures (e.g. > 28°C) the humidity was less than optimal (e.g. less than 80%) for the majority of the survey period. Furthermore, the small size, shape and shallow depth of the of the upper chamber of Cave 13 does not appear to be consistent with a roost that may provide suitable habitat for large aggregations of PLNB to form and support pregnancy, parturition and the raising of young.

The results from the cave occupancy surveys undertaken in early February 2016 determined that the PLNB was not present within Cave 13. Ultrasonic surveys conducted for five consecutive nights following the cave occupancy survey of the upper chamber in February 2016

recorded six PLNB calls for the survey period. Furthermore, no PLNB calls were recorded for any of the nights within a 30 minute period of sunset and PLNB calls were absent from two of the five nights surveyed.

Long term monitoring and analysis of bat calls between March 2014 and February 2016 (ecoscape 2016 and Bat Call WA 2015) recorded PLNB calls at Cave 13 for 22 of the 23 months during the survey period (measured by the average number of calls per night over one month). The PLNB was present at Cave 13 for a period of 14 consecutive months from between January 2015 and February 2016.

Despite the ongoing presence of the species, observational surveys conducted of the upper chamber within Cave 13 to date have not recorded the PLNB. Furthermore, the majority of the observational surveys have been completed during the breeding period of the PLNB.

The information reviewed to date suggests that that Cave 13 is possibly occupied for parts of the year by the PLNB; however, it was not occupied during the period of the cave occupancy surveys suggesting that 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 GHD surveys discussed in this report.

Chateau Cave

The results from the cave occupancy surveys undertaken in February 2016 determined that PLNB were present within the main chamber during the period of the survey.

Considering the information reviewed to date, particularly the presence of the PLNB during the cave occupancy surveys; ongoing PLNB activity for three days during the breeding period (February 2016) and presence of suitable habitat GHD considers that Chateau Cave is a possible Non-permanent breeding roost or Permanent diurnal roost which may be occupied year-round including during the breeding period.

Joe's Cave

The results from the cave occupancy surveys undertaken in early February 2016 determined that the PLNB was not present within Joe's Cave during the period of the survey. Although the PLNB was recorded for five nights of ultrasonic survey following the cave occupancy survey overall activity was low to moderate across the survey period. The timing of the first (within 40-55 mins of sunset) and last calls (within 30-40 mins of sunrise) for the survey period suggests that bats are using the cave as a foraging location, and for temporary refuge throughout the night.

At least five individual PLNB were observed flying in and around the front part of the passage of the cave leading into the main chamber between 19:45-20:15 during the cave occupancy surveys in February 2016. It is possible that the PLNB were attempting to access the main chamber and four individuals were observed flying in circles in front of the barricade for 2-3 minutes before departing.

Considering the information reviewed to date, particularly noting the absence of the PLNB during the cave occupancy survey GHD considers that Joe's Cave is a Transitory diurnal roost. The information reviewed to date suggests that that Joe's Cave is possibly occupied for parts of the year by the PLNB. However, there is no evidence to indicate that the main chamber has been used as a maternity roost during the period of the GHD surveys discussed in this report.

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Appendices

1. Introduction

1.1 Project background

FMG Iron Bridge Pty Ltd (FMGIB) has been granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure, 110 kilometres (km) south-east of Port Hedland (Figure 1). The approval has been granted pursuant to the Conditions outlined in the *Environmental Protection Act 1986* Ministerial Statement 993.

Condition 10 of the Ministerial Statement details the specific measures that FMGIB must implement to mitigate the impacts of the development to the Pilbara Leaf-nosed Bat (PLNB) colony located in Cave 13 due to mining activities. The intent of Conditions 10-3 to 10-11 is to ensure the viability of the PLNB population is maintained through the relocation and establishment of a 'viable portion' of the colony at Cave 13 to an alternative (either natural or artificial) site.

GHD Pty Ltd (GHD) was engaged by FMGIB to undertake surveys for the PLNB within Cave 13, Chateau Cave and Joe's Cave during February 2016. Previous surveys have identified Cave 13, Chateau Cave and Joe's Cave as potential PLNB roost locations. This report also considers the results of surveys undertaken to date of Cave 13 by GHD and other consultants.

1.2 Purpose and scope

The proponent of the North Star Magnetite Project, FMGIB, believes that based on the results from ongoing ultrasonic surveys, Cave 13 is not a maternity cave. The purpose of this study is to prove or disprove this assertion. GHD proposed to undertake a review of the existing information and complete targeted cave occupancy surveys of Cave 13 to achieve this aim. In addition targeted cave occupancy surveys of Joe's Cave and Chateau Cave and ultrasonic monitoring of Nicko's Gorge would also be undertaken.

The scope of this work was to:

- Undertake a review of existing survey data undertaken for Cave 13
- Undertake a field survey including cave occupancy surveys of Cave 13, Chateau Cave and Joe's Cave by the PLNB during the breeding season
- Provide a summary report of the methods and results including key findings and categorisation of the sites into different roosts (e.g. nocturnal, diurnal, maternity).

1.3 Study area

For the purpose of this report, the GHD study area includes Cave 13, Joe's Cave, Chateau Cave and Nicko's Gorge (Figure 2). Table 1 provides further details regarding the location of each site within the study area.

Table 1 Site details

Site name	Location	Figure 2 (symbol) / label	Latitude	Longitude	Elevation
Cave 13	North Star Mine project area	Cave 13	-21.2584	119.0562	395 m
Chateau Cave	North Star Mine project area	Chateau Cave	-21.2562	119.0542	368 m
Joe's Cave	Zane's Gorge area	Joe's Cave	-21.163	118.8921	314 m
Nicko's Gorge pool	Blue Square	Nicko's Gorge	-21.217	118.9542	245 m

Additional information for each site is provided in GHD 2015b.

640,000 670,000 700,000 730,000

7,740,000 7,710,000 7,680,000 7,650,000

PORT HEDLAND
FINUCANE
BOODARRIE LANDING
RED BANK
CARGIL SALT FARM
HOI BRIQUETTED IRON PLANT
WEDGEFIELD
PORT HEDLAND POWER STATION
DIPPINGARRA
BOFFA SIDING
SOUTH HEDLAND RURAL ESTATE
BING SIDING
ALLEN SIDING
NGARLA COASTAL NGAMAL
JINPARINYA
TABBA TABBA CREEK
GOLDSWORTHY LTD RAILWAY
RYAN SIDING
ORD RANGES
RIDLEY RIVER
DE GREY RIVER
MARBLE BAR ROAD
STRELLEY
STRELLEY COMMUNITY SCHOOL
EAST STRELLEY RIVER
BEEBINGARRA CREEK
WEST STRELLEY RIVER
BUNNENGARRA
NORTH WEST COASTAL HIGHWAY
MOUNT NEWMAN RAILROAD
TURNER RIVER EAST
TABBA
WALLA SIDING
TABBA TABBA
MAGPIE RANGE
WALLA
COORUNGCOORANA
GREAT NORTHERN HIGHWAY
TURNER RIVER
GILLAM SIDING
SIX MILE CREEK
MCPHEE CREEK
WODGINA WEST
WODGINA
FALLS POINT
NORTH STAR MAGNETITE / HEMATITE MINE
Nicko's Cave
Joe's Cave
Cave 13
Chateau Cave
CLELAND ROCK
YANDEYARRA
TURNER SIDING
SHAW RIVER
AGRIPPA RIDGE
YULE RIVER
POWDAR CREEK
YANDEE
ABYDOS
ABYDOS SIDING

Paper Size A3

0 2.5 5 10 15

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Fortescue Metals Group Ltd

Pilbara Leaf-nosed Bat North Star Management Plan

Job Number	61-31473
Revision	0
Date	21 Jul 2016

Project Location

Figure 1

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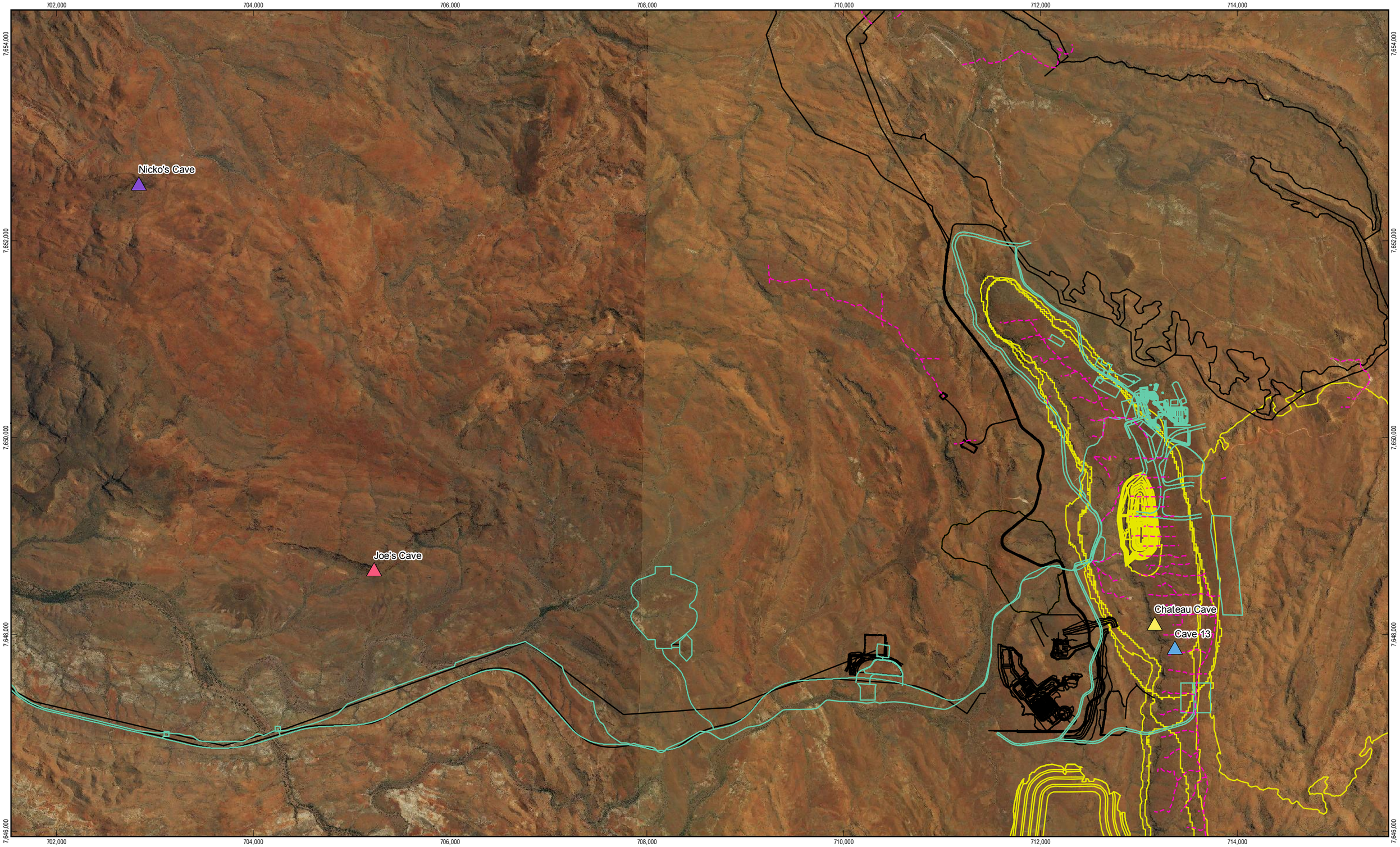
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007, Mine footprint - 20141121; Geoscience Australia: GeoTopo 250k Series III. Created by: AF



Paper Size A3

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

LEGEND

- Sourced Tracks (Landgate)
- Sourced Tracks (FMG)
- Proposed Hematite Project Outlines
- North Star Magnetite Proposed Infrastructure
- North Star GV Proposed Infrastructure

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

Job Number	61-31473
Revision	0
Date	21 Jul 2016

Study Area

Figure 2

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Data source: FMG: Cave 13 Location, Sourced Tracks, Proposed Hematite Project Outlines, North Star Magnetite Proposed Infrastructure, North Star GV Project Proposed Infrastructure; GHD: GHD Survey Effort; Landgate: Imagery (Virtual Mosaic). Created by:mmikkonen

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1.4 Assumption and limitations

This report has been prepared by GHD for FMGIB and may only be used and relied on by FMGIB for the purpose agreed between GHD and FMGIB as set out in Section 1.2 of this report. GHD otherwise disclaims responsibility to any person other than FMGIB arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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

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

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

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

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

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

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

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

2. Review of existing information

2.1 Existing surveys

A review of studies supplied by FMGIB was undertaken to provide a chronological timeline of information collected regarding the occurrence of the PLNB within Cave 13. The main purpose of the review was to provide a summary of the key outcomes of each study and use this information in conjunction with the GHD targeted surveys (Section 3) to determine the category of roost that would apply to Cave 13 with regard to the PLNB.

The following studies were reviewed:

- ecologia environment (7 March 2012) Fortescue Metals Group North Star Project – North Star Level 2 Terrestrial Vertebrate Fauna Assessment
- 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
- GHD 2015a (5 March 2015) Fortescue Metals Group Cave 13 Lateral Extent and Structural Assessment
- FMGIB 2015a Opportunistic surveys including ultrasonic detector surveys of Zane's Gorge and a cave (Wayne Manor) located north-east of Cave 13 during January 2015 by FMGIB. Call analysis results completed by Bat Call WA (Bat Call WA 2015) and cited in GHD 2015b
- Bat Call WA 2015a (10 April 2015) Fortescue Metals Group North Star Pilbara Leaf-nosed Bat Colony; Cave 13 and Fig pool activity Monitoring; March 2014 to March 2015. Results from the first year of monitoring (2014-2015)
- Bat Call WA 2015b (12 May 2015) Fortescue Metals Group North Star Project, Pilbara Leaf-nosed Bat regional survey, November 2014 to March 2015
- FMGIB 2015b Opportunistic surveys including ultrasonic detector surveys of western cliff face of the North Star Plateau during March and April of 2015 for possible Pilbara Leaf-nosed Bat roosts. Unpublished memorandum cited in Appendix C of GHD 2015b
- GHD 2015b (2 November 2015) Fortescue Metals Group Iron Bridge, North Star Mine – Pilbara Leaf-nosed Bat roost habitat survey
- ecoscape (1 July 2016) North Star Annual Pilbara Leaf-nosed Bat Monitoring, FMG Iron Bridge. Results from the second year of monitoring (2015-2016).

Table 2 provides a summary of the key outcomes of each study and relevance to Cave 13 and the PLNB.

Table 2 Summary of studies undertaken for PLNB within the North Star Mine project area

Reference	Purpose of survey and key outcomes	Relevance to Cave 13 / comments including survey limitations
ecologia environment (7 March 2012)	Level 2 fauna survey of the North Star Project area including 3 phases of survey effort. 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.	First record of PLNB at Cave 13. Surveys completed using SM2 bat detectors. Visual inspection was undertaken from the entrance, however a habitat assessment or internal examination of cave structure was not undertaken.
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 Pilbara leaf-nosed bats and it was characterised as a day roost and probably a maternity roost.	Cave 13 categorised as a diurnal (day roost) and possible maternity roost for PLNB (Bat Call WA 2013). Surveys completed using SM2 bat detectors and infrared video surveillance. A visual inspection was undertaken from entrance of main chamber within Cave 13, however the internal structure and habitat was not inspected or described.
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 bat activity using SM2 bat detectors. The results of the study to date show 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 suggest that 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).
GHD 2015a	GHD assessed the lateral and structural extent of Cave 13 in November 2014. GHD assessed that the cave is structurally sound and is not liable to collapse in its current state. The cave is within heavily folded and faulted magnetite and is not structurally or bedding plane controlled, except at an individual passage scale. The lateral extent of Cave 13 is substantially smaller than originally allowed for under Condition 10 and the exclusion zone could be reduced to within 25 m of the identified cave boundary, however as a precautionary approach a 50 m buffer is recommended. Scattered guano was recorded within the upper chamber (recent and older scats), however no obvious deposits of guano was recorded.	Detailed habitat and visual inspection of Cave 13 including upper main chamber undertaken during breeding season. No PLNB observed within the cave during the survey.

Reference	Purpose of survey and key outcomes	Relevance to Cave 13 / comments including survey limitations
Bat Call WA 2015a (10 April 2015)	Long term monitoring of the activity levels of the PLNB at Cave 13 and Fig Pool from March 2014 to March 2015 with the aim of measuring nightly, monthly and seasonal variation of PLNB bat activity using SM2 bat detectors. The results of the study show that the usage by the PLNB at Cave 13 was variable over the 12 month period. Initial activity at the cave in March 2014 was consistent with a primary foraging location for the species, but not a diurnal roost. During April and May 2014, the activity pattern changed to one consistent with diurnally roosting bats being present at the cave similar to that observed in April 2013. Following a two month period in June and July when activity was consistent with foraging only, diurnally roosting bats returned in August. By October, activity was again limited to foraging and this continued until March 2015. A perceived drop in activity from March 2014 to March 2015 is considered to be due to the drier than normal wet season without any cyclonic rainfall events (Bat Call WA 2013).	PLNB recorded as a result of long term monitoring analysis across a 12 month period at Cave 13. Call activity recorded for most days when detector was working. Report acknowledges issues with equipment and gaps in the data (e.g. between September 2014 and February 2015). No visual inspections or habitat assessments undertaken of Cave 13 during monitoring period.
Bat Call WA 2015b (12 May 2015)	Bat Call WA completed a regional survey of PLNB bat activity in November 2014 to assist with characterising the roosting habitat of the PLNB within a 30 km radius of Cave 13 at the North Star mine. Bat Call WA also completed analysis of bat calls from surveys undertaken by FMGIB in January 2015 and GHD in January and February 2015 to assist with characterising the roosting habitat of the PLNB within a 30 km radius of Cave 13. According to the analysis completed by Bat Call WA, PLNB were detected across a broad area, but some sites had higher activity than others. PLNB were detected at nine of twelve sites surveyed using SM2 and EM3 detectors. Detections with high and very high activity levels were made within the Blue Square in Nicko's Gorge and in an area around Zane's Gorge. Low activity levels were detected at Wayne Manor, a cave to the north east of North Star near where limited foraging detections have been made in the past (Bat Call WA 2013).	PLNB recorded as a result of bat call analysis completed for 1 night for Cave 13 (15 November 2014). No visual inspections or habitat assessments undertaken of cave sites other than those assessed by GHD and FMG (see GHD 2015b).
GHD 2015b	Opportunistic habitat surveys undertaken by GHD on the 14th November 2014 of an area located west of Cave 13 (Figure 2, GHD 2015b), as part of a separate field investigation with FMGIB. Survey of the flat top BIF with the telecommunications tower located east of camp and west of Cave 13 and three rocky outcrop locations between the main access road and west of Cave 13 (Figure 2, GHD 2015b). The majority of the flat top BIF was traversed with the exception of culturally sensitive areas located along the eastern and western flanks of the BIF. The areas searched revealed approximately five potential nocturnal roost sites, however no diurnal or maternity roost habitats were recorded. No maternity or diurnal roost habitats were recorded for the three locations along the main access road, however potential nocturnal roost habitat was recorded at each site.	Surveys did not include Cave 13. Not a comprehensive habitat assessment. Not all areas searched.

Reference	Purpose of survey and key outcomes	Relevance to Cave 13 / comments including survey limitations
FMGIB 2015a	Ultrasonic detector surveys of Zane's Gorge and a cave (Wayne Manor) located north-east of Cave 13 during January 2015 by FMGIB. Results reported in Bat Call WA 2015 as cited in GHD 2015b	Surveys did not include Cave 13. Survey results indicated potential diurnal roost at Joe's Cave (Zane's Gorge area).
GHD 2015b	January 2015 habitat assessment and ultrasonic surveys of various caves and habitats within a 30 km radius of Cave 13 (Blue Square area). It was 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 including the colloquially named 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. 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 to Nicko's Gorge. No PLNB were observed in any of the caves surveyed during the survey period.	Survey did not include Cave 13. A brief inspection of the Cave 13 upper main chamber during placement of a data logger did not record PLNB.
GHD 2015b	February 2015 habitat assessment and ultrasonic surveys of various caves and habitats within a 30 km radius of Cave 13 (Zane's Gorge and Joe's Cave). The habitat assessment did not confirm the absence of a maternity roost within the study area, however one site within the colloquially named Zane's Gorge area (Joe's Cave) was classified as a diurnal roost, based on the habitat characteristics of the cave and the analysis of ultrasonic detection survey data and infrared camera data. No PLNB were observed in any of the caves surveyed during the survey period.	Survey did not include Cave 13. A brief inspection of the Cave 13 upper main chamber during equipment check by GHD did not record PLNB.
FMGIB 2015b	Habitat observations, ultrasonic detector surveys and calls analysis completed by FMGIB during March and April of 2015 of the area surrounding Cave 13 (cited in GHD 2015b). Microchiropteran bat surveys using detectors were completed at two sites for three nights at Mammoth Cave and 4 nights at Chateau Cave in the period 25-29 March 2015. Both Mammoth Cave and Chateau Cave recorded PLNB activity. The cave structure at Chateau Cave would lend itself to being suitable as a diurnal roost cave for PLNB. However, the pattern of call detections, commencing well after sunset (peak activity well after sunset, between 9 pm and 12 am) and the low numbers of calls suggest that at the time of survey, the cave was being used as a night foraging roost cave only.	Surveys did not include Cave 13, however included habitat observations and bat detector surveys near Cave 13.

Reference	Purpose of survey and key outcomes	Relevance to Cave 13 / comments including survey limitations
ecoscape 2016	Long term monitoring of the activity levels of the PLNB at Cave 13 and Fig Pool from March 2015 to February 2016 with the aim of measuring nightly, monthly and seasonal variation of PLNB bat activity using SM2 bat detectors. The bat call activity pattern at the Cave 13 site was observed to have peak activity in the summer/winter transition months with the months from July to February recording the lowest number of calls (ecologia 2016). A comparison between the current monitoring event and the 2014 to 2015 (Bat Call WA 2015) monitoring event revealed that both the temporal and seasonal variation patterns remained comparable between each of the monitoring events (ecologia 2016).	PLNB recorded as a result of long term monitoring analysis across a 12 month period at Cave 13. Bat detector located in a different position to that reported in Bat Call WA at Cave 13 (2015). No visual inspections or habitat assessments undertaken of Cave 13.

2.2 Description of Cave 13

Cave 13 is located on the southern side of a gully and has a 5 m wide opening that divides into three separate passages (Figure 3). The passage to the far right (western most edge) is 7 m in length and completely lit by daylight. The central passage is approximately 16 m in length, with several small side chambers sloping gently upwards into the hillside behind. The passage on the far left (eastern most passage) leads into a 1 m high chamber with a 45° inclined passage approximately 2 m high heading to the east (Plate 1 and Plate 2). This inclined passage is approximately 1 m wide and leads into an elevated chamber 6 m wide and 3.5 m deep, and up to 2.5 m high in the central area. This elevated chamber has formed partially through roof decay. There is no evidence for any water activity within this chamber for an extended time period.

The majority of Cave 13 is lit at least partially by daylight, with some twilight zones located within the side chambers of the central passage, and in the lower portion of the eastern most passage. The upper chamber in the eastern most passage is within the dark zone of the cave.

The cave ceiling is generally low (less than 1.2 m) and bedding within the cave varies from nearly horizontal to near vertical. The dramatic changes in bedding dip and strike suggest the bedrock is heavily folded and micro-faulted, thus while individual chambers and passages may be parallel to localised bedding, the cave as a whole cannot be considered to be bedding plane controlled.

Cave 13 can be considered to be highly stable, and is not liable to any significant collapse within human timescales (i.e. hundreds of years). There is no evidence of any recent water movement within the cave that may influence stability in the medium (50 years) term.

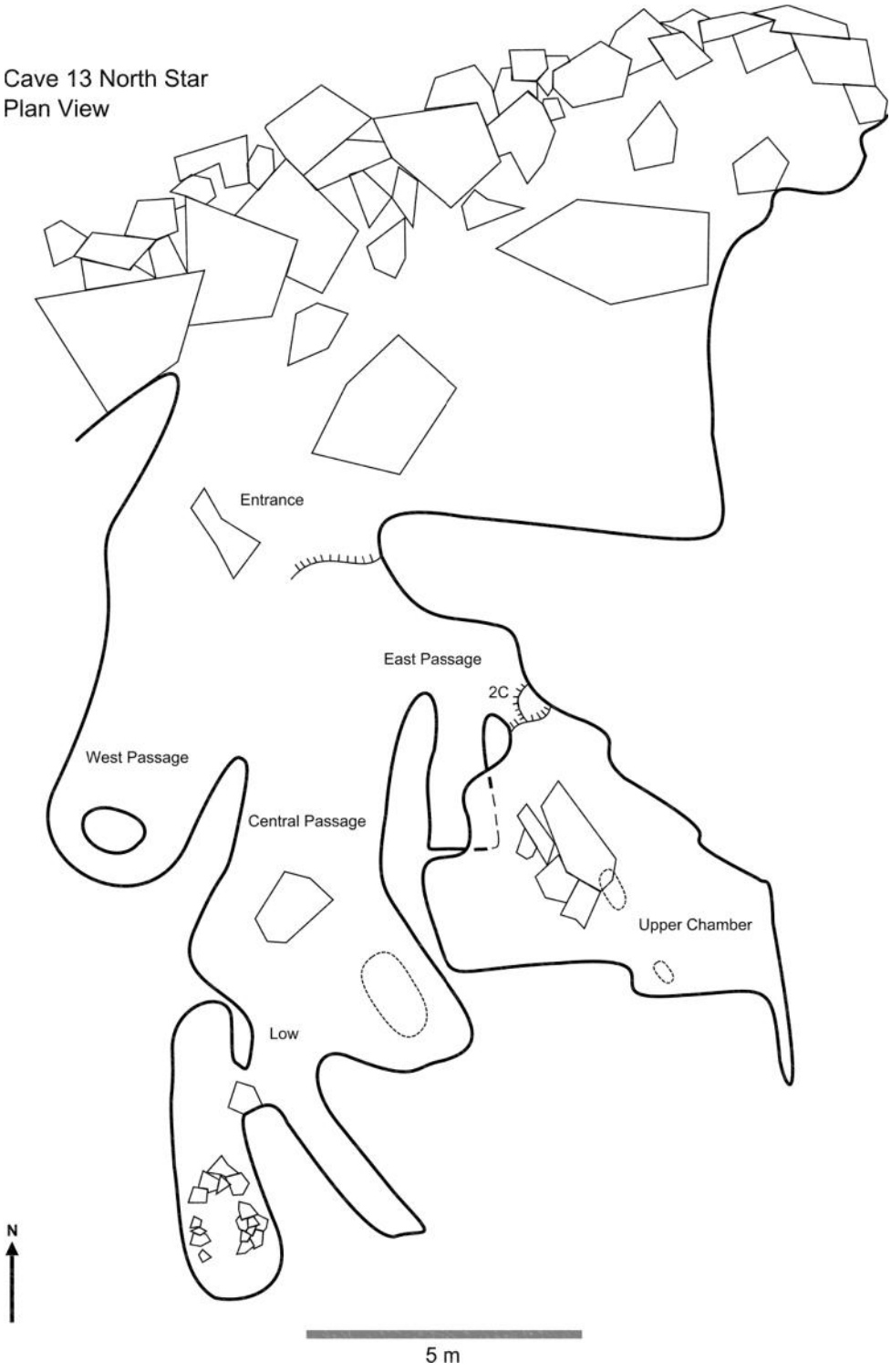

Figure 3 Plan view of Cave 13 (from GHD 2015a)

Plate 1 **Looking up the 45° inclined passage to the upper chamber from the eastern most passage (field of view ~1 m)**

Plate 2 **View south into the western most passage (right) and central passage (field of view ~6 m).**

2.3 Ongoing monitoring surveys of Cave 13

The following is a summary of the results from the North Star Annual Pilbara Leaf-nosed Bat Monitoring (2015-2016) report (ecoscape 2016) for Cave 13. Bat Call WA and ecoscape were both engaged to undertake SM2 monitoring and call analysis of Cave 13 and Figpool during 2014-2016. The ecoscape report also includes a discussion of the results from the first year of monitoring undertaken by Bat Call WA (2015a). Figure 4 provides a summary of the average number of nightly calls reported for each month of the monitoring event from Bat Call WA (2015a) and ecoscape (2016).

Seasonal variation

- The seasonal variation of PLNB activity recorded during the monitoring period (measured by the average number of calls per night over one month –see Figure 4) indicated that the pattern was different between the two monitoring events, however this may be partially an artefact of different call analysis techniques and equipment issues. Despite this the PLNB was present at Cave 13 for 22 of the 23 months during the survey period
- The peak activity period for both monitoring events occurred between March and July (ecoscape 2016)
- The lowest activity period for both monitoring events occurred between November and March (ecoscape 2016). However, the decreased activity during this period in the 2014-2015 event was probably due to the issues with equipment (e.g. between September 2014 and February 2015, Bat Call WA 2015a)
- The point of difference between the two monitoring events at the Cave 13 site was that the 2014-2015 event recorded a second peak in activity in August (Bat Call WA 2015a). This activity was less pronounced in the 2015-2016 monitoring event (ecoscape 2016).

Nightly temporal patterns

- The PLNB was present for the majority of nights for each month during the 2014-2015 monitoring event with the exception of the months from October- January, probably due to equipment issues (Bat Call WA 2015a)
- During the months of March through to June during the 2015-2016 monitoring event the activity was typically characterised by the following call activity pattern for each night '*a small lag after sunset was observed followed by an increase to the maximum number of calls and pulses between 8:00 pm and 11:00 pm. This was then followed by a continual decrease until sunrise*' (ecoscape 2016)
- When averaged across the four months (March through to June 2015) the peak period of activity between 8:00 pm to 11:00 pm accounted for 55% of the total number of calls each night during the 2015-2016 monitoring event (ecoscape 2016)
- The period March through to June 2015 also coincided with the period of peak activity (ecoscape 2016)
- There was a decrease in the frequency of calls per hour and the distribution of the calls changed to be spread more evenly throughout the night for the months July through to October 2015 (ecoscape 2016)
- Another pattern was observed in the months November 2015 to February 2016 where the frequency of nightly calls decreases (ecoscape 2016)
- Both monitoring events observed a peak period of activity each night (when averaged) from March through to June, with May recording the highest activity in the 2014-2015

monitoring event (Bat Call WA 2015) and April 2015 the highest in the 2015-2016 monitoring event (ecoscape 2016)

- The remainder of the year for both events saw a lull in activity, with the lowest activity observed between December and February where calls were more evenly distributed over the night (ecoscape 2016), not considering the issues with equipment during the 2014-2015 monitoring period.

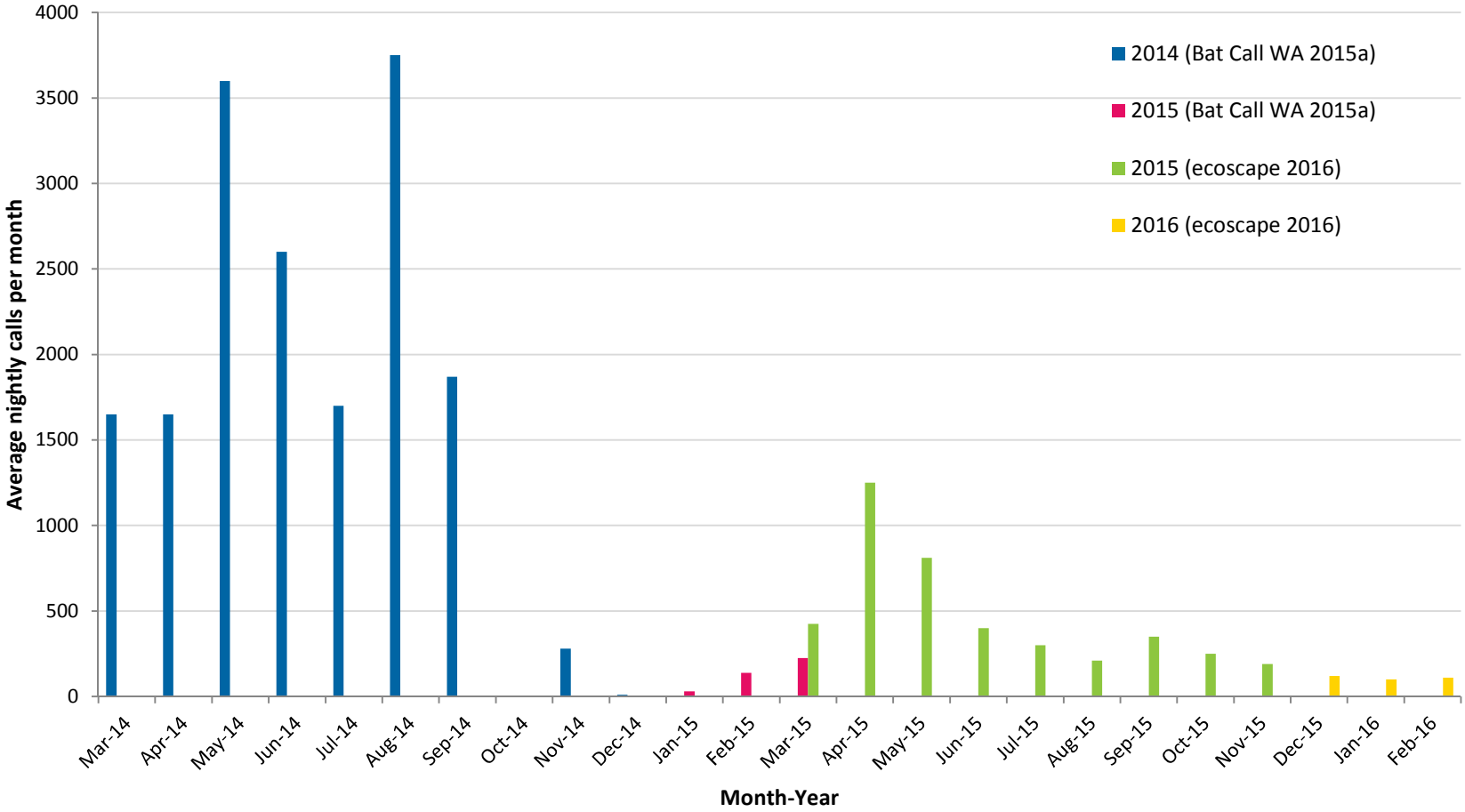

Figure 4 Average nightly calls per month reported from the 2014-2015 (Bat Call WA 2015a) and 2015-2016 (ecoscape 2016) monitoring events.

Note: Decreased activity during September 2014 and February 2015 was probably due to the issues with equipment. No data was collected during the month of October 2014 due to faulty equipment (Bat Call WA 2015a). Average nightly calls for the ecoscape 2015-2016 period taken from an interpretation of Figure 3 in ecoscape 2016.

3. Targeted surveys

3.1 Objective

The objective of the targeted survey was to determine the occupancy of Cave 13, Chateau Cave and Joe's Cave by the PLNB during the breeding season. The information from the GHD 2016 surveys and review of existing information (see Section 2) will be used to discuss the roost categorisation (i.e. the type of roost) of Cave 13, Chateau Cave and Joe's Cave.

3.2 Methods

3.2.1 Roost categorisation

To assist with a standardised approach to categorise the different types of roost habitats for the PLNB, a review of current terms and descriptions was undertaken (TSSC 2016; DPaW 2014; Cramer et al. 2016; Armstrong 2001). Following the review, it was decided that the approach and terms cited in the Department of the Environment (DotE) Conservation Advice for the PLNB (released 10/03/2016 by the Threatened Species Scientific Committee (TSSC)) be adopted for this report.

The TTSC (2016) discuss that an underground diurnal roost is critical to the survival of the PLNB, given their reliance on warm, humid roost microclimates for maintaining their heat and water balance (Kulzer et al. 1970; Baudinette et al. 2000; Churchill 1991; Armstrong 2001 in TTSC 2016). Some roosts are important for breeding and others may only be used in certain seasons or conditions. The conservation advice for the PLNB discusses four standard categories of underground refuges that are important for the survival of the PLNB: permanent diurnal roost, non-permanent breeding roost, transitory diurnal roost, and nocturnal refuge roosts.

- **Permanent diurnal roosts** — occupied year-round and likely the focus for some part of the 9-month breeding period (when aggregations may form to support mating, pregnancy, parturition and the raising of young – TSSC 2016)[1]; considered as critical habitat that is essential for the daily survival of the PLNB
- **Non-permanent breeding roosts** — evidence of usage during some part of the 9-month breeding period (July–March), but not occupied year-round; considered as critical habitat that is essential for both the daily and long-term survival of the PLNB
- **Transitory diurnal roosts** — occupied for part of the year only, outside the breeding season (i.e. April–June), and which could facilitate long distance dispersal in the region; considered as critical habitat that is essential for both the daily and long-term survival of the PLNB
- **Nocturnal refuge** — occupied or entered at night for resting, feeding or other purposes, with perching not a requirement, excludes overhangs; not considered critical habitat, but are important for persistence in a local area.

[1] PLNB young are generally born in December, with lactation from December through late February, primarily during the productive (wet) season. Young are generally weaned late February-early March – see: Department of the Environment (2015). *Rhinonicteris aurantia* (Pilbara form) in Species Profile and Threats Database (SPRAT), Commonwealth Government; and McKenzie, N. L., and Bullen, R. D (2014), Ecology of *Rhinonicteris aurantia* in the Pilbara. Presentation to the DPaW workshop for the Pilbara Leaf-nosed Bat. Unpublished presentation.

3.2.2 Field survey

The field survey team comprised GHD Senior Ecologist Craig Grabham and FMG Senior Environment Advisor, Matthew Dowling. The survey was conducted under "Licence to Take Fauna for Scientific Purposes" (Regulation 17) Permit No. SF010137.

Field surveys were undertaken 8-12 February 2016 within the study area. A summary of the field survey methods is provided below. Table 3 provides a summary of the survey methods and effort completed for each site within the study area. Appendix A provides a detailed description of each method.

The results of these surveys are presented in Section 3.3.

Roost occupancy surveys

Roost occupancy determination surveys were undertaken of Cave 13, Chateau Cave and Joe's Cave using the non-invasive method described in the Survey guidelines for Australia's threatened bats (pp 63, DEWHA 2010)[2]. Surveys were undertaken using a barricade (e.g. black sheet) in conjunction with ultrasonic bat detectors (SM2BAT+ SongMeter recorder (Wildlife Acoustics Inc, USA)) and infrared camera surveillance during the breeding season (see Plates 3 to 5).

Placement of barricade:

- Cave 13 – barricade was placed at the entrance of the eastern passage leading into the upper chamber (see Plate 3)
- Chateau Cave – barricades were placed at the two entrances into the main chamber (see Plate 4)
- Joe's Cave – barricade was placed across the entrance of the main chamber (between the end of the passage and the main chamber (see Plate 5).

Ultrasonic detection surveys

SM2 recorders were placed at Nicko's Gorge (at a pool), Joe's Cave (at the start of the main chamber) and Chateau Cave (at the entrance to the main chamber) for a period of up to 10 days during the breeding season to assist with understanding the temporal activity patterns for the PLNB within the caves and surrounding areas.

Cave habitat assessment

A cave habitat assessment was undertaken of Chateau Cave to assist with classifying the type of roost habitat for the PLNB.

Environmental data

Temperature and humidity was recorded for Cave 13, Chateau Cave and Joes Cave using a handheld temperature and humidity reader and iButton temperature/humidity logger (model DS1923, Maxim Integrated Products, Inc.).

[2] Department of the Environment, Water, Heritage and the Arts (DEWHA) 2010, *Survey guidelines for Australia's threatened bats Guidelines for detecting bats listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*

Plate 3 Cave 13 barricade at entrance of eastern passage leading into upper chamber

Plate 4 Barricade Chateau Cave (entrance 2 of 2)

Plate 5 Barricade Joe's Cave

Table 3 Summary of methods and effort completed for each site within the study area during February 2016

Method	Cave 13 8-9/2/16	Chateau Cave 9-10/2/1	Joe's Cave 10-11/2/16	Cave 13 11-12/2/16	Nicko's Gorge 10-16/2/16
Roost occupancy survey	Onsite 18:10	Onsite 17:50	Onsite 17:45	Onsite 17:45	-
Barricade (sheet up/down)	18:40 – 20:05	18:20 – 20:05	18:30 – 20:10	18:00 – 20:05	-
SM2 behind barricade	18:30 – 08:00	18:30 – 20:05	18:30 – 07:30	18:00 – 05:40	-
SM2 cave entrance	18:30 – 08:00	18:30 – 08:00	18:30 – 07:30	18:30 – 05:40	-
SM2 near cave	18:30 – 08:00	18:30 – 20:05	18:30 – 07:30	18:30 – 05:40	-
Echo Meter Touch detector (microphone on 2 m cable)	behind barricade 18:40 – 20:05	behind barricade 18:40 – 20:05	behind barricade 18:40 – 19:45 and cave entrance 19:45 – 20:05	cave entrance 18:40 – 20:10	-
Infrared camera behind sheet	18:30 – 08:00	18:20 – 20:05	18:30 – 07:30	18:00 – 20:05	-
Ultrasonic detection surveys					
SM2	#Ongoing SM2 surveys already in place	1 detector placed at cave entrance 3.5 nights (9-12/2/16)	1 detector placed in main chamber 6 nights (10-15/2/16)	1 detector placed in main chamber 4 nights (11-16/2/16)	1 detector placed over a pool for 6 nights (10-16/2/16)

3.2.3 Survey conditions and weather

The Bureau of Meteorology (BoM) Marble Bar Station (Station number 004106) is the nearest weather station (see Table 4) to the study area with continuous long-term data. It is located approximately 120 km south-west of the study area. The weather during the February survey period was hot to very hot during the day followed by warm to hot evenings. Daytime temperatures were between 42°C and 45°C and minimum night- time temperatures were around 24°C. No rainfall was recorded during the survey or in the surrounding district for the survey period.

Survey conditions were considered suitable for undertaking the targeted surveys and the weather was not considered a prohibiting factor.

Table 4 Environmental data for survey period (BOM and observational weather data)

Date	Max temp (°C)	Min temp (°C)	Rainfall (mm)	Observational weather data #	Temperature and humidity during roost occupancy surveys#
8/2	42.5* (39.9 @ 1430)	24.2* (29.5 @ 0500)	0	Hot humid morning. Light intermittent wind later in afternoon. Clear night – 0/8 cloud cover with light breeze	Cave 13 - 31°C / 57% humidity in cave at 18:10 8/2
9/2	43.5* (40.8 @1550)	30.8* (31.5 @ 0140)	0	Hot humid during day. Clear night – 0/8 cloud cover light breeze	Cave 13 - 34°C / 54% humidity in cave at 08:10 9/2 Chateau Cave - 33°C / 56% humidity in cave at 18:20 9/2
10/2	43.9* (42.0 @1410)	26.8* (31.9 @ 0430)	0	Hot humid. Light intermittent breeze. Clear night – 0/8 cloud cover.	Joe's Cave - 33°C / 68% humidity in cave at 18:15 10/2 Outside cave - 32°C / 52% humidity.
11/2	44.3* (42.3 @ 1450)	25.9* (31.7 @ 0540)	0	Hot humid morning. Clear night – 0/8 cloud cover. 1/8 moon	Joe's Cave - 31°C / 48% humidity in cave at 07:50 11/2 Cave 13 - 32°C / 54% humidity in cave at 18:15 11/2
12/2	45.1* (43.7 @1410)	25.6* (33.8 @ 0410)	0	Hot	Cave 13 - 30°C / 40% humidity in cave at 05:45 12/2

Table notes:
*data from BOM 2016 for Marble Bar weather station
() data provided by FMGIB – noting weather station located on top of hill
data recorded by GHD during survey via observations or using hand held temperature and humidity gauge.

3.2.4 Survey and data analysis limitations

Experience

Craig Grabham who has 16 years' experience undertaking microchiropteran bat surveys across Australia led the survey team. Craig has undertaken surveys across four separate periods (November 2014, January 2015, February 2015 and February 2016) for the PLNB within the study area and completed bat call analysis for other assessments in the greater Pilbara and Kimberly regions.

Survey timing

The timing of the surveys was suitable to determine the presence of breeding PLNB within the study area. PLNB young are generally born in December, with lactation from December through late February, primarily during the productive (wet) season. Young are generally weaned late February to early March (Dote 2016; McKenzie and Bullen 2014).

It is important to note it was unlikely that all bats present during the surveys were visually observed. Some individuals may have hidden within small cracks/crevices or along narrow passages and small sub-chambers that could not be accessed during the survey. Therefore, it is possible that some of the caves contained one or a few individuals at the time of the surveys, however it is unlikely that the sites contained large colonies (e.g. > 50 individuals) of PLNB at the time of the surveys unless otherwise stated.

Survey and site conditions

Surveys conducted of Nicko's Gorge were constrained by access, terrain and work safety requirements. The restricted vehicle access in combination with the distances required to travel on foot to the site hindered survey efforts preventing the survey team from completing a thorough survey of this location.

Some caves contained narrow passages and small sub-chambers (e.g. Chateau Cave) which did not allow for safe egress.

Data analysis

Bat call analysis focused on PLNB and did not report activity or other data for other species other than providing a species list for each site.

Data from SM2 units was downloaded and viewed using Kaleidoscope Viewer (version 3.1.6, Wildlife Acoustics Inc. 2016) as full-spectrum audio files. WAC files were also converted to Anabat sequence files (zero-crossing format, ZCA) suitable for analysis in AnalookW version 4.1s (Corben 2015).

It is important to note that conversion of WAV and WAC format recordings to Anabat/AnalookW ZCA format has the potential to exclude fainter or lower quality calls, and analysis should take this into consideration (Hourigan 2011). Depending on the survey objectives, it may or may not be critical to recognise every single pulse in a nightly recording.

For the purpose of this survey both full spectrum and zero-crossing analysis data was presented. In the first instance the full spectrum data was analysed using Kaleidoscope Viewer to ensure that all PLNB calls were captured for each site for each survey period. ZCA was then undertaken and used to report first and last calls for a given survey period as AnalookW has the ability to time and date stamp each file, making for a more accurate record of the temporal range of call activity for any given period providing sufficient call quality was recorded.

3.3 Results

3.3.1 Description of Chateau and Joe's Cave

The purpose of this section is to provide a description of Chateau Cave and Joe's Cave. The description provided uses information from GHD 2015b and the recent surveys undertaken by GHD and FMGIB in February 2016. Cave 13 was described in Section 2.2.

Chateau Cave

Elevation: 368 m

Aspect: west

Chateau Cave is located approximately 1 km north-west from Cave 13 along a westerly facing cliff face. There are two main entrances. The largest opening is approximately 3 m height to an initial chamber 5 m wide by 5 m depth (see Plate 6). This opens up to a large hallway type chamber that runs 6 m. The end of the hallway splits to three chambers. The first chamber is a vertical shaft running approximately 6 m before vision is lost. The second chamber bends around a corner back in the same direction as the hallway approximately 4 m which then leads to the smaller of the two openings to the cliff face. The hallway roof then drops to a narrow aperture of approximately 60 cm, which then opens out into a very large cavern (3rd chamber – main chamber) with a roof height of approximately 2–5 m, possibly higher. The extent of this cavern was difficult to gauge by torchlight (estimated to be greater than 10 m deep and up to 10 m wide) and the aperture is too small for safe passage. At the time of inspection, it was very humid in the cave. Large amounts of guano was observed on the cave floor.

Small population of breeding/non-breeding *Taphozous georgianus* and *Vespadelus finlaysoni* occupy this cave and have been regularly recorded within the cave during each of the surveys undertaken to date (see GHD 2015b).

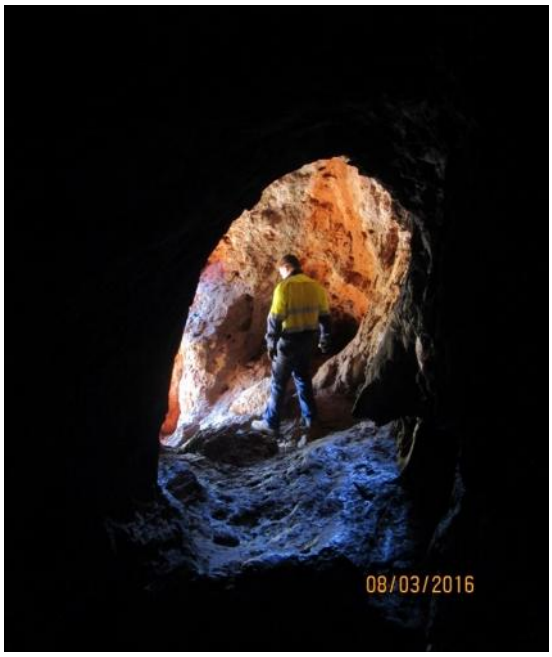

Plate 6 Chateau Cave (looking out from hallway to entrance). The photographer is positioned in front of the narrow aperture into the main chamber.

Joe's Cave

Elevation: 314 m

Aspect: south-west

Very large cave located near top of an extensive banded ironstone formation (BIF) east of Zane's Gorge and approximately 5 km west of Cave 13 (see Plate 7). Cave consists of a large entrance with a passage leading to a very large chamber with a short ceiling. The maximum depth of cave from the entrance is > 32 m. The entrance is dome shaped at 4-5 m wide and 1.5-2.5 m in height and leads into a passage approximately 5-6 m wide, 1.5-2.5 m in height, and 7 m deep with a flat floor. The main chamber is a wide oval shape with a short ceiling and two small shallow sub-chambers/cavities off rear of main chamber. The main chamber is 8-9 m wide, 1-1.5 m in height and 9-15 m deep with a flat floor. It was estimated the ceiling was probably between 2-4 metres deep as the cave was located near the top of the BIF. Roots from trees and other vegetation growing on the cave roof was also recorded protruding through the ceiling.

Small population of breeding/non-breeding *Taphozous georgianus* and *Vespadelus finlaysoni* occupy this cave and have been regularly recorded within the cave during each of the surveys undertaken to date (see GHD 2015b). Guano was recorded throughout the cave with larger piles/deposits recorded along the walls of the main chamber, just in from the passage.

Plate 7 Joe's Cave - Entrance of Joe's Cave behind trees (top photograph). Looking into passage from entrance (bottom photograph).

Note: the main chamber is located at least 5 m behind the large boulder in the centre of the photograph.

3.3.2 Cave occupancy surveys

Cave occupancy surveys were undertaken in February at three locations – Cave 13, Chateau Cave and Joe's Cave. A summary of the key findings for each location is provided below.

Table 5 provides a summary of the first and last call times recorded for PLNB for each of the survey periods during the cave occupancy surveys. The analysis of calls, in particular the first and last call times for PLNB were used to:

- Determine the presence or absence of the PLNB during the period of the cave occupancy surveys including the locations within the study area (e.g. at the entrance of the cave and nearby the cave)
- Compare against the geographical (AGGA 2016) and onsite observational sunset and sunrise times to assist with determining the proximity of the nearest roost location (e.g. if calls were recorded more than 30 mins following sunset then it could be assumed that the nearest roost site was not located within close proximity to the surveyed cave).

Cave 13

No PLNB calls were recorded during the cave occupancy survey inside the barricade for either survey period (see Table 5 and Figure 5 and Figure 6) as a result of the bat call analysis. Two species were recorded *Vespadelus finlaysoni* and *Taphozous georgianus* inside the barricade during the cave occupancy survey as a result of the bat call analysis. Activity for PLNB was first recorded one hour following the completion of the cave occupancy survey for both nights (Table 5).

The infrared camera data provided limited information, and it was difficult to compare the activity patterns captured by the camera to the ultrasonic survey data other than confirming the visual presence or absence of bats during the survey. Approximately 73 and 16 one-minute video clips (8th and 11th February respectively) were recorded during the cave occupancy surveys. Of the 73 clips recorded during the 8th February, 43 contained footage of bats flying behind the barricade. Of the 16 clips recorded during the 11th February, five contained footage of bats flying behind the barricade. Given the absence of PLNB calls, it was assumed that these bats were *Vespadelus finlaysoni* and *Taphozous georgianus* given that both species had been recorded during the cave occupancy survey as a result of the bat call analysis.

The following observations were recorded before and during the survey:

- Prior to the commencement of the survey, observations of free flying bat were first noted on arrival at site where a small number of *Vespadelus finlaysoni* (~ 3) and *Taphozous georgianus* (~2) were disturbed from the central and western passages of the cave
- No bats were observed flying out of the eastern passage or upper chamber prior to the commencement or during the survey

  The first observation of free flying bats during the survey was at 18:15. A small number of bats were regularly recorded in and around the entrance of the cave and flying bats were also recorded in the general vicinity (e.g. along the gully and ridgeline). One *Taphozous georgianus* was recorded with a pup resting on the ceiling of the cave entrance before flying into the adjacent gully
- At least one *Macroderma gigas* was observed flying around the entrance of the cave during the survey

  The upper chamber was investigated the morning of the 10 February 2016 following the recovery of equipment and no PLNB were recorded within the chamber. One *Vespadelus*

finlaysoni was recorded. Scattered guano was recorded within the chamber (recent and older scats), however no obvious deposits of guano were recorded.

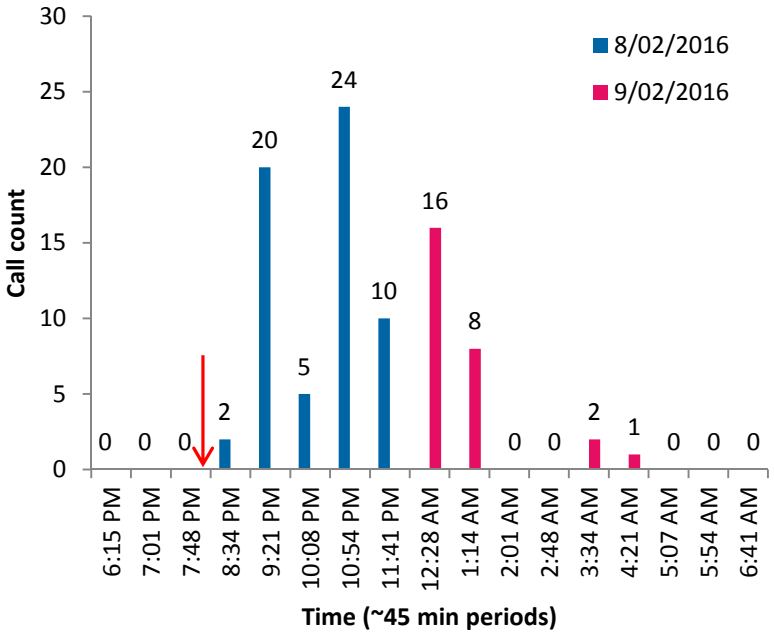

Figure 5 PLNB call activity (~45 minute periods) for Cave 13 during the cave occupancy survey and night of the 8-9/02/16 (full spectrum analysis data).

Note: Arrow indicates approximate time barricade was removed.

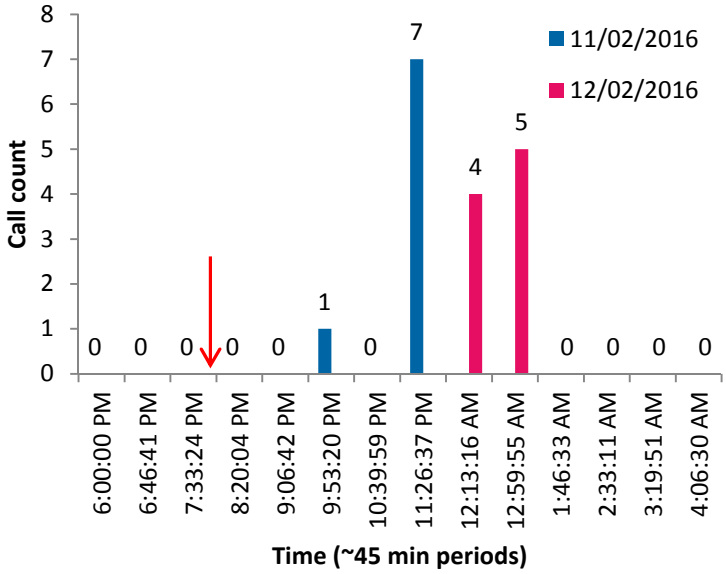

Figure 6 PLNB call activity (~45 minute periods) for Cave 13 during the cave occupancy survey and night of the 11-12/02/16 (full spectrum analysis data).

Note: Arrow indicates approximate time barricade was removed.

Chateau Cave

PLNB calls were consistently recorded during the cave occupancy survey inside the barricade for the survey period (see Table 5 and Figure 7 and Figure 8). A total of 261 calls were recorded as a result of AnalookW analysis compared to 428 calls during the same period as a result of the full spectrum analysis using Kaleidoscope Viewer. At least two other species were recorded (*Vespadelus finlaysoni* and *Taphozous georgianus*) inside the barricade during the cave occupancy survey as a result of the bat call analysis.

The infrared camera data provided limited information, and it was difficult to compare the activity patterns captured by the camera to the ultrasonic survey data other than confirming the visual presence or absence of bats during the survey. Approximately 90 one-minute video clips were recorded of which 83 contained footage of bats flying behind the barricade. As stated in the methods, it is near impossible to identify the bats to species when in flight using this technique, however observations of bat species hanging on the walls of the cave revealed at least two species belong to the *Taphozous* genus (probably *T. georgianus*) and at least one other smaller bat (possibly *Vespadelus finlaysoni* and/or PLNB). It was also obvious by comparing the size and shape of bats flying from a review of paused video footage that at least two species of bat were recorded flying inside the barricade during the cave occupancy survey.

Figure 7 displays the distribution of calls during the cave occupancy survey period for 45 minute intervals using the Kaleidoscope Viewer analysis data counts. Figure 8 displays the number and distribution of calls during the cave occupancy survey period for 1 minute intervals using the AnalookW analysis data counts. Note that AnalookW software has the ability to count and calculate labelled files as part of the count labels tool function, which is not available in Kaleidoscope Viewer.

It is difficult (if not impossible) to gauge the number of individuals present within the main chamber during the survey, however it could be assumed that there is probably more than one PLNB within the chamber during the survey given the frequency of calls for the survey period and the number of small bats of similar size and shape to the PLNB captured flying around the chamber on video footage.

The following observations were recorded before and during the survey:

- Prior to the commencement of the survey, observations of free flying bat were first noted on arrival at site where a small number of *Vespadelus finlaysoni* (~ 2) and *Taphozous georgianus* (~1) were disturbed from near the entrance of the cave, however no bats were observed flying out of the main chamber prior to the commencement or during the survey
- The first observation of free flying bats during the survey was at ~18:45. Bats were regularly recorded in and around the entrance of the cave and flying bats were also recorded in the general vicinity (e.g. along the cliff face and ridgeline) during the survey period
- A small number of bats were observed exiting other parts of the cave at ~18:55 and a nearby cave (most likely *Vespadelus finlaysoni* and *Taphozous georgianus*)
- At least two *Macroderma gigas* were regularly recorded flying around the entrance of the cave with at least one intrusion attempt into the cave during the survey period. This species was identified based from its distinct size, shape and colour and audible social buzzing calls.

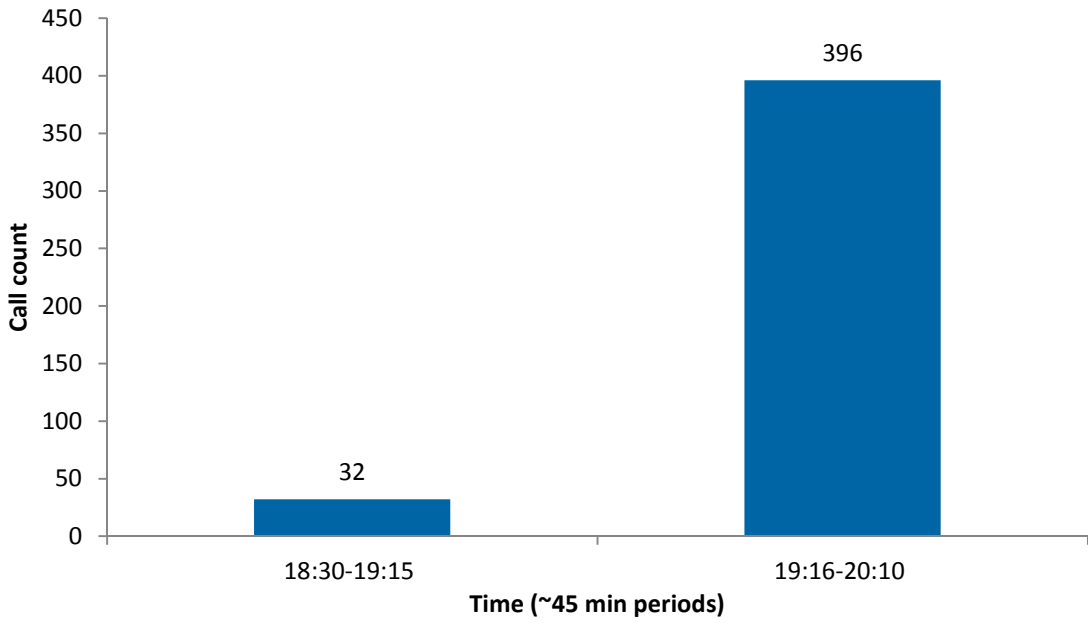

Figure 7 PLNB call activity (~45 minute periods) during the cave occupancy survey at Chateau Cave 9/02/16 (full spectrum analysis data).

Note: Cave occupancy survey commenced at 18:20.

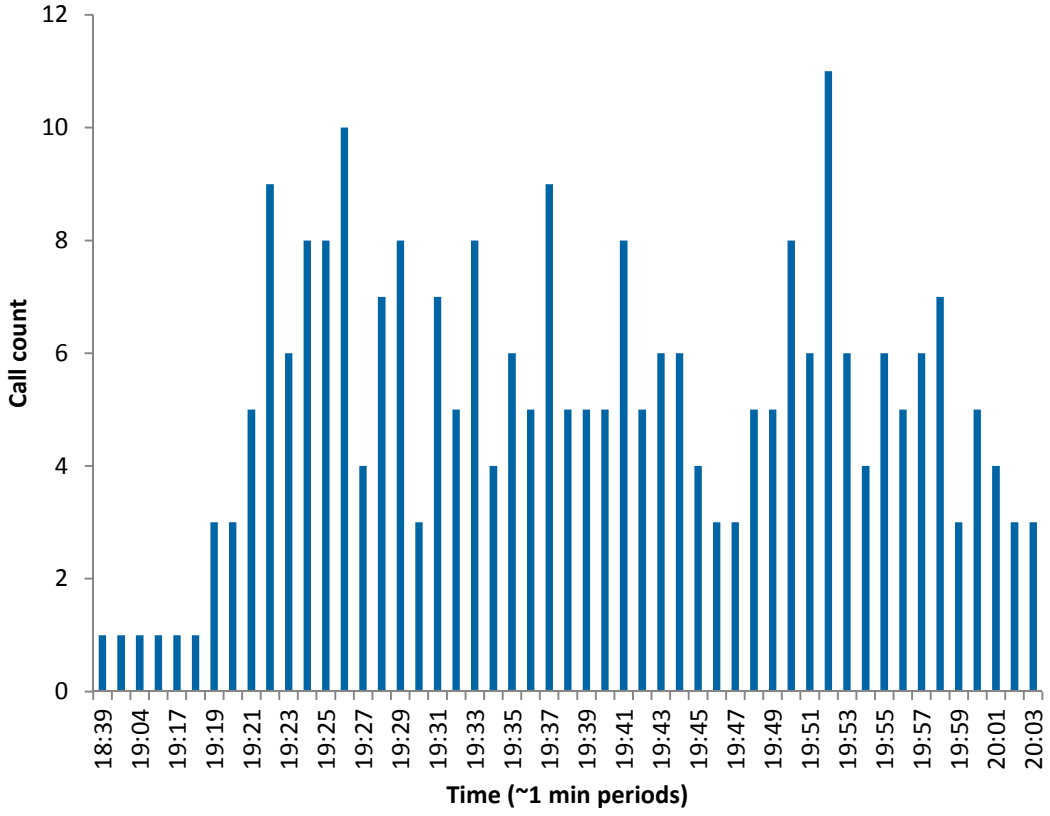

Figure 8 PLNB call activity (1 minute periods) during the cave occupancy survey – Chateau Cave 9/02/16 (ZCA analysis data).

Note: Horizontal scale compressed. Cave occupancy survey commenced at 18:20.

Joe's Cave

No PLNB calls were recorded during the cave occupancy survey inside the barricade for the survey period (see Table 5 and Figure 9). The following observations were recorded before and during the survey:

- Prior to the commencement of the survey, observations of free flying bats were first noted on arrival at site where a small number of *Vespadelus finlaysoni* (~ 5) and *Taphozous georgianus* (~8) were observed in the passage at the twilight zone of the cave. These bats retreated to the main chamber as the barricade was installed
- No bats were observed flying out of the main chamber prior to the commencement or during the survey
- The first observation of free flying bats during the survey was at ~18:55 around the entrance of the cave
- Bats were regularly recorded flying in and around the entrance of the cave and flying bats were also recorded in the general vicinity (e.g. along the cliff face and ridgeline) during the survey period
- At least three *Macroderma gigas* were regularly recorded flying around the entrance of the cave from 19:40-20:20 with at least two intrusion attempts into the cave during the survey period. This species was identified based from its distinct size, shape and colour and audible social buzzing calls
- At least five individual PLNB were observed flying in and around the front part of the passage of the cave leading into the main chamber between 19:45-20:15. The species was identified via real time call analysis using the Echo Meter Touch and their distinct colour as observed in the torchlight. It is possible the PLNB were attempting to access the main chamber and four individuals were observed flying in circles in front of the barricade for 2-3 minutes before departing.

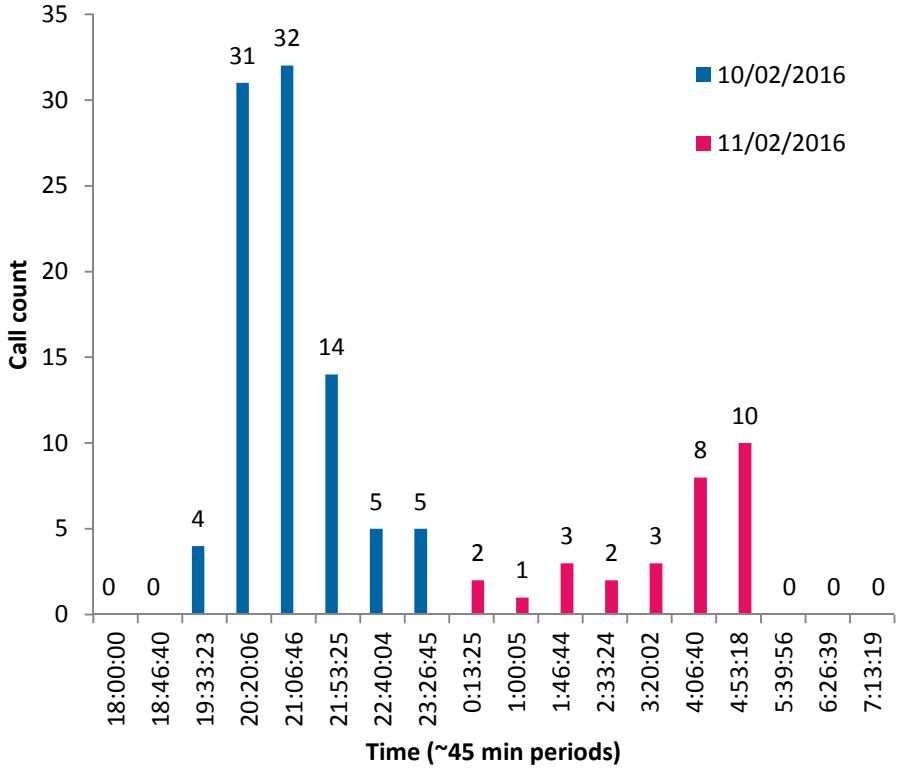

Figure 9 PLNB call activity (~45 minute periods) for Joe's Cave during the cave occupancy survey and night of the 10-11/02/16 (full spectrum analysis data).

Note: Cave occupancy survey commenced at 18:30 and finished at 20:10. No PLNB were recorded within the cave during the COS.

Table 5 Summary of first and last call time recorded for PLNB in comparison to sunrise and sunset times, and SM2 analysis results and observational data for cave occupancy surveys

Site/date/Location	First PLNB call (AL)	Last PLNB call (AL)	Civil twilight – sunset (1) / Sunset (2)	Civil twilight – sunrise (1)/ Sunrise (2)	Analysis and observation
Cave 13					
Inside barricade 8-9/2/16	21:08	4:54	19:09 18:46 *18:45**	5:27 5:51	No PLNB recorded within cave during cave occupancy survey (COS), barricade up / down 18:40 - 20:05. First PLNB call recorded approx. 3 mins following completion of COS and > 60 mins following sunset. Last PLNB call approx. 55 min before sunrise
Cave entrance 8-9/2/16	19:29 (KS)	4:49 (KS)	19:09 18:46	5:27 5:51	First PLNB call recorded approx. 45 mins following sunset. Last PLNB call approx. 60 min before sunrise. Number of calls recorded for night = 183
Nearby 8-9/2/16	19:54	2:35	19:09 18:46	5:27 5:51	First PLNB call recorded > 60 mins following sunset. Last PLNB call > 60 min before sunrise. Number of calls recorded for night = 3
Inside barricade 11-12/2/16	23:47	1:36	19:07 18:44 *18:40**	5:28 5:51	No PLNB recorded within cave during COS, barricade up / down 18:00 - 20:05. First PLNB call recorded > 60 mins following COS and > 60 mins following sunset. Last PLNB call > 60 min before sunrise
Cave entrance 11-12/2/16	20:15	4:46	19:07 18:44	5:28 5:51	First PLNB call recorded approx. 45 mins following sunset. Last PLNB call > 60 min before sunrise. Number of calls recorded for night = 125
Nearby 11-12/2/16	22:55	2:59	19:07 18:44	5:28 5:51	First PLNB call recorded > 60 mins following sunset. Last PLNB call > 60 min before sunrise. Number of calls recorded for night = 3
Chateau Cave					
Inside barricade 9-10/2/16	18:39	20:03	19:09 18:45 *18:50**	N/A	PLNB calls recorded within cave during COS. First PLNB call recorded after the barricade was installed (18:20-20:05) and approx. 6 mins before sunset. Note – detector removed from inside main chamber at end of COS
Cave entrance 9-10/2/16	20:07	5:21	19:09 18:45	5:28 5:51	First PLNB call recorded > 60 mins following sunset and within 5 mins of removing barricade. Last PLNB call within 30 mins of sunrise. Number of calls recorded for night = 315
Nearby 9-10/2/16	-	-	19:09 18:45	5:28 5:51	No PLNB recorded during survey period

Site/date/Location	First PLNB call (AL)	Last PLNB call (AL)	Civil twilight – sunset (1) / Sunset (2)	Civil twilight – sunrise (1)/ Sunrise (2)	Analysis and observation
Joe's Cave					
Sheet 10-11/2/16	20:17	5:13	19:09 18:45 *18:55**	5:28 5:51	No PLNB recorded within cave during COS, barricade up / down 18:30 - 20:10. First PLNB call recorded > 60 mins following sunset and within 10 mins of removing barricade. Last PLNB call within 45 mins of sunrise.
Cave entrance 10-11/2/16	19:24	5:16	19:09 18:45	5:28 5:51	First PLNB call recorded approx. 40 mins following sunset during the COS period. Last PLNB call within 40 mins of sunrise.
Nearby 10-11/2/16	19:50	5:15	19:09 18:45	5:28 5:51	First PLNB call recorded > 60 mins following sunset during the COS period. Last PLNB call within 40 mins of sunrise

Table notes:

Call times

AL - First and last calls taken from analysis of AnalookW files with the exception of one location (Cave 13 entrance 9/2) where Kaleidoscope Viewer (KS) was used to estimate first and last call times for PLNB. Note that AnalookW software has the ability to count and calculate time and date labelled files as part of the count labels tool function, which is not available in Kaleidoscope Viewer.

Sunset and Sunrise times

For the purpose of this report the sunset and sunrise time (source 2) was used as it correlated best with sunset times and observations noted in the field.

Source:

1. Civil twilight time sourced from Australian Government Geosciences Australia: http://www.ga.gov.au/geodesy/astro/sunrise.jsp
2. Sunset and sunrise times from Australian Government Geosciences Australia (AGGA 2016): http://www.ga.gov.au/geodesy/astro/sunrise.jsp.
3. *Sunset time (italicised) from observation taken in field during survey. Best described as the start of darkness when visibility was poor and there was no sunlight on or near the cave entrance. Observation estimated to be accurate to within 10 min +/-.

3.3.3 Ultrasonic surveys

According to the analysis, PLNB were detected at all three sites (Cave 13, Chateau Cave and Joe's Cave) following the cave observation surveys. A summary of the key findings for each location is provided below.

Figure 10 displays the distribution of calls during the survey period for 45-minute intervals using the Kaleidoscope Viewer analysis data counts. Figures 11-13 display the number and distribution of calls during the survey period for 30-minute intervals using the AnalookW analysis data counts. Although the number of calls counted using AnalookW is likely to underestimate the total activity recorded for each night, it is considered unlikely that it significantly underestimates the activity levels and data presented in Figures 11-13 provide a reasonable representation of the activity levels for each site during the survey period.

Table 6 provides a summary of the first and last call times recorded for PLNB for each day of the survey period.

Cave 13

PLNB calls were recorded for three of the five nights surveyed, however call activity was considered very low (ranging from 1-4 calls per night – see Figure 10). Six calls were recorded for the entire survey period.

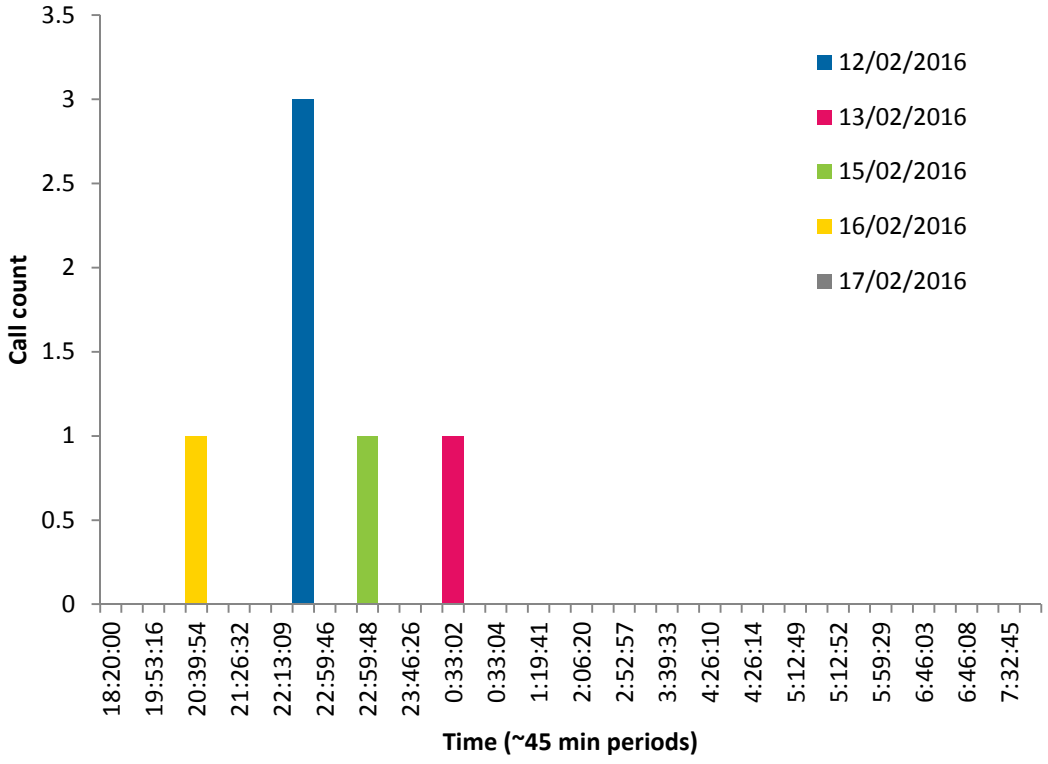

Figure 10 PLNB call activity (~45 minute periods) Cave 13 from 12-17 February 2016 – detector placed in eastern passage facing opening to upper chamber (full spectrum analysis data).

Note: No calls recorded for the 14-15/2/16 or from midnight to 07:30 for the 16-17/02/16.

Chateau Cave

PLNB calls were recorded for all three nights of the survey (Figure 11 and Table 6). Activity was variable ranging from 1-73 calls per 30-minute period. However, overall activity was considered moderate to high across the survey period with a total of 492 calls recorded for three nights. The majority of calls were recorded during the first night of monitoring (9-10/2/16, n= 315) which included a small number of calls recorded during the cave occupancy surveys. Call activity was low for the first half of the night, with the majority of activity occurring after midnight with regular high activity periods for the 10-12 February (> 30 calls per 30 minute period).

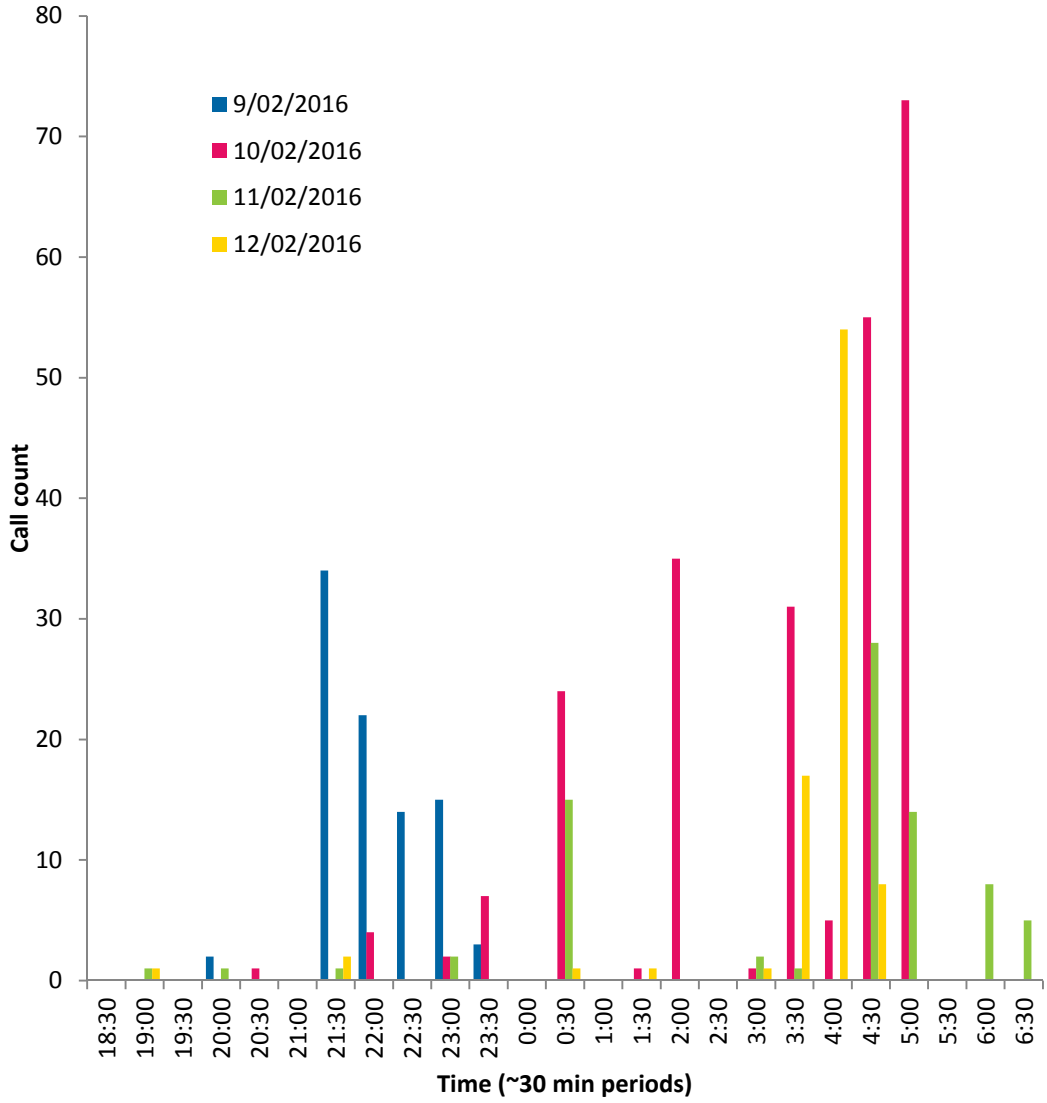

Figure 11 PLNB call activity (30 minute periods) Chateau Cave 9-12/02/16 (ZCA analysis data).

Note: Detector placed at entrance of main chamber.

Joe's Cave

PLNB calls were recorded for all five nights of the survey (Figure 12 and Table 6). Call activity was variable ranging from 1-27 calls per 30-minute period. However, overall activity was low to moderate across the survey period with a total of 352 calls recorded for five nights. The majority of calls were recorded during the first night (11/2/16, n=97) of monitoring, following the night of the cave occupancy surveys. Peak call periods were between 21:30 and 22:00 (all nights) and 4:30-5:30 (most nights).

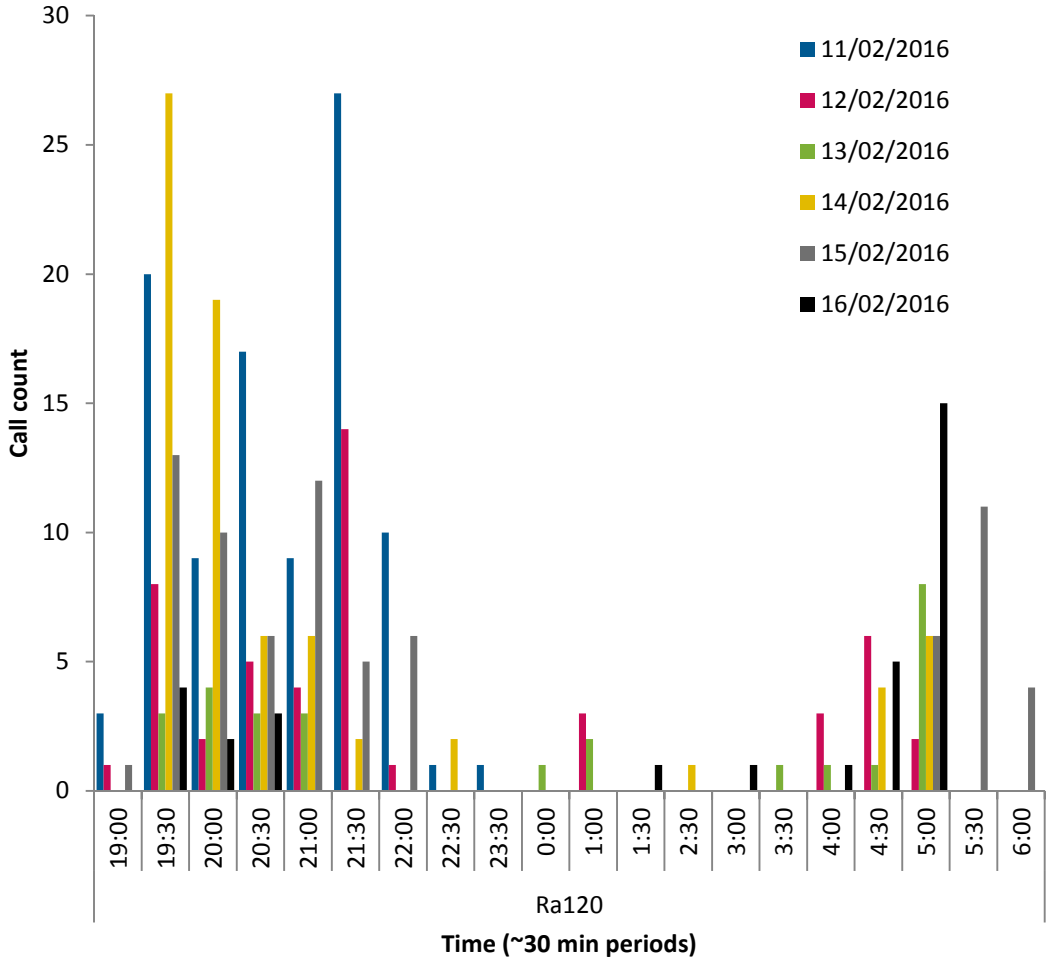

Figure 12 PLNB call activity (30 minute periods) Joe's Cave 11-16/02/16 (ZCA analysis data).

Note: Detector placed at entrance of main chamber.

Nicko's Gorge pool site

Although PLNB calls were recorded each night of the six night survey period (Figure 13 and Table 6), call activity was low ranging from 1-21 calls per 30-minute period with a total of 128 calls recorded. The majority of calls were recorded for the 11-12 February (n = 40). PLNB calls were absent from at least 50% of the 30-minute recording periods over the six survey nights.

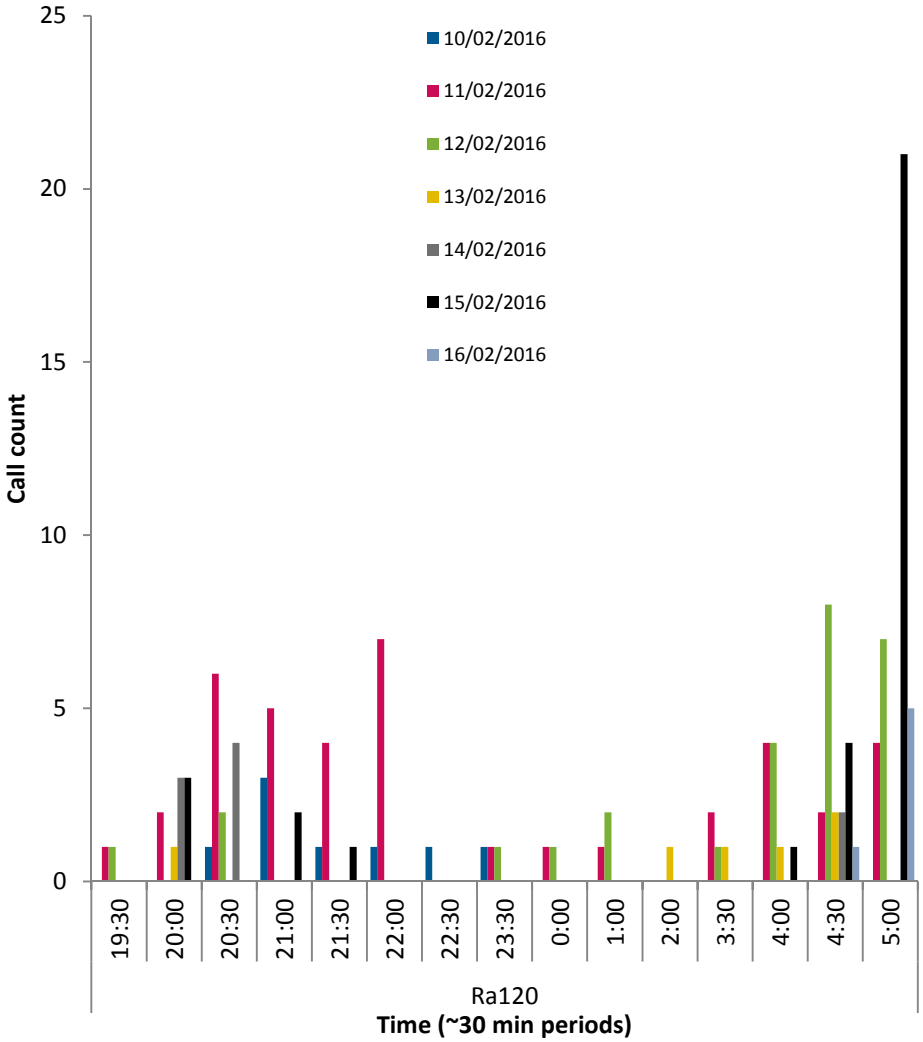

Figure 13 PLNB call activity (30-minute periods) Nicko's Gorge 10-16/02/16 (ZCA AnalookW analysis data).

Note: Detector placed at pool.

Table 6 Summary of first and last call time recorded for PLNB in comparison to sunrise and sunset times ultrasonic surveys

Site/date/Location	First PLNB call (AL)	Last PLNB call (AL)	Civil twilight – set (1)/ Sunset (2)	Civil twilight –sunrise (1)/ Sunrise (2)	Analysis and observation
Cave 13 - cave entrance					
12-13/2/16	1:16	-	19:07 18:44	5:30 5:53	No PLNB calls recorded 12/2. Number of calls recorded for survey period = 1
13-14/2/16	-	-	-	-	No PLNB calls recorded.
14-15/2/16	-	-	-	-	No PLNB calls recorded.
15-16/2/16	23:37	-	19:05 18:42	5:31 5:54	Number of calls recorded for survey period = 1
16-17/2/16	20:49	22:46	19:04 18:41	5:32 5:55	Number of calls recorded for survey period = 4
Chateau Cave - cave entrance					
10-11/2/16	20:50	5:03	19:09 18:45	5:28 5:51	First PLNB call recorded > 60 mins following sunset. Last PLNB call within approx. 50 mins of sunrise. Number of calls recorded for night = 315
11-12/2/16	19:21	4:41	19:07 18:44	5:29 5:52	First PLNB call recorded within 40 mins following sunset. Last PLNB call approx. 50 mins of sunrise. Number of calls recorded for night = 87
12/2/16	19:16	21:37	19:07 18:44	5:30 5:53	First PLNB call recorded > 60 mins following sunset. Number of calls recorded for night = 90
Joe's Cave – entrance of main chamber					
11-12/2/16	19:29	5:15	19:07 18:44	5:29 5:52	First PLNB call recorded approx. 45 mins following sunset. Last PLNB call within approx. 40 mins of sunrise. Number of calls recorded for night = 111
12-13/2/16	19:26	5:18	19:07 18:44	5:30 5:53	First PLNB call recorded within approx. 45 mins following sunset. Last PLNB call within approx. 35 mins of sunrise. Number of calls recorded for night = 49
13-14/2/16	19:46	5:15	19:06 18:43	5:30 5:53	First PLNB call recorded within approx. 55 mins following sunset. Last PLNB call within approx. 40 mins of sunrise. Number of calls recorded for night = 27
14-15/2/16	19:30	6:16	19:06 18:43	5:54 5:31	First PLNB call recorded within approx. 45 mins following sunset. Last PLNB call within approx. 30 mins of sunrise. Number of calls recorded for night = 83

Site/date/Location	First PLNB call (AL)	Last PLNB call (AL)	Civil twilight – set (1)/ Sunset (2)	Civil twilight –sunrise (1)/ Sunrise (2)	Analysis and observation
15-16/2/16	19:25	5:22	19:05 18:42	5:31 5:54	First PLNB call recorded within approx. 45 mins following sunset. Last PLNB call within approx. 30 mins of sunrise. Number of calls recorded for night = 82

Table notes:

Call times

AL - First and last calls taken from analysis of AnalookW files.

Sunset and Sunrise times

For the purpose of this report the sunset and sunrise time (source 2) was used as it correlated best with sunset times and observations noted in the field.

Source:

1. Civil twilight time sourced from Australian Government Geosciences Australia: http://www.ga.gov.au/geodesy/astro/sunrise.jsp
2. Sunset and sunrise times from Australian Government Geosciences Australia (AGGA 2016): http://www.ga.gov.au/geodesy/astro/sunrise.jsp.

3.3.4 Environmental data

Temperature and humidity data was recorded for the following periods using iButton data loggers:

- Cave 13 – 23/02-16/05/2015 and 09/02-02/05/2016
- Chateau Cave - 09/02-02/05/2016
- Joes Cave - 10/02-02/05/2016.

Table 7 provides a summary of the monthly average for temperature and humidity data recorded for each period.

Figures 14 and 15 presents the temperature and humidity data recorded per 30 minute intervals each day for February-May for Cave 13 (2015 and 2016 sampling periods). The minimum and maximum temperatures for the two sampling period were relatively constant and did not significantly vary. For both periods temperature was always above 30°C ranging from 30.2°C-35.1°C (see Table 7 and Figures 14 and 15).

Humidity was highly variable between the two sampling periods for Cave 13 when compared to temperature. Humidity gradually increased during the 2015 sampling period-starting at approximately 55% late February, building to 82% by early May (see Table 7 and Figure 14), whereas the humidity for the same period during 2016 was lower and fluctuated starting at approximately 28% late February, peaking at 68% in mid-May (see Table 7 and Figure 15).

Figure 16 provides a comparison of the daily average temperature and humidity between Cave 13, Chateau Cave and Joe's Cave for the February-May 2016 sampling period. Figures 17 and 18 presents the temperature and humidity data recorded per 30 minute intervals each day for Chateau Cave and Joes Cave for the February-May 2016 sampling period.

Figure 14 Cave 13 - Temperature and humidity data (running tally taken at 30 minute intervals, 23/02-16/05/2015).

Note: Horizontal scale compressed. iButton was located in upper chamber of cave.

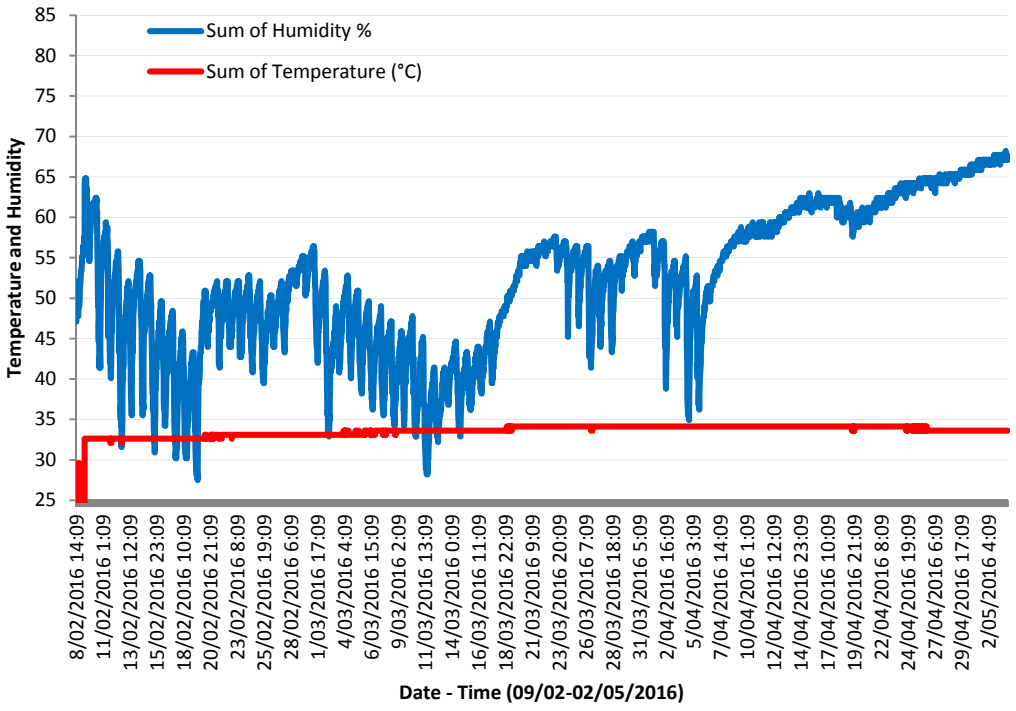

Figure 15 Cave 13 - Temperature and humidity data (running tally taken at 30 minute intervals, 09/02–02/05/2016).

Note: Horizontal scale compressed. iButton was located in upper chamber of cave.

Table 7 Summary of monthly temperature and humidity data for each survey period for Cave 13, Chateau Cave and Joe's Cave

Field	2015				2016											
	Cave 13				Cave 13				Joes Cave				Chateau Cave			
	Feb	Mar	Apr	May	Feb	Mar	Apr	May	Feb	Mar	Apr	May	Feb	Mar	Apr	May
Min Temperature (°C)	34.1	33.6	31.7	30.2	32.1	33.1	33.6	33.6	30.2	30.7	30.7	30.7	32.1	31.1	31.6	31.6
Max Temperature (°C)	34.6	34.6	33.6	31.7	33.1	34.1	34.1	33.6	30.7	31.2	31.2	31.2	32.6	32.6	33.1	32.1
Avg. Temperature (°C)	-	33.9	32.8	31.0	32.8	33.7	34.0	33.6	30.6	30.7	30.7	30.8	32.8	32.5	32.5	31.9
Min Humidity (%)	54.1	63.1	74.1	78.0	27.5	28.2	34.9	65.9	31.9	35.8	31.3	61.3	36.4	31.1	15.6	39.0
Max Humidity (%)	67.2	77.4	81.9	82.9	64.8	57.6	66.5	67.1	72.4	76.9	84.6	82.4	60.0	60.6	55.2	57.0
Avg. Humidity (%)	-	73.2	77.7	80.8	47.5	47.4	59.1	66.7	56.0	57.9	66.8	69.5	52.5	49.4	32.5	49.9

Table notes:
Average temperature and humidity data of for Cave 13 February 2015 was not calculated given the short period of sampling (approx. 5 days).

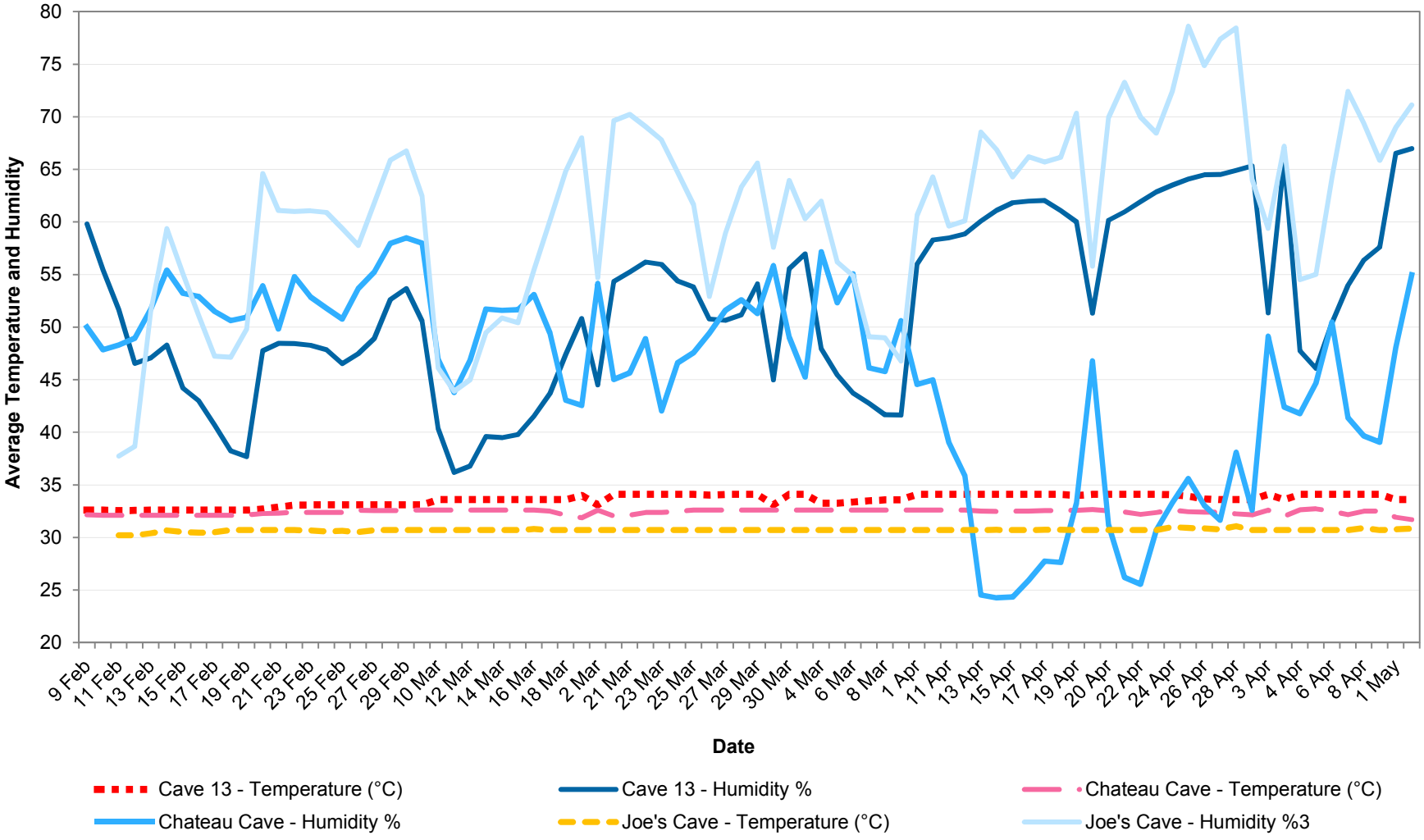

Figure 16 Comparison of daily average temperature and humidity from 09/02– 02/05/2016, Cave 13, Chateau Cave and Joes Cave.

Note: Horizontal scale compressed.

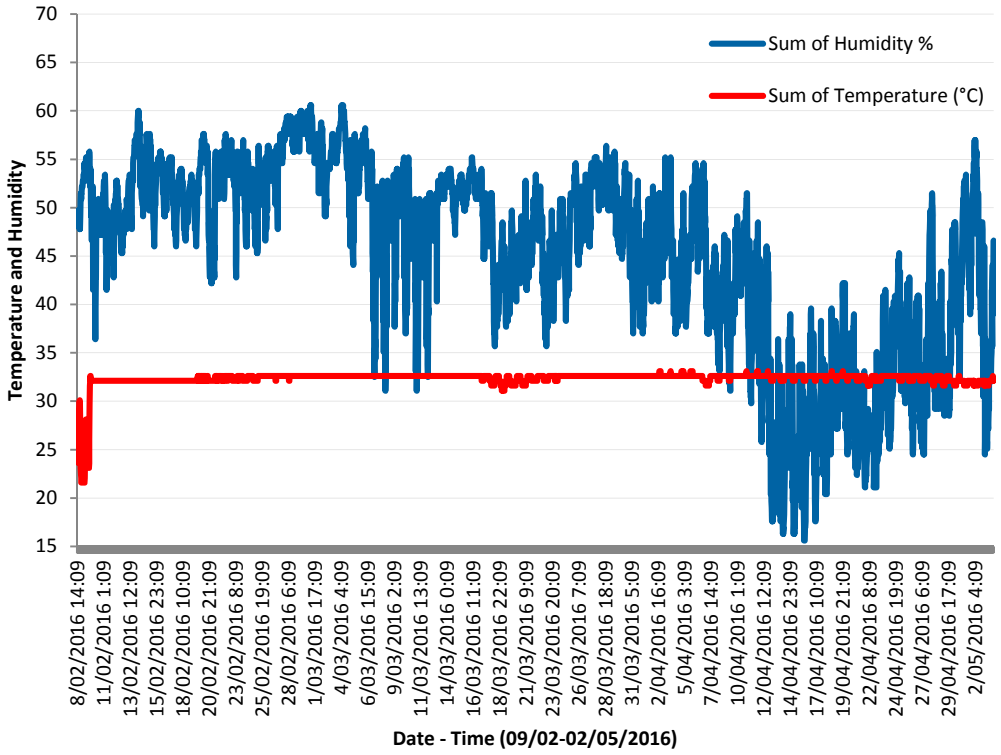

Figure 17 Chateau Cave - temperature and humidity data (running tally taken at 30 minute intervals, 09/02–02/05/2016). Note: Horizontal scale compressed.

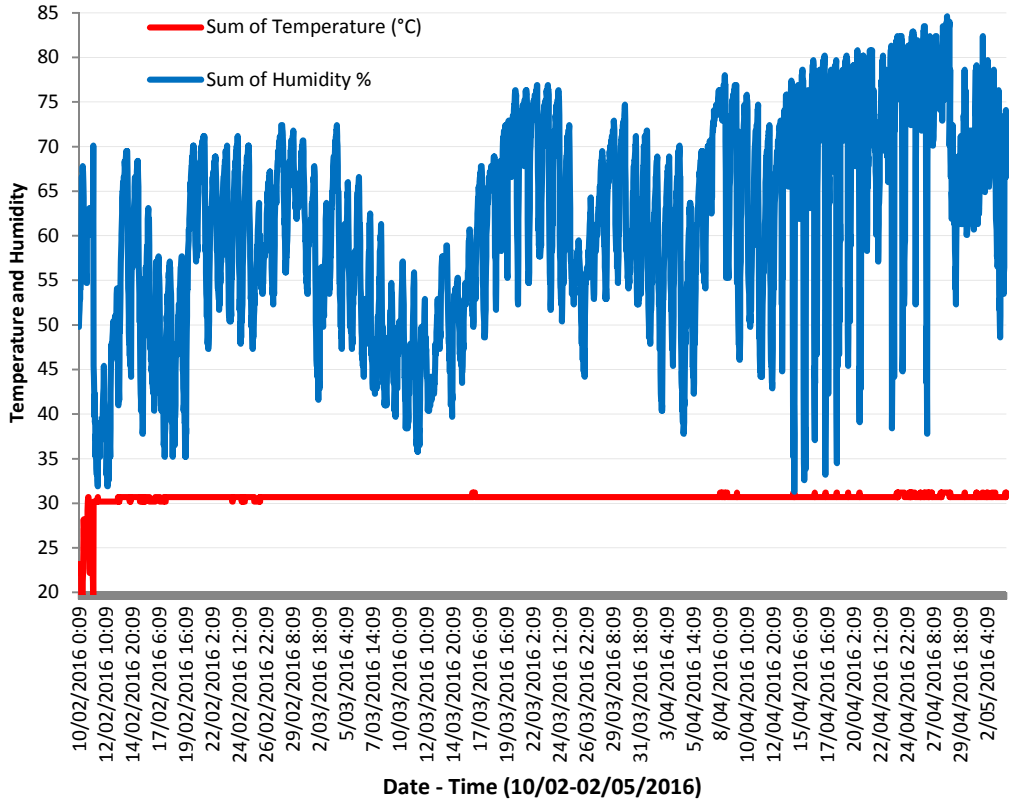

Figure 18 Temperature and humidity data (running tally taken at 30 minute intervals) Joe's Cave (10/02-02/05/2016). Note: Horizontal scale compressed.

4. Discussion and conclusion

GHD was engaged to undertake cave occupancy surveys within the study area for the PLNB during the breeding season. PLNB were recorded within Chateau Cave, however were not recorded within Cave 13 or Joe's Cave during the survey. Considering the above findings and information gained from a review of the data presented in Sections 2 and 3, GHD proposes the following categories for each location based on the categories provided in Section 3.2.1:

- Cave 13 - Transitory diurnal roost
- Joe's Cave – Transitory diurnal roost
- Chateau Cave - Possible Non-permanent breeding roost or Permanent diurnal roost.

The justification for the roost categorisation for each cave is discussed below.

4.1 Cave 13

Cave habitat

It is understood that the primary requirements of a suitable roost site for the PLNB include a stable microclimate with constantly high temperature and humidity (28-32°C and 85-100% relative humidity) to maintain body temperature, conserve water and minimise energy expenditure (Baudinette et al 2000). However, other factors that influence roost selection (i.e. structural properties and proximity to foraging areas) are not as well understood (Cramer et al 2016).

An analysis of the temperature and humidity data from the cave for the two sampling periods suggests that whilst providing optimal temperatures (e.g. > 28°C, ranging from 30.2°C-35.1°C - see Table 7 and Figures 14 and 15) the humidity was less than optimal (e.g. less than 80%) for the majority of the survey period. Between the two sampling periods, the relative humidity was highly variable when compared to temperature. Humidity during the 2015 sampling period displayed a gradual increase throughout the sampling period-starting at approximately 55% late February, building to and peaking at 82% by mid-May (see Table 7 and Figure 14). The humidity for the same period during 2016 was lower and fluctuated throughout the period starting at approximately 28% in late February, and peaking at 68% in mid-May (see Table 7 and Figure 15).

There appears to be a positive correlation (albeit based on limited data) between the first peak activity period during the 2014 monitoring event (increased activity April – June, peaking in May) and the increased humidity from mid-April to start of May (79% building to 82%) suggesting that humidity is a factor, influencing PLNB bat activity in Cave 13.

However, the generally low and fluctuating humidity levels suggest that the cave may not able to sustain the appropriate humidity levels required by the PLNB during key part of the breeding period (November–March), possibly due to outside environmental conditions and/or the cave architecture.

The small size, shape and shallow depth of the of the upper chamber of Cave 13 as described in Section 2.2 does not appear to be consistent with a roost that may provide suitable habitat for large aggregations to form and support pregnancy, parturition and the raising of young. The upper chamber of Cave 13 is easily accessible by potential predators including the Ghost Bat (*Macroderma gigas*). Two other predators (Northern Quoll and Pilbara Olive Python) have been recorded in Cave 13 and in the upper chamber (pers comm C. Grabham February 2015; Bat Call WA 2013).

Surveys

The results from the cave occupancy surveys undertaken in early February 2016 determined the PLNB was not present within Cave 13, in particular the upper chamber during the survey. Ultrasonic surveys conducted for five consecutive nights following the cave occupancy survey in February 2016 recorded a total of six PLNB calls for the survey period. Furthermore, no PLNB calls were recorded for any of the nights within a 30 minute period of sunset and PLNB calls were absent from two of the five nights surveyed. It is important to note that the SM2 detector was placed in the eastern passage facing the opening of the upper chamber for these five days in order to capture the calls of PLNB that may be entering or exiting the upper chamber. To date none of the detector surveys have targeted this location with all other detectors placed at least 10 m from the opening of the eastern passage.

The PLNB activity recorded during the period of the monitoring surveys undertaken by Bat Call WA and ecoscape differed across the seasons. The PLNB was present at Cave 13 for 22 of the 23 months during the survey period (measured by the average number of calls per night over one month –see Figure 4). Furthermore, the monitoring did regularly record the PLNB for the majority of the nights each month during the 2014-2015 monitoring event (excluding October, December and January) and peak activity for the 2015-2016 monitoring event was from March through October.

Although it is not possible to gauge the number of individuals using activity counts it can be said that the PLNB was present at Cave 13 for much of the monitoring survey period including a period of 14 consecutive months from between January 2015 and February 2016. Bat Call WA completed the only visual assessment of individual PLNB occurring within Cave 13 during April 2013 where approximately 200 PLNB were recorded. Since this observation the PLNB has not been observed within Cave 13, including the upper chamber (November 2104, cited in GHD 2015a or January and February 2015, cited in GHD 2015b).

Despite the ongoing presence of the species, observational surveys conducted of the upper chamber within Cave 13 to date have not recorded the PLNB. Furthermore, the majority of the observational surveys have been completed during the breeding period of the PLNB (see Table 2) and Section 3.3.2. Given the lack of evidence to indicate occupation of the PLNB during the maternity period (particularly the parturition and the raising of young) and the habitat characteristics of Cave 13 including the upper chamber, it is considered that Cave 13 is a Transitory diurnal roost.

4.2 Chateau Cave

The FMGIB surveys conducted during March and April 2015 within the mining footprint at North Star identified one cave that may be a potential diurnal roost cave (Chateau Cave – see GHD 2015b).

Cave habitat

An analysis of the temperature and humidity data from the cave for the period sampled suggests that whilst providing optimal temperatures (e.g. > 28°C, ranging from 31.1°C-33.1°C - see Table 7) the humidity was less than optimal (e.g. less than 80%, ranging from 15.6%-60.6%) for the majority of the survey period. Although humidity levels suggest the cave may not be able to sustain the appropriate high humidity levels required by the PLNB, it is not clear from the literature if the PLNB can cope with short term fluctuations in humidity or temperature during the breeding period. It is possible the location of the logger (e.g. near the opening of the main chamber) influenced the humidity levels recorded. Furthermore the temperature and humidity data was recorded over a short period thus should not be considered a comprehensive data set.

The size and shape of the main chamber (3rd chamber – see Section 3.3.1) with a roof height of approximately 2–5 m, possibly higher and cavern estimated to be greater than 10 m deep and up to 10 m wide possibly provide suitable habitat for large aggregations to form and support pregnancy, parturition and the raising of young. Furthermore, the larger cavern with a high ceiling may provide suitable refuge from potential predators.

Surveys

The results from the cave occupancy surveys undertaken in early February 2016 determined that PLNB were present within the main chamber during the period of the survey. Furthermore, ultrasonic surveys were conducted with moderate to high level of activity recorded across the survey period with a total of 492 calls recorded for three nights. It should be noted that the SM2 detector was placed within 3 m of the opening of the main passage for the three night survey period during February 2016 and not within the main chamber.

Considering the above information, particularly noting the presence of the PLNB during the cave occupancy surveys; ongoing PLNB activity for three days during the breeding period and presence of suitable habitat GHD considers that Chateau Cave is a possible Non-permanent breeding roost or Permanent diurnal roost which may be occupied year-round including during the breeding period. However, it is important to note that no surveys have been undertaken to determine the status of the population of PLNB using this cave (e.g. surveys have not been undertaken to determine the presence of breeding).

4.3 Joe's Cave

Joe's Cave within the Zane's Gorge area was classified as a possible diurnal roost during the GHD 2015b surveys, based on the habitat characteristics of the cave recorded during the cave habitat assessment survey and ultrasonic call data analysis.

Cave habitat

An analysis of temperature and humidity data from Joe's Cave, taken over four days during February 2015 (GHD 2015b) suggests that whilst consistently providing optimal temperatures (e.g. > 30 degrees) the humidity was less than optimal (e.g. less than 70% humidity for the survey period). Further analysis of the data collected during the 2016 sampling period suggests the cave provides optimal temperatures (e.g. > 28°C, ranging from 29.9°C–35.6°C - see Table 7). Although the humidity fluctuated greatly (ranged from 31.3%-84.6%, with the highest monthly average of 67.3%), humidity levels were within the optimal range (e.g. > 80%) for the months of April and May. As previously discussed it is not clear in the literature that the PLNB can cope with short term fluctuations in humidity or temperature during the breeding period. It is also possible the location of the logger (e.g. near the opening of the main chamber) influenced the humidity levels recorded.

The main chamber of Joe's Cave is very large size (8-9 m wide, 1-1.5 m in height and 9-15 m deep with a flat floor, see Section 3.3.1). Although the size and environment (e.g. constant temperature and favourable humidity) provides potentially suitable habitat for large aggregations to form and support a maternity roost, the main chamber is very accessible to potential predators including the *Macroderma gigas* which has been recorded hunting at the entrance and in the passage leading into the main chamber (GHD 2015b and Section 3.2.3).

Surveys

The results from the cave occupancy surveys undertaken in early February 2016 determined the PLNB was not present within Joe's Cave during the period of the survey. Ultrasonic surveys recorded the PLNB for five consecutive nights during February 2016. Although PLNB calls were recorded for all five nights of the survey, overall activity was low to moderate across the survey

period with a total of 352 calls recorded for five nights. Peak call periods were between 21:30 and 22:00 (all nights) and 4:30-5:30 (most nights). The timing of the first (within 40-55 mins of sunset) and last calls (within 30-40 mins of sunrise) for the survey period suggests that bats are using the cave as a foraging location, and for temporary refuge throughout the night.

At least five individual PLNB were observed flying in and around the front part of the passage of the cave leading into the main chamber between 19:45-20:15 during the cave occupancy surveys. It is possible the PLNB were attempting to access the main chamber and four individuals were observed flying in circles in front of the barricade for 2-3 minutes before departing.

Considering the above information, particularly noting the absence of the PLNB during the cave occupancy survey GHD considers that Joe's Cave is a Transitory diurnal roost. The information reviewed to date suggests Joe's Cave is possibly occupied for parts of the year by the PLNB. However, there is no evidence to indicate that the main chamber has been used as a maternity roost during the period of the GHD surveys discussed in this report.

4.4 Conclusion

The information reviewed to date suggests that Cave 13 is possibly occupied for parts of the year by the PLNB, however it was not occupied during the period of the cave occupancy surveys suggesting that 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 has been used as a maternity roost during the period of the GHD surveys discussed in this report.

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Appendices

Appendix A – Methods

Field survey methods

Roost occupancy surveys

Roost occupancy determination surveys were undertaken of all three caves using the non-invasive method described in *Survey guidelines for Australia's threatened bats* (pp 63 point 6, DEWHA 2010)[3], in conjunction with ultrasonic surveys and infrared camera surveillance surveys during the breeding season[4].

Roost occupancy determination surveys were undertaken for at least one night at each cave pending the outcome of the first night. The purpose of using this technique is to assess roost occupancy and emergence at dusk without cave entry by an observer.

The entrance was barricaded with a large black bed sheet for 1-2 hours beginning at sunset. Prior to barricading the entrance, a bat detector (SM2BAT+ SongMeter recorder, Wildlife Acoustics Inc., USA) was placed inside the barricade to record echolocation calls coming from within the cave. A second SM2 was placed inside the entrance of the cave (on the other side of the barricade and not within 5 m of the first detector) and a third SM2 was placed nearby the cave (within 20-30 m) to record bat calls from outside but nearby the cave.

For all surveys with the exception of Chateau Cave a second detector EMT (Echo Meter Touch ultrasonic module, Wildlife Acoustics Inc., USA) connected to an iPad (Apple Inc) via a 2 m cable was also used to view real time recordings of bat calls inside the barricade. The EMT provided real time viewing and identification of bat calls as well as provided a backup recording of bat calls.

Roost occupancy could be determined by the real time EMT records and/or by later call analysis of the 'inside-facing' bat detector recordings made over the 1-2 hours.

In addition to the bat detectors, low glow LED infrared cameras (LTL Acorn - model 5310s or equivalent models and/or a Panasonic HX-A Action camera) were used to capture video samples of bats inside and outside the cave during the roost occupancy surveys. The data captured by the cameras when combined with the ultrasonic call analysis of echolocation calls may provide visual information which cannot be provided by ultrasonic analysis alone.

Ultrasonic detection surveys

The primary method of recording ultrasonic bat calls was the SM2BAT+ SongMeter recorder (Wildlife Acoustics Inc., USA). In addition to the bat detectors used during the roost occupancy surveys, SM2 detectors were placed at Nicko's Gorge, Joe's Cave and Chateau Cave for a period of up to 10 days during the breeding season to assist with understanding the temporal activities patterns for the PLNB within the caves and surrounding areas.

Bat calls were recorded between sunset and sunrise across consecutive nights with audio settings designed to optimise detection and recording of the target species (*Rhinonicteris aurantia*). Recorded call data were saved as 45 minute to 1 hour blocks in Wildlife Acoustics' patented WAC compressed audio format.

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[3] Department of the Environment, Water, Heritage and the Arts (DEWHA) 2010, *Survey guidelines for Australia's threatened bats Guidelines for detecting bats listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*

[4] PLNB young are generally born in December, with lactation from December through late February, primarily during the productive (wet) season. Young are generally weaned late February-early March – see: Department of the Environment (2015). Rhinonicteris aurantia (Pilbara form) in Species Profile and Threats Database (SPRAT), Commonwealth Government; and McKenzie, N. L., and Bullen, R. D (2014), Ecology of Rhinonicteris aurantia in the Pilbara. Presentation to the DPaW workshop for the Pilbara Leaf-nosed Bat. Unpublished presentation

Cave habitat assessment

Upon entering the cave observer one will undertake a visual assessment assisted by the use of a low-glow LED infrared camera (LTL Acorn - model 5310s) and/or torch light (dim beam) so as to record the presence of roosting bats (e.g. location in cave) and reduce the level of disturbance to roosting bats. If the target species or other bat species of conservation significance is recorded, the observer will retreat from the cave to minimise disturbance and return either early that evening (following roost occupancy surveys) or early the following morning (at least 60 minutes before sunrise) to conduct the cave assessment. Details recorded include:

- Cave unique identification number, location (GPS), date and time of assessment, and assessors
- Photographs including cave entrance and internal cavity
- Cave morphology: external cave position (upper, lower slope), entrance orientation, approximate entrance width and height, cave depth and number and approximate dimensions for chambers.
- Habitat type and condition outside cave including signs of disturbance and presence of water nearby and inside cave
- Presence of bats: number of individuals, time of use, type of use (e.g. feeding roost, day roost, maternity roost), presence of gravid females or juveniles
- Level of bat use (based on guano/ scat pile accumulations)

This information was then used to assist with categorising the cave type.

Data analysis methods

Call analysis

Craig Grabham from GHD completed the analysis of all data collected during the survey using ultrasonic bat detectors. Data from SM2 units was downloaded and viewed using Kaleidoscope Viewer (version 3.1.6, Wildlife Acoustics Inc 2016) as full-spectrum audio files. WAC files were also converted to Anabat sequence files (zero-crossing format) suitable for analysis in AnalookW version 4.1s (Corben 2015).

Full spectrum analysis

WAC files were viewed and bat calls were identified using Kaleidoscope Viewer (version 3.1.6, Wildlife Acoustics Inc. 2016) by visually comparing the Kaleidoscope Viewer spectrogram and call characteristics (e.g. characteristic frequency and call shape) with reference calls and/or species call descriptions from available reference material (Armstrong and Cole 2007; McKenzie and Bullen 2009; 2012). The spectrogram displayed each call sequence (see below for call definition) with information on the number and timing of calls.

Zero-crossing analysis

Calls were identified using AnalookW by visually comparing the Analook time-frequency graph and call characteristics (e.g. characteristic frequency and call shape) with reference calls and/or species call descriptions from available reference material (Armstrong and Cole 2007; McKenzie and Bullen 2009; 2012).

It is important to note that conversion of WAV and WAC format recordings to Anabat ZCA format has the potential to exclude fainter or lower quality calls, and analyses should take this into consideration (Hourigan 2011). Depending on the survey objectives, it may or may not be critical to recognise every single pulse in a nightly recording. Thus, ZCA-converted recordings

may need to be re-analysed in the original full spectrum format to confirm absence of the species in a recording.

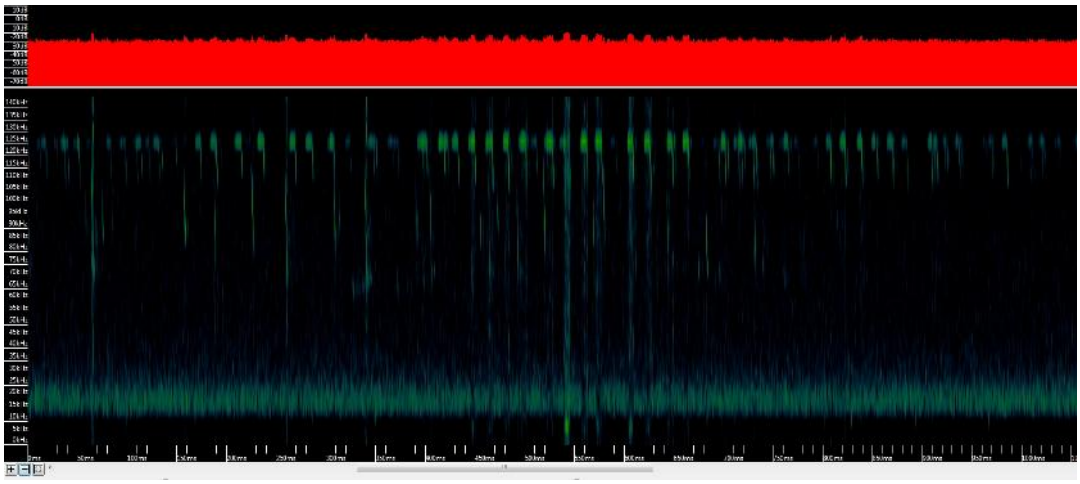
For the purpose of this survey both full spectrum and zero-crossing analysis data was presented. In the first instance the full spectrum data was analysed using Kaleidoscope Viewer used to ensure all that PLNB calls were captured for each site for each survey period. Zero-crossing analysis was then undertaken and used to report first and last calls for a given survey period as the as the ZCA have the ability to time and date stamp each file, making for a more accurate record of the temporal range of call activity for any given period providing sufficient call quality was recorded.

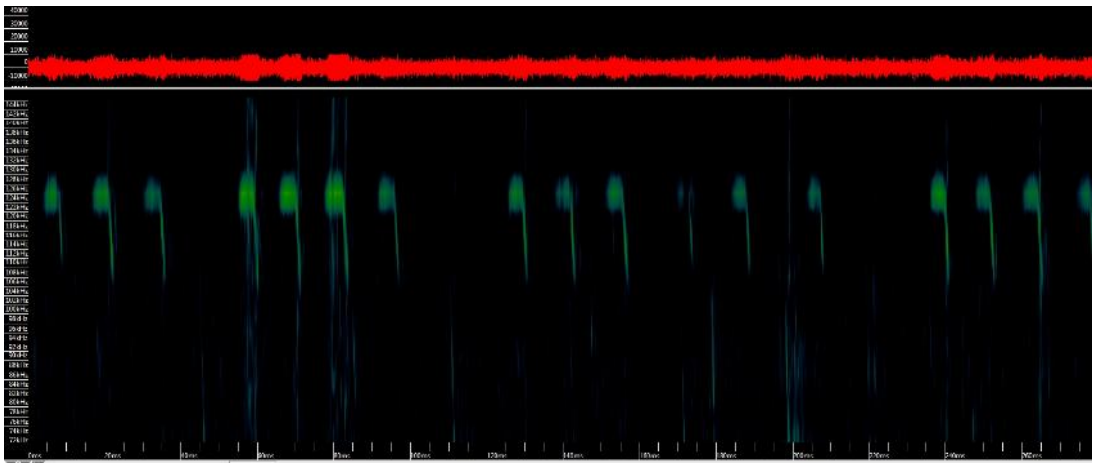
Call definition

A call (pass) was defined as a sequence of three or more consecutive pulses of similar frequency and shape. Calls with less than three defined consecutive pulses of similar frequency and shape were not unambiguously identified to a species but were used as part of the activity count for the survey area.

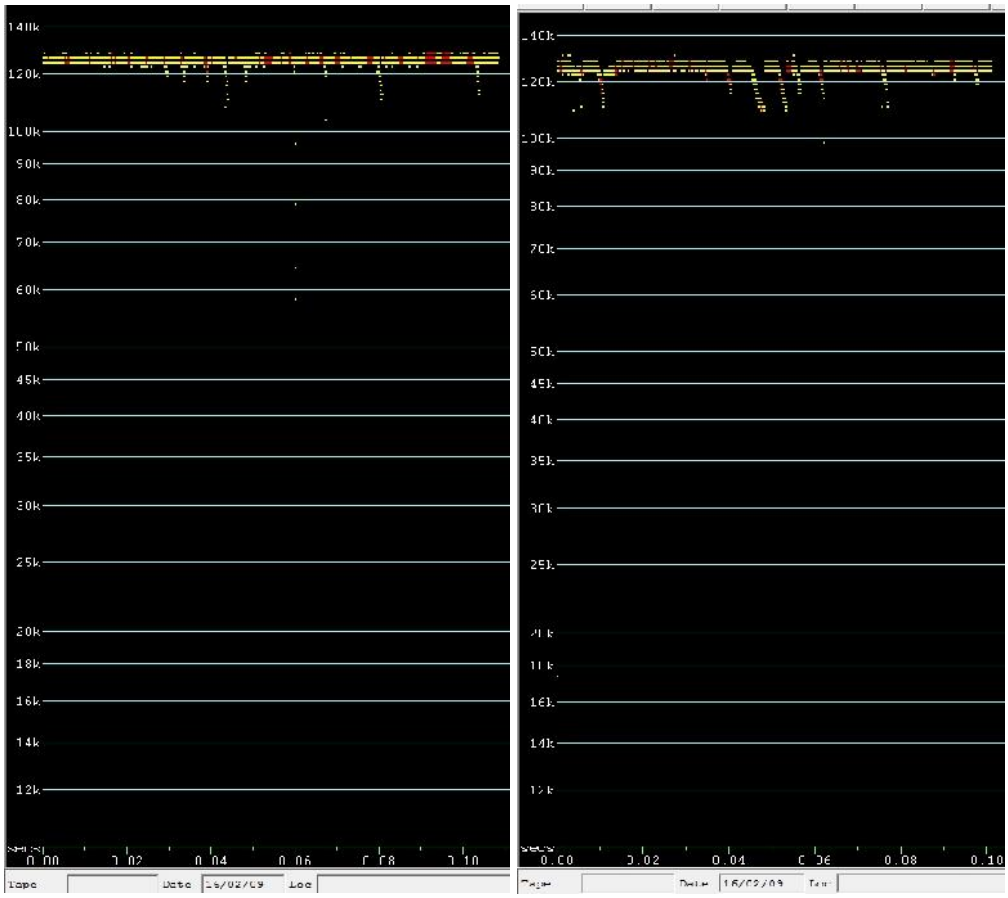
The exception to this call definition is the Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*). The Pilbara Leaf-nosed Bat has a distinct call from all other microchripteran bat species in the Pilbara region. Unlike other species, the pulse structure is constant frequency (CF) with a characteristic frequency (Fc) of 118–128 kHz (DEWHA 2010). Their echolocation calls are readily identifiable from the characteristic (or maximum or peak) frequency, pulse shape, enabling even short call sequences with few pulses to be successfully recognised (Hourigan 2011).

Identification for the PLNB was confirmed from a minimum of two or more consecutive pulses, each being > 4 ms in duration and < 500 ms between the next consecutive pulse in a sequence within the characteristic range of the species. PLNB activity levels were assessed based on the number of calls counted for a given period (e.g. 45 minute to 60 minute periods for the WAC files or 30 minute periods for ZCA files)





Sample files of PLNB call from Kaleidoscope Viewer



Sample files of PLNB call from AnalookW

Call analysis considerations

It should be noted that the activity level graphs shown in Section 3.3.1 and 3.3.2 of this report show a measure of the activity (e.g. number of bat calls per period, also commonly referred to as passes). The number of calls should not be used as the sole source of information for species use of a site nor should bat activity data be solely used to determine the categorisation of a site (e.g. diurnal or maternity roost). Bat activity data other than to determine presence and absence of a species should always be used in conjunction with other complimentary survey methods to assist with determining usage and type of habitat which a site may support.

Infrared video camera surveillance analysis

Low glow LED infrared camera (LTL Acorn - model 5310s) were used to record bat activity at each of the cave occupancy determination survey locations. The purpose of using the cameras was to confirm the presence of bat within the cave behind the barricade and assist with understanding the temporal activity of the bat population at each of the cave sites.

The data captured by the video camera provides visual information (e.g. presence of bats and departure and entry into a cave following the removal of the barricade), which cannot be provided by ultrasonic analysis alone. Ultrasonic call analysis may reveal high activity levels, which may be created by a few bats, or may be created by bats flying around the entrance to a cave.

The LTL Acorn cameras were pre-programmed to record 1 minute video clips every minute during the cave occupancy surveys. Given the speed that bats are known to fly it was best to set the cameras to record for set periods of time rather than rely upon the sensors of the camera to detect movement.

Camera analysis considerations

The poor quality of the video footage in combination with the speed at which the bats were flying within the cave prohibited the positive identification of bats to species level. Identification of some individuals to genus level was possible where bats were observed clinging to the wall of the cave, yet quality and type (i.e. black and white footage) prevented identification to species level.

Environmental data

Temperature and humidity was recorded for Cave 13, Chateau Cave and Joes Cave using a handheld temperature and humidity reader and iButton temperature/humidity logger (model DS1923, Maxim Integrated Products, Inc.).

One iButton was placed toward the centre of the main chamber or as near as possible when access (e.g. Chateau Cave) to the main chamber was prohibited. iButtons were set to record air temperature and relative humidity at pre-determined times (to save power and increase the length of the monitoring) and were deployed for at least 60 days at each location.

Temperature and humidity data was recorded for the following periods:

- Cave 13 – 23/02-16/05/2015 and 09/02-02/05/2016. iButton logger was placed approximately 50 cm up the wall of the upper chamber approximately half way into the chamber
- Chateau Cave - 09/02-02/05/2016. iButton logger was placed approximately 1 m into the main chamber on the floor, next to the wall
- Joes Cave - 10/02-02/05/2016. iButton logger was placed approximately 2 m in the main chamber on the floor next to a wall.

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