Fortescue Metals Group Ltd

Glacier Valley and South Star Fauna Surveys

Fauna survey report

February 2020

Executive summary

The Glacier Valley ore body extension lies immediately south of the North Star deposit. FMG Iron Bridge Australia (FMGIB) are proposing to extend the North Star mining project into Glacier Valley Mining Development (GVMDE) area. In order to determine the environmental significance of the GVMDE additional work is required on the *Environment Biodiversity and Conservation Act 1999* listed (EPBC Act) fauna known to occur in the locality, specifically the Pilbara Leaf-nosed Bat (*Rhinonicterus aurantia*), Ghost Bat (*Macroderma gigas*), Northern Quoll (*Dasyurus hallucatus*) and Pilbara Olive Python (*Liasis olivaceus barroni*).

FMGIB engaged GHD to undertake a desktop review and surveys for the four EPBC Act listed species within the GVMDE and surrounding area (the survey area). This report documents the methods and key results for the surveys undertaken to date that will be used to inform the environmental approvals process for the proposed mine development.

Pilbara Leaf-nosed Bat and Ghost Bat

The targeted bat surveys recorded at least five species of bat including the Pilbara Leaf-nosed Bat from 13 sites and the Ghost Bat from at least four sites.

A review of the bat calls recorded within the first hour for each night of the survey revealed that Pilbara Leaf-nosed Bat calls were recorded within 20 mins of civil twilight (+/- 5 mins) for seven nights at five locations from within the GVMDE. These records suggest that a diurnal roost(s) may be nearby the survey area (e.g. Chateau Cave) and/or within the survey area, particularly given the number of records following civil twilight for each night. The source of these calls could originate from bats roosting within known roost sites such as Chateau Cave or Cave 13.

As a result of the cave habitat searches 33 sites were recorded with known or potential diurnal roosting habitat for Pilbara Leaf-nosed Bat and/or Ghost Bat, of which 26 sites are within the GVMDE. Eight of the sites investigated were confirmed as diurnal roosting and foraging habitat for the Ghost Bat (Cave numbers 1, 2, 3, 11, 14, 28, 30 and 32) and are within the GVMDE. Of the eight caves three were of particular importance (e.g. evidence for ongoing use and use during the maternity period):

- Cave number 30 (labelled Cave 3 located north side of South Star Pool) is a confirmed roost for a large number of Ghost Bats (26-30 Ghost Bats). This cave is most likely a maternity roost considering the number of Ghost Bats recorded and the timing of the surveys (January).
- Cave number 1 (Python Cave) – is a historical Ghost Bat roost. Additional evidence was recorded during the current survey to suggest that the cave could be used during part of the breeding cycle for the Ghost Bat.
- Cave number 32 – confirmed diurnal roost as one Ghost Bat flushed from roost during survey.

There is approximately 634 ha of collective potential roosting habitat mapped for the survey area for both the Pilbara Leaf-nosed Bat and Ghost Bat of which approximately 415 ha occurs within the GVMDE.

Based on the distribution of records collected to date and information regarding the habitats and movements of both species in the adjacent North Star area it can be confidently estimated that the entirety of the GVMDE (1346 ha) and the majority of the survey area (4815 ha) is utilised as foraging habitat by both the Ghost Bat and Pilbara Leaf-nosed Bat.

Unlike the Pilbara Leaf-nosed Bat the foraging habitats of the Ghost Bat are not categorised. The TSSC 2016b conservation advice for the Ghost Bat lists conservation and management actions for the species. Two of the actions include protection of land with significant colonies (high priority) and protection of roost sites and surrounding foraging areas from disturbance (medium priority). Given the overlapping habitat requirements and the presence of a known maternity roost within the survey area for the Ghost Bat, the entirety of the habitat in the GVMDE and at least within a 5 km radius (TSSC 2016b) of the maternity roost site (Cave number 30 Table 9, Figure 7a) should be regarded as high priority for the Ghost Bat. The TSSC 2016(b) states that modification to foraging habitat is a threatening factor.

Pilbara Olive Python

Eight records of the species were observed during the field survey. The rocky ridgeline habitats, pools (of all types) and drainage lines (and associated riparian vegetation) in the area around and within the survey area are core habitat for this species. However, the lack of targeted survey effort for this species prohibited the accurate habitat mapping across the entire survey area and it should be assumed that the amount (1223 ha) and distribution of habitat within the GVMDE, probably underestimates the overall area of habitat used by this species within the GVMDE and larger survey area due to access issues.

Northern Quoll

Of the 115 cameras deployed 64 had observations of Northern Quoll with at least one record of a Northern Quoll from all bar one of the 21 sites. Given the distribution and frequency of the camera records and other observations within the survey area, the Northern Quoll is likely to occupy (including breeding) and hunt within the entirety of the MDE (1346 ha) and of the GVMDE (4,815 ha), however according to DotE 2016 the core habitat areas of the GVMDE is 1637 ha (see Appendix F, Figure 8). However this is likely an under represented figure due to access issue with in the GVMDE area.

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1. Introduction

1.1 Project background

IB Operations Pty Ltd (Iron Bridge) continues to develop iron ore mining operations located at North Star in the Pilbara region of Western Australia (WA). Iron Bridge is a majority-owned subsidiary of Fortescue Metals Group Ltd (Fortescue), which owns and operates a number of mining and infrastructure projects in WA.

Iron Bridge has commenced construction for the North Star magnetite mine (NS) approximately 110 kilometres (km) south of Port Hedland.

The Glacier Valley ore body extension lies immediately south of the North Star deposit. FMGIB are proposing to extend the North Star mining project into Glacier Valley Mining Development Area (GVMDE) (Figure 1). In order to determine the environmental significance of the GVMDE additional work is required on the EPBC Act listed fauna known to occur in the locality, specifically the Pilbara Leaf-nosed Bat (*Rhinonicterus aurantia*), Ghost Bat (*Macroderma gigas*), Northern Quoll (*Dasyurus hallucatus*) and Pilbara Olive Python (*Liasis olivaceus barroni*).

1.2 Project purpose and scope of works

FMGIB has engaged GHD Pty Ltd (GHD) to undertake a desktop review and surveys for the Pilbara Leaf-nosed Bat, Ghost Bat, Northern Quoll and Pilbara Olive Python within the GVMDE and surrounding area. This report documents the methods and key results for the surveys undertaken to date and will be used to inform the environmental approvals process for the proposed mine development.

FMGIB required the following tasks to be completed:

1. Review existing fauna survey results for the survey area to determine suitable habitats for the four conservation significant fauna in the survey area with an emphasis on species habitat within the GVMDE
2. Ground truthing potential habitats including bat roost cave areas within the survey area
3. Undertake targeted surveys for potential conservation significant species following FMG requirements and EPA guidelines.

For the purpose of this report the survey area consists of the GVMDE and the South Star and Glacier Valley survey extension area (see Figure 1), collectively known as the survey area. The GVMDE includes a small portion of the North Star Mining Development Area. The survey area is approximately 4,815 ha.

710000

715000

7645000

7640000

7635000

Chateau Cave

Cave 13

Main Camp Access Road

Comms Tower Access Road

Pipeline Access Road

Valley Road

Craigie Pass

South Star pool

Python Cave

LEGEND

- Cave
- Pool
- Road/Major Track
- Minor Track
- Drill Line
- River
- MDE - South Star and Glacier Valley
- South Star and Glacier Valley Survey Extension

Paper Size ISO A3

0 0.5 1 1.5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

Glacier Valley, South Star study area

FIGURE 1

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Print date: 03 Feb 2020 - 08:03

Data source: FMG: Mine Development Envelope, Roads and Tracks (2018); GHD: Caves and Pools (2016); Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

1.3 GHD Disclaimer

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 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 and weather events. 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 survey area shown in Figure 1.

2. Methods

2.1 Desktop assessment

GHD completed a desktop review of relevant databases and literature to:

1. Document and map the distribution of records for the four fauna species of conservation significance within the survey area and the locality (30 km radius of the GVMDE) – see Figure 2a and 2b.
2. Document and map preliminary habitats for the four key fauna species of conservation significance within the GVMDE.

Databases and other information sources to achieve these tasks included:

- Department of Biodiversity, Conservation and Attractions (DBCA) – records for the Pilbara Leaf-nosed Bat, Ghost Bat, Northern Quoll and Pilbara Olive Python
- Existing spatial data from FMG containing records for surveys undertaken by a variety of consultants for the survey area and locality
- Specialised Zoological (2017). A review of past surveys for Pilbara bats of conservation significance including spatial information. Unpublished report for FMG
- Inspection of Google Earth Pro online imagery which contains recent 3D /elevation imagery to further delineate areas with potential for cave-forming geology. The imagery can be used to identify gorges, gullies, sheers cliff faces and water sources
- Department of the Environment 2016 - 'EPBC Act referral guideline for the endangered northern quoll, Commonwealth of Australia, 2016'
- Hill, B.M. & S.J. Ward (2010). National Recovery Plan for the Northern Quoll *Dasyurus hallucatus*. Department of Natural Resources, Environment, The Arts and Sport, Darwin
- Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2011) Survey guidelines for Australia's threatened mammals. EPBC Act survey guidelines 6.5
- Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2011) Survey guidelines for Australia's threatened reptiles. EPBC Act survey guidelines 6.6
- Department of the Environment, Water, Heritage and the Arts (DEWHA) (2010) Survey Guidelines for Australia's Threatened Bats. EPBC Act survey guidelines 6.1

A key objective of the desktop assessment was to undertake a review of spatial information and other data to identify areas that may have suitable roosting habitat within the survey area for the Pilbara Leaf-nosed Bat and Ghost Bat. The process to identify potential roosting areas is detailed in *North Star Magnetite Project – Survey Plan for Pilbara Leaf-nosed Bat,* Step 1 (Unpublished report to Iron Bridge Pty Ltd, GHD 2017). In summary the step by step process involves:

1. Evaluation of existing survey data (e.g. previous studies and records)
2. Evaluation of spatial data layers including contour, elevation modelling, aerial imagery and geological information
3. Mapping of potential roost habitat.

2.2 Field Surveys

GHD conducted six separate surveys during 2018 and 2019. The purpose of each survey and a summary of the timing, duration and survey effort for each trip is provided in Table 1. A summary of survey effort per species is provided in Tables 2. The location of the survey methods are presented in Figures 3 - 5.

2.2.1 Pilbara Leaf-nosed Bat and Ghost Bat

Reconnaissance surveys in combination with preliminary cave habitat surveys and ultrasonic surveys were undertaken for both bat species. These methods are detailed in GHD 2017 (*North Star Magnetite Project – Survey Plan for Pilbara Leaf-nosed Bat,* Step 1 and Step 2. Unpublished report to Iron Bridge Pty Ltd).

Reconnaissance surveys were undertaken to determine opportunities for access to survey areas, refine the prospective field survey area and identify or eliminate potential roost locations. This process was greatly assisted by using a helicopter.

Where potential roost locations have been identified by the desktop review/reconnaissance surveys and are accessible, preliminary cave habitat surveys were undertaken. When a potential roost location was identified GHD placed a full spectrum ultrasonic recorder for at least two consecutive nights to interpret patterns of activity in the context of the diurnal usage of the potential roost.

Roost occupancy surveys

Roost occupancy determination surveys were undertaken of Chateau Cave and South Star Pool Cave using the non-invasive method described in the *Survey guidelines for Australia's threatened bats* (pp 63, DEWHA 2010)[1]. Surveys were undertaken using a barricade (e.g. black sheet) in conjunction with full spectrum ultrasonic recorder.

Chateau Cave was sheeted on the 21 January 2019 during the maternity period for Pilbara Leaf-nosed Bat to see if the species was utilising the cave over this period. In addition a cave at South Star Pool was also sheeted on the 23 January 2019 to assess for the presence of the Pilbara Leaf-nosed Bat.

Ultrasonic survey and bat call analysis

Bat calls were recorded during field surveys using *in situ* (stationary) full spectrum Song Meter (SM2 bat plus and SM4 FS) detectors (Wildlife Acoustics) and Anabat Swift detectors (Titley Scientific). Appendix A summarises the ultrasonic call analysis methods.

2.2.2 Northern Quoll

GHD used remote cameras and species evidence searches in suitable habitat for the presence of the Northern Quoll.

Survey locations were determined whilst undertaking roost location surveys outlined above. Current survey guidelines (DotE 2016) recommend a survey regime of 10 cameras spaced at 100 m intervals per linear survey area for four nights. However due to potential accessibility limitations we deployed five (5) cameras spaced at approximately 100 m intervals through suitable habitat in situ for up to 14 nights.

Secondary evidence searches consisting of den sites, scats, prints or remains in and around suitable habitat (rocky areas, ridgelines, water areas) were undertaken. When dry quoll scats

[1] 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*

were collected, the sample was stored in 70% ethanol or stored in silica gel. Alternatively, when a fresh scat was collected it was stored in zip bag, then placed in a freezer.

All evidence of Quoll was recorded with GPS location, habitat description and photographs. GHD revised and where necessary based on the results of the field survey the habitat mapping undertaken during the desktop assessment. Where portions of the survey area were inaccessible the lack of data obtained did not allow for detailed mapping for Northern Quoll.

2.2.3 Pilbara Olive Python

GHD completed opportunistic diurnal active/visual surveys for active or basking individuals and secondary evidence searches consisting of scat, sloughed skin or remains in and around caves and crevices.

Sign or sightings were recorded with GPS location, habitat description, photographs and notes on the sighting (e.g. estimated length, sex, condition etc.). Unfortunately the peak activity period for the species (October to March) did not coincide with all of the field surveys, limiting to amount of data collected on this species. The effect that the data obtained to date does not allow for detailed mapping for POP.

Water bodies with in survey area were identified and classified into permanency, semi permanency and seasonal. These definitions are based on the requirement of POP to persist in the environment rather formal classification. However could be considered useful in understanding the nature of the water body's persistence in the area.

Table 1 Summary of purpose, methods and survey effort for each field trip

Trip	Dates	Purpose	Personnel	Methods and effort
1	9 - 13 May 2018	Ground truth the findings of the desktop review and conduct preliminary fauna surveys using species specific techniques within the GVMDE. Confirm and document the types and extent of habitat for four target species - Pilbara Leaf-nosed Bat, Ghost Bat, Northern Quoll and Pilbara Olive Python within the GVMDE.	Glen Gaikhorst Craig Grabham	Deployed seven sites of remote cameras (40 cameras in total) and six ultrasonic detectors. Active searches of seven gorges and associated areas and utilised a helicopter for aerial assessment of gorges, water bodies and caves within the GDVME, survey area and locality north and north –west of the survey area
2	5 - 7 June 2018	Recover cameras and detectors deployed during May and redeploy to new sites. Continue to ground truth the findings of the desktop review and conduct preliminary fauna surveys using species specific techniques. Continue to document the types and extent (known and predicted) of habitat within the survey area.	Glen Gaikhorst Craig Grabham Joshua Levett (FMG IB) Ashleigh Harris (FMG IB)	Recovered three sites of remote cameras and two detectors Deployed three sites of remote cameras and two detectors, active searches of three gorges and associated areas. Two camera sites and two detectors remained in situ from May (25 cameras in total) Trip cut short due to heavy rainfall and access constraints
3	3 - 6 July 2018	Recover cameras and detectors deployed during May and June and redeploy to new sites. Continue to ground truth the findings of the desktop review and conduct preliminary fauna surveys using species specific techniques. Continue to document the types and extent (known and predicted) habitat for four target species in survey area.	Glen Gaikhorst Ashleigh Harris	Recovered all camera sites deployed in May and June Deployed six new sites of remote cameras (30 cameras in total) Deployed six new bat detectors and traversed / investigated potential cave habitat around South Pool Active searches of five gorges/valleys and associated areas
4	8 - 10 August 2018	Recover cameras and detectors deployed during July.	Glen Gaikhorst Ashleigh Harris	Recovered all camera sites and detectors deployed in July A large fire went through portions of the survey area during the 17-18 July 2018 which impacted remote camera and bat detector records.
5	21 - 24 January 2019	Deploy cameras and detectors at existing and new sites. Continued to ground truth the findings of previous surveys particularly around South Pool and associated western flank and conduct preliminary fauna surveys using species specific techniques. Continue to document the types and extent (known and predicted) of habitat for four target species within survey area.	Glen Gaikhorst Marc Morris (FMG IB)	Deployed six sites of remote cameras (30 cameras in total), three sites were repeat location and three new. Off the three new two were regional. Deployed five bat detectors, three were repeat sites and two new. Sheeted Chateau Cave (breeding season) and a cave at South Pool. Visually monitored two other caves at South Pool. Traversed and investigated potential cave habitat around the western flank opposite South Pool and undertook active searches of three new and three known gorges/valleys and associated areas
6	26 - 28 February 2019	Recover cameras and detectors deployed during January.	Glen Gaikhorst Marc Morris	Recovered all camera sites and detectors deployed in January.

Table 2 Summary of survey effort per species

Species	Method	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Total effort
Pilbara Leaf-nosed Bat and Ghost Bat	Ultrasonic detector (SM4 FS or SM2 Bat +)	Four sites for at least six consecutive nights, two sites for at least 10 consecutive nights	Two sites for at least 24 consecutive nights each	One site for three consecutive nights, Four sites for at least seven consecutive nights and one site for 20 consecutive nights	-	Five sites (three repeat, two new) for up to 31 nights. Sheeted Chateau and South Star Pool Cave	-	19 sites, at least 182 nights analysed at approximately nine hours each night)
Pilbara Leaf-nosed Bat and Ghost Bat	Habitat assessments and preliminary cave searches	Seven gorges Approximately 27 potential cave locations identified (via walking and helicopter transects)	Three gorges (via vehicle and walking transects)	Six gorges Approximately five potential cave locations identified (via walking transects), South Star Pool area	Additional ground truthing and visual inspection of habitat around South Star Pool and west facing gorges.	Three Gorges Valleys including cave areas around South Star Pool	-	More than 43 locations (most with multiple potential sites e.g. overhangs, caves)
Northern Quoll	Remote camera deployment (Reconyx 550 and Scout Guard)	Seven sites of five or 10 cameras per site for 24 to 28 days	Three sites of five cameras and two remaining sites from Trip 1 for 28 to 54 days	Six sites of cameras per site for 34 to 35 days	All cameras collected with additional ground truthing and visual inspection of habitat around South Pool and west facing gorges.	Six sites of cameras per site for 36 to 40 days	Visual inspection of all areas associated with camera collection.	22 sites of remote cameras of either five or 10 cameras per site, set for 24 to 54 days. In total 3760 trap nights were undertaken.
Pilbara Olive Python	Habitat assessment, water hole assessment and evidence based searches	Eight small temporary or semi permanent pools found and assessed. All caves assessed for bats were also investigated.	All eight pools identified in Trip 1 revisited (to collect cameras). No new pools investigated due to weather conditions.	Four small temporary, semi permanent or permanent (South Pool) pools found and assessed. All caves assessed for bats were also investigated.	All four pools identified in Trip 3 revisited with one additional gorge investigated with pools and seeps. Additional ground truthing and visual inspection of habitat around South Star Pool and west facing gorges.	Nocturnal assessments of South Star Pool and habitat areas along Western Flank opposite South Star Pool.	Visual inspection of all pools associated with camera collection.	17 small temporary, semi permanent or permanent pools found and assessed. All caves assessed for bats were also investigated. All Pools can be seen in Appendix D

2.3 Survey conditions and weather

Table 3 provides a summary of the conditions and weather experienced during the surveys.

Table 3 Survey conditions and weather

Survey Periods	Timing	Weather	Comment
Trip 1	9 - 13 May 2018	Fine hot and humid	No impact to field survey
Trip 2	5 - 7 June 2018	Two days of hot and partly humid overcast conditions before large storms set in	Heavy prolonged rain prevented completion of trip and impacted two camera and one bat detector site
Trip 3	3 - 6 July 2018	Fine and warm	No impact to field survey
Trip 4	8 - 10 August 2018	Fine and warm	A large fire burnt portions of the survey area during the 17 - 18 July 2018, which impacted four camera and three bat detector sites.
Trip 5	21 - 24 January 2019	Fine hot and humid. Scattered afternoon thunderstorms	No impact to field survey
Trip 6	26 - 28 February 2019	Fine hot and humid	No impact to field survey

2.4 Survey limitations

Topography

Surveys conducted of the survey area were often constrained by access, terrain and work safety requirements. It was impossible to safely access and therefore determine the type of potential bat roost sites in some areas, particularly the near vertical slopes and steep walled gorges. The restricted vehicle access in combination with the distances required to travel on foot to the site hindered survey efforts in some areas, preventing the survey team from completing a thorough survey of some locations. It is possible that suitable roosting habitat occurs in these inaccessible areas.

It is also important to note it was unlikely 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. Some caves contained narrow passages and small sub-chambers which do not allow for safe egress. Therefore, it is possible that some of the caves contained one or more individuals at the time of the surveys.

Weather

Weather experienced during the survey was generally suitable and typical of the weather patterns experienced over the survey period with the exception of the flood and fire events mentioned previously (Table 3). These adverse conditions did inhibit to a small degree the survey program and may have adversely affected the behaviour of local animals for short periods during and following each event.

During the project two extreme weather events impacted the timing and level of survey effort (e.g. number and distribution of sites) within the GVMDE. During the June 2018 field survey,

heavy rain created flooding which restricted access across the survey area, effectively cutting short the field survey. Data recorded by two cameras and one ultrasonic bat detector was affected.

Between the July and August field trips a very large fire occurred within the GVMDE which covered the majority of the western flank of the main deposit and more than half of the survey area. Four cameras and three ultrasonic bat detectors were damaged/destroyed reducing the data collected for the survey period. The large scale of this fire and areas impacted would have reduced/modified the activity of species assessed, particularly the Northern Quoll and Pilbara Olive Python.

3. Results

3.1 Targeted bat surveys

This section provides a summary of the desktop review and field survey results for the Pilbara Leaf-nosed Bat and the Ghost Bat.

The Pilbara Leaf-nosed Bat is listed as Vulnerable under both the Commonwealth EPBC Act and the Western Australian *Biodiversity Conservation Act 2016* (BC Act). The primary consideration for this species is the protection of its roosts and breeding colonies from mining and disturbance.

The Ghost Bat is listed as Vulnerable under both the Commonwealth EPBC Act and the Western Australian BC Act. The most severe key threats to this species identified are the destruction and disturbance of roost sites from mining and human visitation. Entanglement in barbed wire fences also has the potential to extirpate local occurrences and reduce area of occupancy.

The majority of the information used to develop the desktop summary was extracted from a literature review of the species completed by Specialised Zoological (2017) for FMGIB, Cramer et al, 2016 and the SPRAT profile for both species (DotEE 2018a, b) and a review of data for both species in the locality. Figure 2a Appendix F displays the local database records for both species. The information provides background context to the discussion of the key outcomes resulting from the recent surveys for the survey area.

3.1.1 Desktop review Pilbara Leaf-nosed Bat

Taxonomy

The Pilbara Leaf-nosed Bat is the isolated Pilbara population of the Orange Leaf-nosed Bat *Rhinonicteris aurantia* (Armstrong 2008; Woinarski et al. 2014). It is considered as a separate 'form' of the Orange Leaf-nosed Bat *Rhinonicteris aurantia* under Commonwealth Government environmental legislation, but is not yet described formally as a separate subspecies.

The Orange leaf-nosed Bat is Australia's only living representative of a newly described family of bats—the Trident bats Rhinonycteridae, which was recognised as distinct from the Hipposideridae on the basis of a comprehensive molecular study (Foley et al. 2015; Armstrong et al. 2016). It is the last relict of a diverse radiation in the Tertiary wet forests of northern Australia (Hand and Archer 2005). The genus contains one living species only, plus at least one fossil species, *Rhinonicteris tedfordi* (Hand 1997).

A more recent population-wide (Pilbara-wide) genetic study of the Pilbara Leaf-nosed Bat was undertaken for another mining proponent (Armstrong 2011b unpublished report), and was based on microsatellite genetic markers and expanded sampling. This study did not have sufficient samples to adequately resolve the taxonomic issue, but it did provide evidence that the Pilbara and Gascoyne colonies of the Pilbara Leaf-nosed Bat functioned as a single panmictic (interbreeding) regional population (K.N. Armstrong pers. comm. 27 May 2019).

The latest study built even further on an expanded sample set by corroborating the previous observation of Armstrong (2011b) that the Pilbara Leaf-nosed Bat functioned as a single interbreeding population in the Pilbara region, separate from the Kimberley, Northern Territory and north-west Queensland population/s. It also provided evidence of finer-scale population substructuring that suggested limited movement and genetic exchange between some sets of colonies in different parts of the region (Armstrong et al. 2017 conference presentation of unpublished data). Samples from the North Star area were not part of the study, but individuals

in this area of the Pilbara are likely to be connected with other colonies north of the Fortescue Valley (K.N. Armstrong pers. comm. 27 May 2019).

Extent of occurrence

Records of occurrence of the Pilbara Leaf-nosed Bat are spread throughout the Pilbara region, though it is generally encountered in rocky areas that provide opportunity for roosting in caves or disused underground mines—particularly the ironstone hills of the Hamersley Range, the granite boulder piles of the granite terrain, the disused underground mines in greenstone ranges of the eastern Pilbara, and the massive metamorphosed folded silcretes at the southern margins of the region (Armstrong 2001, 2003).

The area of occupancy (AOO) in the Pilbara region has been most recently calculated by Woinarski et al. (2014). For cave-roosting bats such as the Pilbara Leaf-nosed Bat that are reliant for their daily survival on suitable but relatively few roosts for half of every day, the AOO is best considered as the total area of its roost sites only (excluding foraging habitat), given that AOO can be defined as “the smallest area essential at any stage to the survival of existing populations of a taxon” (IUCN 2001). The total number of known roosts is 10, with at least another 25 suspected (Cramer et al. 2016), so the total area of all these underground sites is very small.

A review of studies supplied by FMGIB was undertaken to provide a chronological timeline of information collected regarding the occurrence of the Pilbara Leaf-nosed Bat within the locality (Table 4). The following studies were reviewed:

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

- GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report.
- GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat.

Roosting and breeding ecology

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

When not foraging, it is essential that it roosts in physiologically benign environments (28–32 ^{o}C and 85–100% relative humidity) to maintain its body temperature and conserve body water with minimum energy expenditure (Kulzer et al. 1970; Baudinette et al. 2000). The full range of roost microclimate conditions (temperature, relative humidity) has not been documented, but in the Northern Territory, studies by Churchill (1991) showed that the Orange Leaf-nosed Bat occupied areas with a temperature of 30–31 °C and vapour density of 30–31 g m^3 (>24 °C and >70% relative humidity in the Pilbara, and 27–28 °C and >90% relative humidity in the Kimberley; Armstrong 2000, 2001).

In the Northern Territory, they have a typical seasonally monoestrous reproductive pattern. Females reach sexual maturity after about seven months, and males at about 16 months. Mating occurs in July, followed by a prolonged gestation of 150 days. Parturition (birth) begins in December, and lactation coincides with the greater biomass productivity of the wet season, which obviates the need for sperm storage or delayed embryonic development. Young are weaned and independent by late February.

The breeding cycle is assumed to be similar in the Pilbara form. Armstrong (2001) captured pregnant females in December at Barlee Range and Bamboo Creek. In March, observations from captured females suggested that young had recently been weaned and were independent. In the Pilbara, breeding is thought to take place in roosts where bats are present year-round. Some caves in the Pilbara become unsuitable for the species in the hottest and driest times of the year (in the period of relatively low rainfall and increasing ambient temperatures between August and December), and it is thought that bats contract back to the relatively few deep structures that offer suitable microclimate conditions in all seasons (Armstrong 2001). Breeding activity encompassing aggregating to mate, gestation of females, births and raising of young falls between July and February, meaning that presence at a particular roost during this period is a sign that the site has a role in at least some stage of the breeding cycle.

Table 4 Summary of surveys for Pilbara Leaf-nosed Bat and Pilbara Leaf-nosed Bat roost habitat undertaken for the locality

Reference	Key survey outcomes
ecologia environment (7 March 2012)	First record of Pilbara Leaf-nosed Bat at Cave 13. Pilbara Leaf-nosed Bat was recorded from 18 locations across the project area using bat detectors. Based on the analysis of the timing of call density peaks, three of these locations were considered diurnal (day) roost cave locations. The majority of records were from the North Star mining and infrastructure areas and consisted of ridge/breakaway/rocky gorge habitats with or without semipermanent water.
Bat Call WA 2013 (18 July 2013)	Targeted survey in April 2013 to confirm the general location of the day roost within the Fortescue project area and then to identify the cave(s) containing the roost considering the ecologia survey findings (2012). Surveys included the use of bat detectors and infrared video surveillance. One cave within the project area (Cave 13), was found to contain a colony of over 200 Pilbara leaf-nosed bats and it was characterised as a day roost and probably a maternity roost.
Bat Call WA 2014 (25 May 2014)	Long term monitoring of the activity levels of the Pilbara Leaf-nosed Bat 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 Pilbara Leaf-nosed Bat activity using SM2 bat detectors. The results of the study showed the characteristics of the Pilbara Leaf-nosed Bat colony at Cave 13 changed between March and May 2014. March activity at the cave was consistent with a primary foraging location for the species, but not a diurnal roost. During April, the activity pattern changed to one consistent with diurnally roosting bats being present at the cave in line with the results of 2013. This pattern continued into May. Data from Cave 13 suggests there is an unknown permanent diurnal roost close by (within approximately 10 km of Cave 13) and that bats from this roost are attempting to colonise Cave 13 at the end of the wet season. Additional data collected using SM2 bat detectors following the breeding season suggests Cave 13 maybe a non-permanent diurnal roost (Bat Call WA 2014) and that bats may roost in another location, at least for part of the year.
Atlas Iron 2016	Atlas Iron monitored the presence and activity of bats of conservation significance at numerous sites in the Abydos project area to document potential changes to the presence of the Pilbara Leaf-nosed Bat and their habitats during the life of the mine, and to assess the effectiveness of Atlas Iron's management commitments. The Abydos project area covers an area of upland ironstone with a northern-facing escarpment just west of Strelley Gorge. Most records of the Pilbara Leaf-nosed Bat and Ghost Bat are centred on this ironstone feature, or areas immediately adjacent. These records probably derive from bats roosting in the Abydos area itself, as well the disused Lalla Roohk mine further east on Panorama Station. Bat colonies and suspected or possible bat roosts have been monitored annually for the life of the project in a standardised programme with acoustic recorders. Monitoring focussed not only on the presence and activity of bats, but also their potential response to nearby mining activity and the structural condition of their roosts. Four caves (named as A, B, D and H) were suspected to be used as diurnal roost sites by the Pilbara Leaf-nosed Bat on the basis of the activity patterns derived from measurements of the number of echolocation call sequences made at cave entrances. A range of management measures have been implemented during mining.

Reference	Key survey outcomes
GHD 2015b (2 November 2015) Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Pilbara Leaf-nosed Bat roost habitat survey.	Surveys were undertaken by GHD to locate and describe diurnal and maternity roost sites within two pre-determined search areas: the Blue Square and Zane's Gorge for the Pilbara Leaf-nosed Bat. Report also includes the findings of opportunistic habitat assessments completed by GHD and FMGIB during November 2014 and habitat assessments and ultrasonic surveys completed by FMGIB during March and April of 2015. In excess of 52 caves with the majority being classified as potential nocturnal roosts, were surveyed. The habitat assessment did not confirm the absence of a maternity roost within the study area however one Joe's Cave was classified as a diurnal roost. It was also determined that the likelihood of a maternity or diurnal roost occurring within the Blue Square would be limited to the south-west portion and southern boundary of the Blue Square, including Nicko's Gorge and possibly a small area of the north-east portion of the Blue Square associated with the tributaries of Black Boy Creek. The Blue Square also contains at least three large pools which in turn support riparian vegetation which provides an important resource for the Pilbara Leaf-nosed Bat. Although not located during the field survey, the analysis of the ultrasonic survey data revealed that there may be a diurnal roost located within or immediately adjacent Nicko's Gorge. No Pilbara Leaf-nosed Bat were observed in any of the caves surveyed during the survey period, however two other species were regularly recorded roosting within different cave habitats (*Taphozous georgianus* and *Vespadelus finlaysoni*). The Ghost Bat was recorded at two sites during the survey. The FMGIB surveys conducted during March and April of 2015 within the mining footprint at North Star identified one cave that may be a potential diurnal roost cave (Chateau Cave).
GHD 2016a (26 July 2016), Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Cave 13 Pilbara Leaf-nosed Bat Survey.	GHD completed roost occupancy surveys for the Pilbara Leaf-nosed Bat within Cave 13, Chateau Cave and Joe's Cave during February 2016 during the breeding season. The surveys used the roost occupancy survey the method described in the Survey Guidelines for Australia's Threatened Bats (DEWHA 2010); ultrasonic detection and cave habitat assessments. Temperature and humidity data was also reviewed for each of the caves. Pilbara Leaf-nosed Bat were recorded within Chateau Cave but not with Joe's Cave or Cave 13. Following a review of the results, the following categories were proposed for each site: Cave 13 - Transitory diurnal roost; Chateau Cave - Possible Non-permanent breeding roost or Permanent diurnal roost; Joe's Cave – Transitory diurnal roost.
GHD 2016b (21 September 2016), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Chateau Cave, Cave 13 and Joe's Cave - Pilbara Leaf-nosed Bat surveys including roost occupancy surveys.	GHD completed roost occupancy surveys for the Pilbara Leaf-nosed Bat within Cave 13, Chateau Cave and Joe's Cave during September February 2016 during the breeding season. The surveys used the roost occupancy method described in the Survey Guidelines for Australia's Threatened Bats (DEWHA 2010); ultrasonic detection and cave habitat assessments. Pilbara Leaf-nosed Bat were recorded within Chateau Cave but not with Joe's Cave or Cave 13. The results confirmed the preliminary categorisation of the caves from earlier in 2016: Cave 13 - Transitory diurnal roost; Chateau Cave - Possible Non-permanent breeding roost or Permanent diurnal roost; Joe's Cave – Transitory diurnal roost.

Reference	Key survey outcomes
GHD 2017b (17 January 2017), Unpublished memorandum for Fortescue Metals Group Iron Bridge - Roost emergence survey and roost count for Pilbara Leaf-nosed Bat - Chateau Cave, North Star Mine 14 - 18 November 2016.	GHD completed a roost emergence surveys to estimate the population size of the colony of Pilbara Leaf-nosed Bat that inhabit Chateau Cave. The roost survey was completed from the 14 – 18 November 2016 using a full spectrum ultrasonic recorder, infrared camera (IR cameras) and bat counter (the Apodemus BatCounter) with the aim of recording the ingress/egress of bats at the entrance of the main chamber of Chateau Cave during the roost emergence period from sunset for approximately one hour. The bat counter was also used to count 'passings' for the entire night. Manual observation counts of the IR camera recording and comparison with ultrasonic call data post survey were undertaken in an attempt to validate the 'passings' logged by the bat counter. The preliminary estimate of the population size of the Pilbara Leaf-nosed Bat colony occupying the main chamber of Chateau Cave during the November 2016 is up to 120 individuals. Further survey and analysis is required to validate these findings.
GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report.	The trapping and radio-tracking program focussed on the area between and in the vicinity of Chateau Cave and Joe's Cave including the majority of the North Star mining development and associated infrastructure envelope during July 2017. At total of 51 bats of three species were captured including 7 Pilbara Leaf-nosed Bat which were fitted with digitally encoded transmitters and monitored using an array of 11 base stations (stationary data logging receivers) for between 7 and 13 nights each from the 13-27 June 2017.
GHD 2019 (review of ultrasonic data from Chateau Cave for the 5-17 July 2018) – data analysis (no report)	GHD have reviewed the ultrasonic data from the SM2 unit placed within the main chamber of Chateau Cave. Between 10-13 July a bushfire burnt large portions of the North star area including up to the front of Chateau Cave (approximately the 10-11th July). Data was reviewed for a 13-day period (5-17th July). The data analysis revealed that Pilbara Leaf-nosed Bat were present within the main chamber of the cave for the 13-day period. Furthermore, analysis revealed that Pilbara Leaf-nosed Bat were active within the main chamber for each night of the 13-day period. An analysis of the first Pilbara Leaf-nosed Bat call for each night revealed that for nine of the 12 nights (including the 9-13th July) first calls occurred before civil twilight (e.g. before the emergence period). For the remaining three nights first calls were within 2-3 minutes of civil twilight. Calls recorded prior to civil twilight indicate bats were occupying the cave prior to the emergence period. An analysis of the last Pilbara Leaf-nosed Bat call for each night revealed that for nine of the 12 nights (including the 9-13th July) the last call was past civil twilight (between 10 and 30 minutes) indicating that there was Pilbara Leaf-nosed Bat activity within the main chamber during the daylight period, which in turn confirms occupation of the main chamber by Pilbara Leaf-nosed Bat.

There has been a concerted effort since early 2015 to categorise known roost sites and locate additional roost sites within the North Star mine locality. The approach to locate and categorise these sites has included a combination of desktop and field survey techniques (e.g. preliminary roost habitat assessments and targeted sheeting surveys to confirm occupancy of Pilbara Leaf-nosed Bat within roost sites).

Known diurnal roost sites

At least three known diurnal roost sites occur within the locality (see Figures 2) including:

Cave 13 – Category: *Transitory diurnal roost*. The information reviewed to date suggests Cave 13 is a natural cave occupied for parts of the year by the Pilbara Leaf-nosed Bat; however, it was not occupied during the period of the cave occupancy surveys (February and September 2016) suggesting the Pilbara Leaf-nosed Bat was not using Cave 13 as a maternity roost during the 2015-2016 breeding season. Furthermore, there is no evidence to indicate that the upper chamber or any other part of Cave 13 was used as a maternity roost during the period of the surveys undertaken to date by GHD. A recent review of long-term ultrasonic data by Armstrong (2018) also supports these findings and that this cave is most likely to function as a 'nocturnal refuge' and at times a 'transitory diurnal roost' for Pilbara Leaf-nosed Bat.

Chateau Cave - Category: *Permanent diurnal roost*. The results from the cave occupancy surveys undertaken in February and September 2016 by GHD determined that Pilbara Leaf-nosed Bat were present within the main chamber during the period of the survey. Both records occur within the 9-month breeding cycle of the Pilbara Leaf-nosed Bat (DotEE 2017). Therefore, the natural cave is considered to be important habitat for the Pilbara Leaf-nosed Bat and is probably used as a maternity roost (i.e. a roost used during the gestation-parturition-weaning period). Furthermore, a recent review of long-term ultrasonic data by Armstrong (2018) also suggests that this cave most likely functions as a 'permanent diurnal roost' that has an important role in the breeding cycle for the Pilbara Leaf-nosed Bat.

Joe's Cave – Category: *Transitory diurnal roost*. The results from the cave occupancy surveys undertaken in February and September 2016 determined the Pilbara Leaf-nosed Bat was not present within Joe's Cave during the period of the survey. The information reviewed to date suggests that this natural cave is possibly occupied for parts of the year by the Pilbara Leaf-nosed Bat. However, there is no evidence to indicate that the main chamber has been used as a maternity roost during the period of the surveys. A recent review of long-term ultrasonic data by Armstrong (2018) suggests that this cave is likely to function as a 'permanent diurnal roost' or 'non-permanent breeding roost' for the species, however the long-term monitoring data did not consider the other assessments undertaken of Joe's Cave including the occupancy surveys and habitat assessment. The categorisation of 'transitory diurnal roost' is maintained with consideration of all the information reviewed.

A fourth roost is located approximately 15 - 20 km north-east of Cave 13 in the Abydos Mine Project, Atlas Iron. Four caves were suspected to be used as some type of diurnal roost (not categorised) by the Pilbara Leaf-nosed Bats. The caves were retained and excluded from the development area and buffers were established preventing any works within 50 m of the caves. Atlas Iron established a significant species management plan which included actions to monitor Pilbara Leaf-nosed Bats within the caves.

Other potential roost locations

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

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

Table 5 identifies locations that could provide potential diurnal roosting of some type (including possible permanent diurnal roost, non-permanent breeding roost, or transitory diurnal roosts). Nocturnal refuge roosts have not been included as these locations are unsuitable for roost augmentation. The location of each roost is provided in Figure 3 in *GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat.*

Table 5 Summary of potential roosting locations for Pilbara Leaf-nosed Bat recorded to date (note: known nocturnal refuge roost not included)

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

Location	Site name (map label)	Altitude approx. (m)	Type of roost	Date	Tenement
Joe's Cave/ Zane's Gorge area	Bone Cave	-	Potential roost location unknown type	March 2015 and November 2016	Other
Joe's Cave/ Zane's Gorge area	Vertical cave	-	Potential roost location unknown type	March 2015	Other
Joe's Cave/ Zane's Gorge area	Cliff cave	-	Potential roost location unknown type	March 2015	Other
Joe's Cave/ Zane's Gorge area	RS1	352	Possible transitory diurnal roost	22 June 2017	Other
Joe's Cave/ Zane's Gorge area	RS3	352	Potential roost location unknown type	22 June 2017	Other
Joe's Cave/ Zane's Gorge area	RS4	367	Possible transitory diurnal roost	22 June 2017	Other
North Star MDE or adjacent	Wallaby Cave	340	Potential roost location unknown type	March 2015	FMG
North Star MDE or adjacent	Wayne Manor	313	Potential roost location unknown type	21 February 2015	FMG
South of North Star MDE	Python Cave	364	Potential nocturnal refuge Pilbara Leaf-nosed Bat	February 2016 May 2018	FMG

3.1.2 Desktop review Ghost Bat

The Ghost Bat (family Megadermatidae) ranges from the Pilbara and Kimberley regions of Western Australia, through the Top End and Gulf Fall country of the Northern Territory, to parts of northern Queensland (Churchill 2008; Woinarski et al. 2014). It is endemic to Australia, and the last relict of a diverse radiation in the Miocene rainforests of northern Australia (Hand 1996). Once distributed throughout most of the continent, it declined in the Holocene and further after European settlement, and now exists as a group of geographically and genetically isolated populations across northern Australia (Molnar et al. 1984, Churchill and Helman 1990; Worthington Wilmer et al. 1994, 1999). While it shows some variation in morphology and fur colour across its range (Douglas 1962; Hand and York 1990), it does not contain any recognised subspecies (Simmons 2005).

The Ghost Bat inhabits Pilbara ironstone formations with relatively deep caves and iron ore exploration adits, as well as granite boulder rockpiles and disused underground gold and copper mines in the granite-greenstone terrain of the eastern Pilbara (Armstrong and Anstee 2000). They prefer warm, humid roost microclimates, especially when breeding, because of a limited ability to maintain heat and water balance in drier conditions, and are unable to enter torpor (Leitner and Nelson 1967; Churchill 1991; Armstrong and Anstee 2000; Baudinette et al. 2000). Deeper caves and mines that can support these conditions are relatively uncommon, which limits roosting opportunity, area of occupancy, and results in aggregations in relatively few subterranean structures. It often shares cave and mine roosts with the Pilbara Leaf-nosed Bat, which has similar roosting requirements.

Numerous documented anecdotal and published observations have shown that while the deepest and most warm and humid underground structures support the largest colonies and individuals in breeding condition (i.e. most of the known population and breeding sites), small numbers or individual Ghost Bats are sometimes encountered in smaller caves, with drier or cooler microclimates (Armstrong and Anstee 2000; Woinarski et al. 2014; K.N. Armstrong unpublished observations). However, these probably function as transitory diurnal roosts, nocturnal refuges and/or feeding sites.

In general, they prefer warm, humid roost microclimates (temperatures of 27–28.5 °C and vapour density of 20–24 g m^{-3} was recorded in the Northern Territory; Churchill 1991), because of a limited ability to maintain heat and water balance in cooler conditions, and do not enter torpor to save energy (Leitner and Nelson 1967; Kulzer et al. 1970; Armstrong and Anstee 2000; Baudinette et al. 2000). Physiological studies showed that the Ghost Bat requires roosts that are relatively warm to maintain body temperature, but it is less limited by humidity compared to the Orange Leaf-nosed Bat (Leitner and Nelson 1967; Baudinette et al. 2000). The full range of roost microclimate conditions (temperature, relative humidity) tolerated by both species has not been documented.

A remarkable feature of the Ghost Bat is its carnivorous diet, which comprises small mammals, birds, reptiles, frogs and large insects (Pettigrew et al. 1986; Schulz 1986; Boles 1999). It hunts from perches and captures prey on the ground or in trees, and its prey remains and scat accumulations that can be found towards the entrances of caves and mines provide unambiguous evidence of its presence in an area. It can have a short home range (Pettigrew et al. 1986), but equally, studies of its flight capability show that it is capable of a significant nightly flight range (Bullen and McKenzie 2002).

Another distinctive trait of the Ghost Bat is the relatively high site fidelity of females (Worthington Wilmer et al. 1994, 1999), which results in stable breeding colonies, the tendency of females to stay at the site of their birth, and consequently the low likelihood of short-term female recolonisation should they be dispersed or extirpated from a breeding site. Individual males are often observed in shallower caves and mine adits, and their greater rates of movement promote gene flow within the region.

The roost microclimate requirements for breeding, especially after young are born are unknown, but larger colonies with breeding activity tend to be in deep caves with relatively warm and humid microclimates (Hall et al. 1997; Armstrong 2001). Females give birth to a single young, and most females breed by two years of age (Hoyle et al. 2001). Parturition occurs over a month commencing in mid-October, and young can be shifted to other caves as caves become warmer as summer progresses. Juvenile bats commence flying at seven weeks with all young capable of flight by the end of January (Toop 1985). Generation time is estimated at 8 years (Woinarski et al. 2014).

The population size in the Pilbara has been estimated at around 1000 individuals (Armstrong and Anstee 2000; or more, given new records following that publication), and there is evidence for shrinkage in area of occupancy and an associated reduction in population size with the loss of two major roost sites since the surveys of Hall et al. (1997) and Armstrong and Anstee (2000). The largest colonies (dozens to several hundred individuals in each case) occupy only four disused underground mines in the eastern Pilbara, with numerous smaller colonies occupying caves and adits in the ironstone terrain and other smaller mines and rockpiles in the granite-greenstone terrain.

The paucity of data to date in the survey area and locality is an artefact of the recent listing of this species under the EPBC Act. Prior to 2018, there is very little or no targeted survey effort in the survey area or for much of the locality. Furthermore, the ultrasonic call of the Ghost Bat call is often difficult to record, and survey effort prior to 2018 often focussed on programming bat

detectors to maximise the chance of recording Pilbara Leaf-nosed Bat at the expense of lower frequency calling species including the Ghost Bat. These issues have all contributed to a lack of historical information when compared to the Pilbara Leaf-nosed Bat.

Table 6 summarises the known and potential Ghost Bat roosting locations within the locality to date. The location of each roost is provided in Figure 3 in *GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat.*

Table 6 Summary of known and potential roosting locations recorded to date for Ghost Bat

Location	Site name (map label)	Altitude approx. (m)	Type of roost	Date	Tenement
North Star MDE	Chateau Cave	368	Potential occasional use diurnal roost (passage and second chamber). GB observed hunting out front of cave and inside passage. No confirmed roosting to date.	2016 -	FMG
North Star MDE	Cave 13	350	Potential occasional use diurnal roost	2015 -	FMG
Nicko's Gorge	Nicko's Gorge	250	Multiple potential roost locations	9 January 2015	Other
Blue Square	C8BS	331	Potential roost location unknown type	9 January 2015	Other
Joe's Cave/ Zane's Gorge area	Giant's Cave	-	Potential roost location unknown type	November 2016	Other
Joe's Cave/ Zane's Gorge area	Bone Cave	-	Known Ghost Bat diurnal roost – 1 and 2 Ghost Bat recorded in back chamber, each visit	March 2015 and November 2016	Other
Joe's Cave/ Zane's Gorge area	Vertical cave	-	Potential roost location unknown type	March 2015	Other
Joe's Cave/ Zane's Gorge area	Cliff cave	-	Potential roost location unknown type	March 2015	Other
North Star MDE or adjacent	Wallaby Cave	340	Known Ghost Bat diurnal roost – 4 Ghost Bat recorded	March 2015	FMG
North Star MDE or adjacent	Wayne Manor	313	Potential roost location unknown type	21 February 2015	FMG
South of North Star MDE	Python Cave	364	Known Ghost bat diurnal roost – scat pile displaying historical evidence recorded	February 2016	FMG
Western flank opposite South Pool	Cave 32	380	Known Ghost Bat diurnal roost – 1 Ghost Bat recorded	January 2019	FMG
South Pool	Cave 3 (mapped as 3)	310	Know diurnal roost, highly likely Maternal roost due to large numbers of bats (up to 30) and time of year present (January)	23 January 2019	FMG
Western flank south of cave 32	Cave 33	380	Potential roost location unknown type, feeding evidence and scat present	January 2019	FMG

3.1.3 Field survey results

Ultrasonic surveys

Data from 18 sites for 182 nights was recorded using full spectrum Song Meter detectors (SM2 bat plus and SM4 FS). The location of each ultrasonic detector site is displayed on Figure 3 (Appendix F). One site was lost to the July 2018 fire and the data was not able to be recovered from the recording unit.

Summary of key survey results:

- The number of nights recorded at each site ranged from 3 – 28 nights. At least five species of bat were identified with Common Sheathtail Bat (*Taphazous georgianus*) and Finlaysons Cave Bat (*Vespadelus finlaysoni*) most commonly recorded.
- Pilbara Leaf-nosed Bat was recorded for 68 of the 182 nights and from 13 of the 18 sites. Table 8 provides a summary of the Pilbara Leaf-nosed Bat calls detected at each site for each night of the survey.
- Pilbara Leaf-nosed Bat calls were recorded within 20 mins of civil twilight (+/- 5 mins[2]) for seven nights at five locations (see Figure 3). Two of the records are from the South Star pool detector site. Table 7 provide a summary of the sites with Pilbara Leaf-nosed Bat calls recorded within 20 minutes of civil twilight detections. These records suggest that a diurnal roost(s) may be nearby the survey area (e.g. Chateau Cave) and/or within the survey area, particularly given the number of records following civil twilight for each night. The source of these calls could be from bats roosting within Chateau Cave or Cave 13, located within 2-4 km north of the survey locations. Further surveys are required to test these assumptions, and data should also be compared with local long term monitoring sites (e.g. Chateau Cave and Cave 13).
- No sites reviewed to date recorded high activity levels for Pilbara Leaf-nosed Bat, (based on the number of calls recorded per hour for each night for each site) with most sites recording low activity levels.
- One tentative probable Ghost Bat call was recorded from one site (Site 1, 14/5/18). No other Ghost Bat calls were recorded during the emergence period for any of the nights analysed to date. No other Ghost Bat calls were definitely recorded however this may be a function of the analysis process and it is possible that Ghost Bats were recorded at additional locations during the survey later in the night (e.g. post the emergence period). Therefore, the ultrasonic detector data cannot be used to confirm absence at the site for the night(s) of the survey.

[2] Source of civil twilight times: Australian Government Geosciences - http://www.ga.gov.au/geodesy/astro/sunrise.jsp e.g. 9/5/2018 – sunset = 5:33 PM / civil twilight = 5:56 PM. 9/8/18 – sunset = 5:44 PM / civil twilight = 6:07 PM

Table 7 Summary of emergence calls within 20 minutes of civil twilight (+/- 5 mins)

Site	Date	Civil twilight	Time first bat call / Species	First Pilbara Leaf-nosed Bat call	Comment
5	9/05/2018	5:59 PM	5:57 PM *V. finlaysoni*	6:23 PM	Few calls within 20 minutes of Civil Twilight (CT), low activity, few Pilbara Leaf-nosed Bat calls for the night
7	24/06/2018	5:55 PM	6:09 PM *V. finlaysoni*	6:23 PM	Few calls within 20 minutes of CT, low activity, few Pilbara Leaf-nosed Bat calls for the night
7	26/06/2018	5:56 PM	5:54 PM *V. finlaysoni*	6:20 PM	Few calls within 20 minutes of CT, low activity, few Pilbara Leaf-nosed Bat calls for the night
10 - South Star Pool	6/07/2018	5:56 PM	5:52 PM *V. finlaysoni*	6:08 PM	Pilbara Leaf-nosed Bat calls from 6:08 pm – 6:38 pm. Moderate activity throughout night.
10 - South Star Pool	7/07/2018	5:57 PM	5:50 PM *V. finlaysoni*	6:09 PM	Pilbara Leaf-nosed Bat calls from 6:09 pm – 6:25 pm. Moderate activity throughout night.
11	8/07/2018	5:57 PM	6:05 PM *V. finlaysoni*	6:10 PM	Few calls within 20 minutes of CT, low activity, few Pilbara Leaf-nosed Bat calls for the night
13	7/07/2018	5:57 PM	5:57 PM *V. finlaysoni*	6:18 PM	Few calls within 20 minutes of CT, low activity, few Pilbara Leaf-nosed Bat calls for the night

Source of civil twilight times: Australian Government Geosciences - http://www.ga.gov.au/geodesy/astro/sunrise.jsp

Table 8 Summary of detections for each site for each day of the ultrasonic surveys for Pilbara leaf-nosed Bat

Site	Site	Month/Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Comments and limitations
1	Dry creek/ rocky gully	May 2018																																All data reviewed
2	Dry waterfall rocky/outcrop	May 2018													L							L												All data reviewed
3	Dry creek/ rocky gully	May 2018										L				L	L	L	L	L	L	L	L	L										All data reviewed
4	Rocky gorge, west face	May 2018											L	L	L	L		L	L															All data reviewed
5	Dry elevated creek/gully	May 2018									L*			L		L																		All data reviewed
6	Rocky hills	June 2018																																All data reviewed
6	Rocky hills	July 2018	L																															All data reviewed
7	Dry rocky gully	June 2018								L	L	L			L		L	L	L	L	L	L		L	L	L*	L	L*	L	L				All data reviewed
8	Rocky gorge above pool	July 2018																																Reviewed from first call for 1.5 hours
9	Open gorge/ drop off	July 2018																																Reviewed from first call for 1.5 hours
10	Over South Star Pool	July 2018						M*	M*	L									L					L										Reviewed from first call for 1.5 hours
11	Gully end at ridge face	July 2018								L*																								Reviewed from first call for 1.5 hours
12	Gully end west ridge face	July 2018						L				L			L																			Reviewed from first call for 1.5 hours (8 of 34 nights)
13	Gully east flank of ridge	July 2018							L*			L		L	L																			Reviewed from first call for 1.5 hours (8 of 34 nights)
14	Python Cave	Jan 2019																						L	L	L	L	L	L	L	L		L	All data reviewed Note: Minimum frequency set high and may miss Ghost Bat calls
14	Python Cave	Feb 2019	L																															As above
15	Gully east flank of ridge	Jan 2019																						-	-	-	-	-	-					Reviewed from first call for 1.5 hours Note: maximum frequency set to 95 kHz hence PLNB calls excluded
16	Over South Star Pool	Jan 2019																								L	L	L	L					Reviewed from first call for 1.5 hours Note: maximum frequency set to 125 kHz hence some PLNB calls excluded
17	Seep in gully	Jan 2019																										L	L					Reviewed from first call for 1.5 hours
18	Gully, large overhangs	Jan 2019																								L								Reviewed from first call for 1.5 hours

Key to table 4

	grey square indicates absence of Pilbara Leaf-nosed Bat or extremely low detection rates within limitations (See Appendix A)
L	blue square indicates detection of Pilbara Leaf-nosed Bat with low activity (e.g. 1 or 2 calls per hour, less than 50 calls per night) throughout the night
M	green square indicates detection of Pilbara Leaf-nosed Bat with moderate activity (e.g. > 2 calls per hour, > 50 calls per night) throughout the night
*	indicates detection of Pilbara Leaf-nosed Bat within 20 minutes of civil twilight (+/- 5 mins)

Cave sheeting

Chateau Cave Sheeting 21/01/2019 survey observation notes

The team arrived on site at approximately 6:15 pm. The weather was calm, hot and overcast. The following observations were recorded:

- SM4 unit turned on at 6.24 pm and in place in the main chamber behind the sheet 6:30 pm.
- Common Sheathtail Bat (*Taphazous georgianus*) and Finlaysons Cave Bat (*Vespadelus finlaysoni*) both active and flying within the second chamber and the entrance.
- First bat activity after sheet was placed at entrance of main chamber at 7:06 pm – two Common Sheathtail Bat flying outside into the cave entrance and then out.
- 2 x Ghost Bat (*Macroderma gigas)* recorded flying outside at 7.20 pm, both flew into cave entrance and out and disappeared south down the western flank of the ridge.
- 1 x Ghost Bat flying near entrance at 7.31 pm with audible social calls (screeching)
- 1 x Ghost Bat flying near entrance at 7.38 pm with audible social calls (screeching)
- 7.56 pm 1 x Common Sheathtail Bat broke through sheet and exited cave, and 1 other smaller unidentified bat. Whilst fixing sheet several bats were noted flying in the main chamber.
- 8.08 pm at least 2 x Pilbara Leaf-nosed Bats observed flying around cave entrance.
- 8.10 pm Ghost Bats flying and screeching, and a number of smaller bats, most likely Finlaysons Cave Bat close to cave entrance.
- 8.12 pm 1 x Pilbara Leaf-nosed Bat flew into cave entrance.
- Sheeting complete at approximately 8.20 pm.

A review of the detector data post survey was undertaken. Data from the SM4 was reviewed as summarised in Table 9. In additional data from the long term monitoring detector (SM2) inside the main chamber was reviewed for the 20, 21 and 22 January 2019.

Table 9. Review of songmeter detector data from sheeting surveys 21/01/2019

Attribute	SM2	SM4	Comments
Microphone location	Inside main chamber on bracket at 15 cm from floor	Inside main chamber off floor on rock	Location of the SM4 microphone may have influenced the call detection ability and therefore number of calls recorded
Effort/timing	Start 5:04 pm – all night	Start 6:24 pm End 8:20 pm	SM2 start at 5 pm each night and end at 7 am each morning
First bat call	21/1/19 5:22 pm – Common Sheathtail Bat	6:27 pm – Common Sheathtail Bat	-
First PLNB call	20/1/19 – 7:40 pm 21/1/19 - 7:43 pm 22/1/19 – 7:43 pm	8:10 pm	Timing of first calls from the SM2 is consistent (+/- 3 mins) for each of the dates. The call data suggests PLNB was roosting within Chateau Cave
Number of PLNB calls for sheeting survey (end at 8:20 pm)	20/1/19 – last PLNB call at 04:46 am 21/1/19 - 4 calls (sheeting survey). Approx 303 calls	1	21/1/19 - Few calls recorded by SM2 during survey, however a small peak in calls occurred from 8:36 pm. A brief review of the SM2 data revealed call activity generally consistent across the three nights, with

	for night, last call at 04:37 am 22/1/19 – last PLNB call at 04:59 am		a peak in activity during the middle of the night and small peaks early in the evening and late in the morning.
Other species recorded	Finlaysons Cave Bat	Finlaysons Cave Bat	-

Civil twilight for the 20-22/1/19 approx 7:12 pm - Source of civil twilight times: Australian Government Geosciences - http://www.ga.gov.au/geodesy/astro/sunrise.jsp

There are three possible explanations for the Pilbara Leaf-nosed Bats observed flying in the entrance at 8:08 pm and 8:12 pm during the sheeting survey: 1 – the individuals may have escaped though the gap before it was fixed, 2 – alternatively, one or more PLNB were roosting in the second chamber of Chateau Cave and emerged during the survey, 3 – alternatively the individuals were from another roost site (e.g. Cave 13 or an unknown roost site in the locality). Given the timing of the observations and following a review of the detector data from behind the sheet in the main chamber at this time all three options are plausible and require further investigation.

The lack of call data during the sheeting survey period may be attributed to the presence of the barrier, which in turn may have delayed the emergence of the Pilbara Leaf-nosed Bat and/or there were few Pilbara Leaf-nosed Bat roosting within the main chamber during the survey.

Cave 1 - 23/01/2019 survey observation notes

Note: Cave 1 was not sheeted however a detector was placed in front chamber of cave. A review of the detector data post survey revealed the following:

- First bat call recorded at 6:07 pm (Common Sheath tail Bat)
- Both Common Sheathtail Bat and Finalysons Cave Bat were recorded from the inside the cave during the sheeting survey. No other bat species recorded.

Cave 3 - Sheeting 23/01/2019 survey observation notes

On approach to the cave (approximately 5:30 pm), approximately 13 Ghost Bats exited and disappeared over the waterfall and south along the rocky ridgeline. The following observations were noted:

- The cave was sheeted and detector placed inside at 6:00 pm.
- Social bat calls probably Common Sheathtail and Ghost Bat could be heard inside the cave.
- Several Ghost bats attempted to exit at 6.56 pm.
- Between 7:02 and 7:24 pm 13 x Ghost bat flew into the sheet and were able to exit the cave
- Between 7:25 and 7:40 pm 9 x Ghost bats broke through the sheet and exited the cave
- At approximately 7:40 pm at least four more Ghost Bats were heard and observed behind the sheet and remained inside the cave for the duration of the sheeting.
- Sheeting finished at 8:00 pm.

A review of the detector data post survey revealed the following:

- First bat call recorded at 6:01 pm (Common Sheathtail Bat)
- First Ghost Bat call at 6:28 pm. Many probable Ghost Bat calls recorded during sheeting survey, with a peak in call activity between 6:28 pm and 7:53 pm, however calls consisted of a mixture of stress/social (e.g. chirp/twitter calls as described by Specialised Zoological (2017)) and lower frequency echolocation calls but were not typical of free-flying Ghost Bat calls. Some calls were also tentatively attributed to the Common Sheathtail Bat.

An Infrared (IR) Monocular was used to monitor bat movements during the cave sheeting survey. The IR monocular was placed facing the top cave from the waterfall and was in-situ from civil twilight for the duration of battery life (about 25 minutes). The second observer was based below the cave entrance and visually monitored the cave for activity for the duration of the assessment period and bats recorded if exited. Table 9 below provides a summary of the observed bat activity in the vicinity of South Star Pool during the cave sheeting survey.

Table 10 Summary of observed bat activity near Cave 3 23/01/2019

Location	Common Sheathtail Bat	Small bats most likely Finlaysons Cave Bat	Ghost Bat
Cave 1	3	7	-
Cave 2	10	13	-
Cave 3 (sheeting survey)	2	-	26 to 30
Top Cave	-	-	-

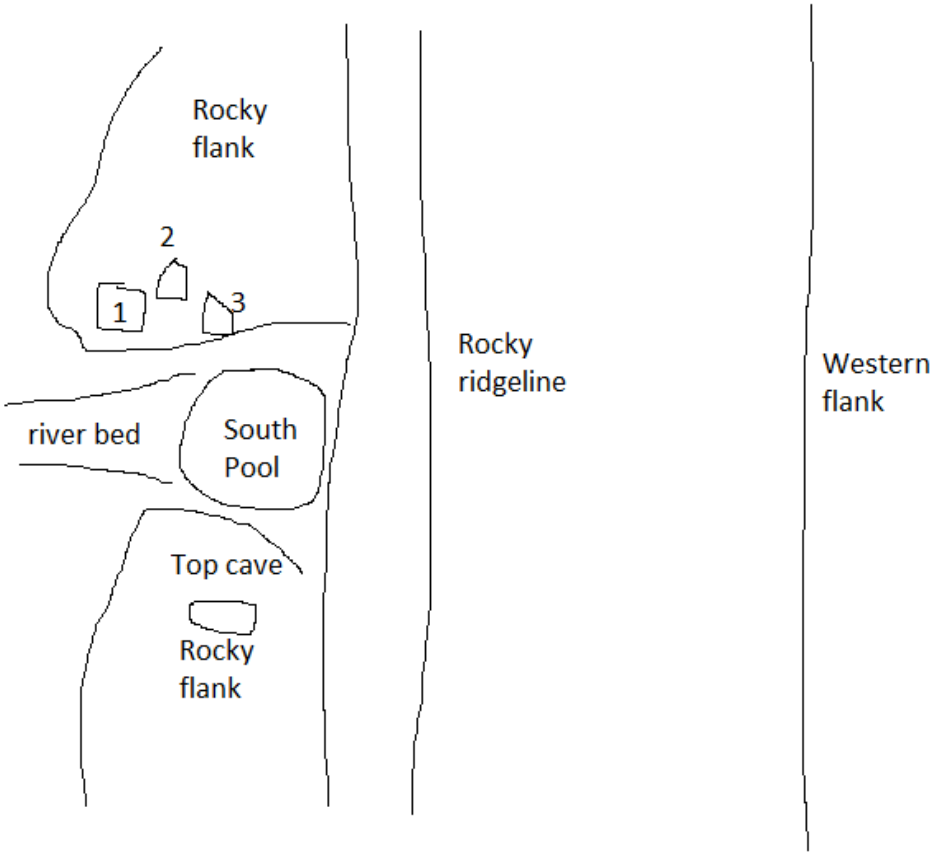

Plate 1 Sketch of Cave 1,2,3 and Top Cave with regard to South Star Pool

Habitat assessment

GHD investigated more than 43 locations (e.g. slopes, gorges and near the top of ridges and plateaus) on foot and/or by helicopter when undertaking searches for potential diurnal roost

habitat. As a result of the cave habitat searches 33 sites were recorded with known or potential diurnal roosting habitat for Pilbara Leaf-nosed Bat and/or Ghost Bat. Figure 7a displays each of the 33 sites described in Table 10.

Summary of key survey results regarding roosting habitat:

- Twenty-six (26) of the 33 sites investigated are located in the GVMDE.
- Eight (8) of the 33 sites investigated were confirmed as diurnal roosting and foraging habitat for the Ghost Bat (Cave numbers 1, 2, 3, 11, 14, 28, 30 and 32). Of the eight caves, three were of particular importance (e.g. evidence for ongoing use and use during the maternity period):
  - Cave number 30 (labelled Cave 3 located north side of South Pool – see Plate 1) is a confirmed diurnal roost for a large number of Ghost Bat (Cave 3, 26-30 Ghost Bats). This cave is most likely a maternity roost considering the number of Ghost Bats recorded and the timing of the surveys (January).
  - Cave number 1 (Python Cave) – is a historical Ghost Bat roost. Additional evidence was recorded during the current survey to suggest that the cave could be used during part of the breeding cycle for the Ghost Bat, however further investigations are required to confirm this finding.
  - Cave number 32 – confirmed diurnal roost as one Ghost Bat flushed from roost during survey.
- At least six of the 33 sites in addition to the eight confirmed sites were determined to provide potential occasional use diurnal roosting and foraging habitat for the Ghost Bat.
- At least 13 of the 33 sites (all within the GVMDE) were determined to provide potential nocturnal refuge for the Pilbara Leaf-nosed Bat, with two of these sites also providing potential temporary diurnal roosting habitat.

The potential distribution of roosting habitat including diurnal and breeding roost habitat for both the Ghost Bat and Pilbara Leaf-nosed Bat is also displayed on Figure 7a (collectively labelled as potential roost habitat). There is approximately 634 ha of collective potential roosting habitat mapped for the survey area for both species of which approximately 415 ha occurs within the GVMDE. It is important to note that this data layer is a combination of the desktop assessment process and the field surveys undertaken to date. There are some areas within the GVMDE and survey area that have not been investigated to date or are inaccessible, therefore the precautionary approach applies and it has been assumed that additional areas may have potential for diurnal roosting habitat. Further surveys are required to refine the diurnal roost and breeding habitats required for both species.

Table 11 Summary of searches for cave habitat (all surveys combined)

Number (Figure 7a) and location	Cave name and type	Position and elevation (m)	Entrance description	Floor as viewed from entrance	Internal characteristics as viewed from entrance	Bat species/ evidence
1 - GVMDE	Python Cave - Confirmed diurnal roost and foraging for Ghost Bat. Potential breeding/maternity roost for Ghost Bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	South side of gully. 364 m	2 x entrance. Large entrance triangle shape, shallow directly into the main chamber and 2nd small entrance tunnel shape at 1 to 2 m deep located up slope above 1st entrance. 1 at 80 - 150 cm and 2 at 50 - 70 cm. Aspect west and north west. Entrance position - 1 large entrance located near base of watercourse at ground level, 1 small entrance above first entrance. Entrance condition - stable	Front main chamber sloping up to back of cave. Condition - large and small rocks from ceiling, dusty floor, 2 plus cm deep some spots	1 large main chamber 8-9 m deep 5-7 m high with small ceiling chutes plus 2 that are 2-3 m plus deep (could not see back of chutes)	*Taphozous georgianus* x 30 plus, *Vespadelus finlaysoni* x 6. *Taphozous georgianus* at two locations - upper ceiling and front of small chute, *Vespadelus finlaysoni* located midway up back wall. Scats - old and recent small scats, few old scattered ghost bat scat. No recent ghost bat scat piles recorded
2 - GVMDE	Confirmed temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	South side of gully. 354 m	1 entrance. Round. 100 - 110 cm. Aspect north facing. Entrance position - Ground level, at watercourse. Entrance condition - stable	Flat and narrow then drops to sub chamber with a flat narrow floor. Condition both chambers dusty, small rocks, sub chamber contains small pool water at front	Small pool with water sub floor	22 *Taphozous georgianus* toward front ceiling of sub chamber. Scat - lots old new scats, recent ghost bat scat
3 - GVMDE	Confirmed temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	South side near end of gully. 344 m	1 entrance, very large. Square at 4 x 3 m. Aspect north west facing. Entrance position - up slope, near top small rise. Entrance condition - stable	Slight slope upwards toward back of cave. Condition - lots large fallen rocks and few boulders, dusty	Very large main chamber at 8-10 m deep and 6 plus m high ceiling, 3-4 m wide. Large and open	150 plus *Taphozous georgianus*, majority located in sub chamber above entrance and scattered on ceiling and upper walls in cave. Scat - lots both fresh and old deposits. Occasional old scattered ghost bat scat
4 - GVMDE	Potential cave habitat area - not inspected		Viewed from helicopter or not accessible during survey			
5 - GVMDE	Potential cave habitat area - not inspected		Viewed from helicopter or not accessible during survey			
6 - GVMDE	Potential cave habitat area - not inspected		Aspect south east facing, At least 3 large openings high up slope. May not be accessible			
7 - GVMDE	Potential cave habitat area - not inspected		Aspect east facing, Several large openings high up eastern facing steep slope. May not be accessible			

Number (Figure 7a) and location	Cave name and type	Position and elevation (m)	Entrance description	Floor as viewed from entrance	Internal characteristics as viewed from entrance	Bat species/ evidence
8 - GVMDE	Potential cave habitat area - not inspected		Top of gully, above dense vegetation. May not be accessible			
9 – survey area	Potential cave habitat area - not inspected		Aspect south facing, At least one opening. May not be accessible			
10 - GVMDE	Potential cave habitat area - not inspected		Viewed from helicopter or not accessible during survey			
11 - GVMDE	Confirmed temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	North side of rocky gorge base of dry waterfall. 346 m	1 large entrance. Short but wide and open at 1 to 2 m. Aspect south facing. Entrance position - Ground level, low just above creek. Entrance condition - unstable fallen rocks, located in geology with columns	Gentle slope. Condition - lots rocky debris large rocks from ceiling, mostly dusty	Large chamber at rear. 1 to 1.5 m high 0. 8 m deep and wide	30 plus *Taphozous georgianus*. Scat - Old Ghost bat scat at entrance. Lots of old and fresh other bat scat
12 - GVMDE	Potential cave habitat - Potential temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge and temporary diurnal roost for Pilbara Leaf-nosed Bat	North side of wide gully up slope. 327 m	1 entrance. Rectangle at 1 to 1.5 m. Aspect south west facing. Entrance position - Ground level although up slope. Condition - unstable fallen rocks	Gentle slope. Condition - lots rocky debris large rocks from ceiling, mostly dusty	2 x sub chambers at rear, small plus very high dome ceiling near front chamber opening. One of 4 caves at least 1 other potential ghost bat	40 plus *Taphozous georgianus* located ceiling chamber and one rear chamber. Scat - lots of scat on rocks and over floor new and old deposits, no ghost bat visible
13 - GVMDE	Potential cave habitat area - not inspected		Viewed from helicopter or not accessible during survey			
14 - GVMDE	Confirmed temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	North side of dry gully. 410 m	2 x entrance. 1 large wide and low, other very low less than 1 m and wide. 1 to 2 m and less 1 m. Aspect west and south west. Entrance position - Ground level although up slope. Entrance condition - stable	Flat. Condition - lots small rock , scattered rock and very dusty	Deep and wide cave with low ceilings, may have small dome in ceiling near junction	2 x *Vespadelus finlaysoni*. Scat - moderate scat coverage including new and old, 1 x old ghost bat scat
15 - GVMDE	Potential cave habitat area - not inspected		Viewed from helicopter or not accessible during survey			

Number (Figure 7a) and location	Cave name and type	Position and elevation (m)	Entrance description	Floor as viewed from entrance	Internal characteristics as viewed from entrance	Bat species/ evidence
16 – GVMDE	Potential cave habitat - Potential temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal and temporary diurnal roosting for Pilbara Leaf-nosed Bat	Top of BIFF. 379 m	North side of gully. Square. 1 to 1.5 m. Aspect south. Entrance condition - stable	Flat. Condition - irregular small rises	Small passage 2 m from cliff to chamber at 1 m h x 8 m wide x 6 m deep oval shape, with possible ceiling chutes and 2 rear sub chambers both small, cave ceiling at 0.8 m to 1 m	5 plus *Taphozous georgianus*. Scat - moderate floor cover. No ghost bat scat
17 - GVMDE	Potential cave habitat - Potential temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal roosting for Pilbara Leaf-nosed Bat	South side gully at base near permanent pool	2 x entrance. Tall narrow rectangle at 60 dg angle, slot like entrance shape x 2 connected. 1.5 to 2 m, 0.7 to 1 m w. Aspect north. Entrance position - low at ground. Entrance condition - stable	Flat to sloping v narrow. Condition - some rocks, dusty	Chambers x 2 at 4 to 6 m h, 6 to 8 m deep, 1 to 2 m wide	40 plus *Taphozous georgianus*. Cave floor covered
18, 19, 20, 26 and 27 (survey area) 21, 22, 23, 24, 25 (GVMDE)	Potential cave habitat area - not inspected		Viewed from helicopter or not accessible during survey			
28 - GVMDE	Cave 1 - South Pool, north side - Confirmed temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge and diurnal roosting for Pilbara Leaf-nosed Bat	South facing midway in ridgeline at 320 m	One of three caves together. Western most entrance. South facing	Rocky, rugged with boulders and soil on a 45 degree floor angle.	Large main chamber approx 10 m deep to small opening in back wall which opens into a second chamber, at least 6 m deep. This chamber has at least three sub entrance along the rocky flank.	Numerous Ghost Bat droppings and feathers at entrance. South facing. January 2019 - *Taphozous georgianus* present. Feeding evidence of Ghost bats including scat and Diamond Dove feathers. Not sheeted however a detector was placed at its back chamber.

Number (Figure 7a) and location	Cave name and type	Position and elevation (m)	Entrance description	Floor as viewed from entrance	Internal characteristics as viewed from entrance	Bat species/ evidence
29 - GVMDE	Cave 2 - South Pool, north side - Potential temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge and diurnal roosting for Pilbara Leaf-nosed Bat	South facing midway in ridgeline at 320 m	Second cave in rock face, south facing	Rocky and flat/ horizontal. Large amounts of microbat scat present at least 3 inches deep. Skeletons (animal) present in the cave at around 7 m.	Main chamber approx 7 m deep and 1.5 m high, enters into a second chamber going back at least another 7 m. Could not see end.	*Taphozous georgianus* heard calling. Second cave in rock face, entrance has deep piles of microbat scat. Best seen, south facing.
30 - GVMDE	Cave 3 - South Pool, north side - Known diurnal roost and feeding roost for Ghost bat. Highly likely a maternity cave	South facing at bottom of ridgeline above pool at 310 m	Third cave in rock face, long and narrow, south facing	Rocky and flat/horizontal with numerous scats (micro bats present)	Main chamber consists of a long narrow chamber of about 15 m by 1.2 m and regressing. Possibly opens up into deeper cavern as Taphozous georgianus disappear further into cave.	Third cave in rock face, long and narrow, *Taphozous georgianus* present, south facing. Observation and sheeting survey of the cave in January 2019 presented up to 30 Ghost Bats present/observed.
31 - GVMDE	Top cave - South Pool, south side - Potential temporary diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	North facing top in ridgeline at 330 m	Caves along eastern facing ridgeline. Large but inaccessible due to rock face		One large chamber in softer rock structure. Appears quite crumbly and unstable. Main chamber 2 m wide and elevates and extends into rock face. A chamber looks to extend of roof.	*Taphozous georgianus* present and heard calling in cave
32 - GVMDE	Western Flank - Confirmed diurnal roost and feeding roost for Ghost bat. Potential nocturnal refuge for Pilbara Leaf-nosed Bat	West facing in top if ridgeline at 380 m	Series of caves as faults along western flank in gorge.	Undulation with rock and soil present. Lots of areal fig roots and seeps with small pools of water	Large fault in roof cave in overhang.	Ghost bat flushed from a large fault into a roof cave in overhang. Many *Taphozous georgianus* present in numerous spots

Number (Figure 7a) and location	Cave name and type	Position and elevation (m)	Entrance description	Floor as viewed from entrance	Internal characteristics as viewed from entrance	Bat species/ evidence
33 - GVMDE	Western Flank - Potential temporary diurnal roost and feeding roost for Ghost bat (just south of 32).	West facing in top if ridgeline at 380 m	A large over hang with numerous small caves and faults into the rear wall. Undulation with rock and soil present.	Undulation with rock and soil present. Lots of litter just at entrance	A large over hang with small caves a fault in rear wall	Ghost bat feeding evidence in overhang entrance. Many *Taphozous georgianus* present in numerous spots

The distribution of records collected to date for the Ghost Bat and Pilbara Leaf-nosed Bat and information regarding the habitats and movements of both species in the nearby North Star area, was used to assist with the extent of foraging habitat within the survey area including the GVMDE. Using this information and recently published information regarding the foraging behaviour of the Ghost Bat (Augusteyn et al 2017) it can be confidently assumed that the entirety of the GVMDE and the majority of the survey area is used as foraging habitat by both the Ghost Bat and Pilbara Leaf-nosed Bat.

The type and quality of foraging habitat surrounding known and potential roost sites can be critical to the survival of the Pilbara Leaf-nosed Bat (TSSC 2016a) and the Ghost Bat (TSSC 2016b). A colony for either species requires access to suitable foraging habitat within its nightly flight range (TSSC 2016a,b), Larger colonies of the Pilbara Leaf-nosed Bat might require access to greater proportion of the landscape and maternity colonies for the Pilbara Leaf-nosed Bat might require access to high quality habitats within a smaller nightly flight range (TSSC 2016a).

Given the lack of understanding around which habitats are required to sustain a roosting colony of Pilbara Leaf-nosed Bat it is difficult to define critical foraging habitat for the species (TSSC 2016a). However, based on the observations of where Pilbara Leaf-nosed Bat are most often encountered and the assumption that the condition of these areas is suitable for sustaining nearby colonies the TSSC 2016a have prioritised the types of foraging habitat for the species. Table 11 summarises the foraging habitat within the GVMDE and the survey area according to the categories in the *Conservation Advice Statement for the Rhinonicteris aurantia (Pilbara form)* (TSSC 2016a).

Unlike the Pilbara Leaf-nosed Bat the foraging habitats of the Ghost Bat are not categorised. The TSSC 2016b conservation advice for the Ghost Bat lists conservation and management actions for the species. Two of the actions include protection of land with significant colonies (high priority) and protection of roost sites and surrounding foraging areas from disturbance (medium priority). Given the overlapping habitat requirements and the presence of a known maternity roost within the survey area for the Ghost Bat, the entirety of the habitat in the GVMDE and at least within a 5 km radius (TSSC 2016b) of the maternity roost site (Cave number 30 Table 9, Figure 7a) should be regarded as high priority for the Ghost Bat. The TSSC 2016(b) states that modification to foraging habitat is a threatening factor.

Table 12 Pilbara Leaf-nosed bat foraging habitats (refer to Figure 7b)

Habitat category (see TSSC 2016a)	GVMDE (ha)	Survey area (ha) (including GVMDE)	Comments
Gorges with pools (Priority 1) – watercourses through upland areas bounded by sheer rock walls for parts, often containing pools that remain for weeks or months, sites of relatively large biomass production, sometimes with caves	6.23 – including up to 4 pools mapped in Figure 7b	99.12 -including all pools mapped in Figure 7b	Portions of this area include potential roosting habitat for both species
Gullies (Priority 2) – primary drainage with limited riparian development in upland rocky habitats, sometimes with pools that may last for weeks, with less biomass production that P1 habitat	814.74	1072.39	Portions of this area include potential roosting habitat for both species
Rocky outcrop (Priority 3) – areas of exposed rock at top of rocky outcrops and mesa hills that contain caves and overhangs, and boulder piles in the granite terrains	157.31	1859.59	Portions of this area include potential roosting habitat for both species
Major Watercourses (Priority 4) and Open Grassland and woodland (Priority 5). P4 – riparian vegetation on flat land plus main gravelly or sand channel of the river bed, sometimes containing pools that persist for weeks/months and generally support a higher biomass than the surrounding habitat. P5 – dominated by *Triodia,* on lowland plains colluvial slopes and hilltops.	275.61	1877.68	Priority 4 and 5 habitats are not displayed in Figure 7b, but it is assumed that they form the majority of the remaining unmapped habitat areas
Total area (ha)	**1254.89**	**4908.78**	-

3.2 Pilbara Olive Python

3.2.1 Desktop review

This section provides a summary of the biology of the Pilbara Olive Python (*Liasis olivaceus barroni*). The majority of the information used to develop the summary was extracted from current literature including the Pilbara Olive Python SPRAT profile from DotEE (2018). The information provides background context to the discussion of the key outcomes resulting from the recent surveys for the survey area. Figure 2b Appendix F displays the local database records for the species.

Summary

The Pilbara Olive Python is currently listed as Vulnerable under both the EPBC Act and BC Act. There is little ecological data on the Pilbara Olive Python with no long term research undertaken.

The Pilbara Olive Python's range is restricted to the Pilbara region, north Western Australia, and the Dampier Archipelago (Pearson 2007, DotEE 2018). The species is considered a large snake with maximum recorded length of 3.97 m and weighing 13 kg (Pearson 2007), however most specimens encountered average 2.5 m in length (Cogger 2000). Colouration is typically olive with a pale underside however individuals can vary from olive to olive brown, brown and rich red brown with either a white or buff underside (Pearson 2007).

Their diet consists of mammals (including rodents, fruit bats, kangaroos and wallabies), birds, reptiles and frogs and prey items are likely selected based on the individual's size.

The species breeding season occurs from June to August, after males moving long distances in the warmer months in search of breeding females (Pearson 2007, Wilson and Swan 2010). The species is less active over the winter months. Female lay eggs around October and which hatch from late December to January with breeding events only occurring once every 4-5 years (Pearson 2007). Juveniles measure around 840 mm total length and weigh approximately 55 g (Pearson 2007).

Sex	J	F	M	A	M	J	J	A	S	O	N	D
Male												
Female												

Orange Shade = Period in which breeding is most likely to commence

Yellow Shade = Period in which incubation could extend to

Black Shade = Period in which species is active

Habitat consists of rocky escarpments, gorges and waterholes, granophyre rock piles, spinifex grasslands and caves (Pearson 1993; 2003). The species will also utilise manmade areas such as road overburden stockpiles, railway bunds, sewerage treatment ponds and recreational lakes (Pearson 2003, 2007).

3.2.2 Field survey

All eight records (see Figure 6 Appendix F) from the current surveys were from drainage lines and major watercourses that supported semi-permanent, seasonal and permanent pools. The rocky ridgeline habitats, pools (of all types) and drainage lines (and associated riparian vegetation) in the area around and within the survey area are core habitat for this species. However, the lack of targeted survey effort for this species, including nocturnal searches during the active period for the species (e.g. night time) prohibited the accurate habitat mapping across the entire survey area. It should therefore be assumed that the amount (1223 ha) and distribution of habitat within the GVMDE (see Figure 9 Appendix F) probably underestimates the overall area of habit used by this species within the GVMDE and larger survey area.

3.3 Northern Quoll

3.3.1 Desktop review

This section provides a summary of the biology of the Northern Quoll (*Dasyurus hallicatus*). The majority of the information used to develop the summary was extracted from current literature including the Northern Quoll SPRAT profile from DotEE (2018) and the current Northern Quoll Recovery Plan 2010 (Hill and Ward 2010). The information provides background context to the discussion of the key outcomes resulting from the recent surveys for the survey area. Figure 2b displays the local database records for the species.

Summary

The Northern Quoll is a small omnivorous mammal with distinctive white spots on a dark brown body with a long thinly furred tail (DotEE 2018). The species is currently listed as Endangered under both the Commonwealth EPBC Act and the Western Australian BC Act.

The species is predominately nocturnal and solitary. Northern Quolls are sexually dimorphic, with males being larger (up to 370 mm head-body/345 mm tail/1120 g weight) than females (up to 310 mm head-body/300 mm tail/690 g weight) based on specimen weights in the wet tropics (Menkhorst and Knight 2001, Oakwood 2008). Pilbara specimens have been captured up to 1800 g for males (G. Gaikhorst pers. comm.).

The Northern Quoll has experienced range restrictions throughout it's distribution and now exists in several geographically disjunct populations spread across the northern parts of Australia. Populations include far North Queensland, the Northern Territory, Kimberley region and the Pilbara region in Western Australia (CoA 2016, Hill and Ward 2010). Northern Quolls are present on many islands throughout their range (CoA 2016). The population of Northern Quolls in the Pilbara Region of Western Australia are considered isolated from other populations. Importantly the Pilbara Quolls are not yet suffering from the precipitous decline facing the species in other regions; this decline is, at least in part, attributed to the toxic Cane Toad (*Bufo marinus*) (Hill and Ward 2010).

The species occurs in rainforests, woodlands, grasslands, deserts and forests habitat and is commonly associated with rocky escarpments and complex terrain around drainage lines and rivers. Rocky, complex terrain is considered prime habitat and has shown higher population density and longer lived individuals (CoA 2016, Burnett 1997; Oakwood 2000). Northern Quolls can be arboreal or terrestrial adapting to utilise a range of micro-habitat types for foraging and den sites including tree hollows, logs, caves, crevices, Goanna burrows and house roofs (Hill and Ward 2010). The CoA 2016 identifies critical habitat in the Pilbara for the Northern Quoll as "rocky habitats such as ranges, escarpments, mesas, gorges, breakaways, boulder fields, major drainage lines or treed creek lines and structurally diverse woodland or forest areas containing large diameter trees, termite mounds or hollow logs". It also acknowledges that any habitat within 1 km of critical habitat be regarded as dispersal and foraging habitat (CoA 2016).

The home range of a male Northern Quoll can expand to over 100 ha in the breeding season as the males roam between female home range areas, often overlapping with other male Quoll home ranges. Females have a much smaller home range of 35 ha that can overlap with other females (Oakwood 2002).

The species breeds annually and mates generally over a three to four week period during Late May/June and July, although in the Pilbara mating is spread over a longer period between June and September. Young are typically born during the "dry" (June - Sept) and attain independence by the early wet (November) (Oakwood 2008, Menkhorst and Knight 2001). The overall breeding season is from May to November. After a gestation period of 21 to 26 days, females give birth to an average of seven young (from a maximum of eight).

The young are carried in the pouch for eight to nine weeks and then deposited in dens where the mother returns regularly to allow the young to suckle. The young begin to eat insects by 4 months of age and are weaned and fully independent by 6 months of age. Only two or three young survive to independence. Northern Quolls are sexually mature at 11 months of age, the males rarely live beyond the first breeding season and females usually only live for 2 years in the wild (Oakwood 2000).

J	F	M	A	M	J	J	A	S	O	N	D

Black Shade = Period in which breeding is most likely to commence

Orange Shade = Period in which weening could extend to

Northern Quoll have a variable omnivorous diet consisting vertebrates (small mammals, birds, reptiles and frogs) as well as arthropods, molluscs, fruit, and carrion (Dunlop et al 2017). Invertebrates comprise the most utilised food group (Dunlop et al 2017) in the Pilbara. The species is known to forage widely over several kilometres, particularly on spinifex plains adjacent to rocky refuge habitat.

3.3.2 Field survey

Twenty two sites of between five and ten cameras (115 cameras in total) at each site were deployed for between 24 to 54 nights over the survey period (see Appendix B and Figure 5 Appendix F). In total 3760 camera nights were recorded and analysed. Of the 115 cameras deployed 64 had observations of Northern Quoll with at least one record of a Northern Quoll from all bar one site (21 sites). The Northern Quoll data is summarised in Appendix E and Figure 5 Appendix F. Hits on cameras varied from 1 to 18. Based on the data collected from camera and anecdotal data recorded during field investigation Northern Quoll were recorded in all habitat types. Core habitat mapping (DotE 2016) was undertaken (see Appendix F, Figure 8). Given the distribution and frequency of the camera records and other observations within the survey area, the Northern Quoll is likely to occupy (including breeding) and hunt within the entirety of the MDE (1346 ha) and of the GVMDE (4,815 ha), however according to DotE 2016 the core habitat areas of the GVMDE is 1637 ha (see Appendix F, Figure 8). However this is likely an under represented figure due to access issue with in the GVMDE area.

3.4 Additional species records

During each of the surveys anecdotal records of all species identified were recorded. Numerous additional species were recorded on cameras and via bat detectors. In total 122 species were recorded during the field investigations. This comprised 71 birds, 28 reptiles, 19 mammals, 3 frogs and 1 fish. Of the 19 mammals, three were introduced and include, Cattle (*Bos taurus*), Camel (*Camelus dromedarius*) and Feral Cat (*Felis catus*).

Apart from the four species discussed above two additional conservation significant species were recorded, the Peregrine Falcon (*Falco peregrinus*) and Long-tailed Dunnart (*Sminthopsis longicaudata*). Both species were recorded once in the survey area and the Long-tailed Dunnart record was from a badly blurred camera image, however the key identifiable feature in the image is the distinctly long tail of this species. It is unlikely to be any other species. All of the species recorded during the surveys are presented in Appendix C.

4. Summary of key findings

There are numerous historical records within the locality of the GVMDE for the Pilbara Leaf-nosed Bat, Ghost Bat, Northern Quoll and Pilbara Olive Python. The majority of these records are within the approved North Star Magnetite Project area including two known diurnal roost sites for the Pilbara Leaf-nosed Bat, known as Cave 13 and Chateau Cave.

Pilbara Leaf-nosed Bat and Ghost Bat

The targeted bat surveys recorded at least five species of bat including the Pilbara Leaf-nosed Bat from 13 sites and the Ghost Bat from at least four sites.

A review of the bat calls recorded within the first hour for each night of the survey revealed that Pilbara Leaf-nosed Bat calls were recorded within 20 mins of civil twilight (+/- 5 mins) for seven nights at five locations from within the GVMDE. These records suggest that a diurnal roost(s) may be within the survey area, particularly given the number of records following civil twilight for each night. The source of these calls could also originate from bats roosting within Chateau Cave or Cave 13.

As a result of the cave habitat searches 33 sites were recorded with known or potential diurnal roosting habitat for Pilbara Leaf-nosed Bat and/or Ghost Bat, of which 26 sites are within the GVMDE. Eight of the sites investigated were confirmed as diurnal roosting and foraging habitat for the Ghost Bat (Cave numbers 1, 2, 3, 11, 14, 28, 30 and 32) and are within the GVMDE. Of the eight caves:

- Cave number 30 (labelled Cave 3 located north side of South Pool – see Plate 1) is a confirmed roost for a large number of Ghost Bats (26-30 Ghost Bats). This cave is most likely a maternity roost considering the number of Ghost Bats recorded and the timing of the surveys (January).
- Cave number 1 (Python Cave) – is a historical Ghost Bat roost. Additional evidence was recorded during the current survey to suggest that the cave could be used during part of the breeding cycle for the Ghost Bat.
- Cave number 32 – confirmed diurnal roost as one Ghost Bat flushed from roost during survey.

There is approximately 634 ha of collective potential roosting habitat mapped for the survey area for both the Pilbara Leaf-nosed Bat and Ghost Bat of which approximately 415 ha occurs within the GVMDE.

Based on the distribution of records collected to date and information regarding the habitats and movements of both species in the nearby North Star area it can be confidently estimated that the entirety of the GVMDE (1,346 ha) and the majority of the survey area (4,815 ha) is used as foraging habitat by both the Ghost Bat and Pilbara Leaf-nosed Bat.

Given the overlapping habitat requirements with the Pilbara Leaf-nosed Bat and the presence of a known maternity roost within the survey area for the Ghost Bat, the entirety of the habitat in the GVMDE and at least within a 5 km radius (TSSC 2016b) of the maternity roost site (Cave number 30) should be regarded as high priority for the Ghost Bat.

Pilbara Olive Python

All eight records for the Pilbara Olive Python from the current survey were from drainage lines and major watercourses that supported semi-permanent, seasonal and permanent pools. The rocky ridgeline habitats, pools (of all types) and drainage lines (and associated riparian vegetation) in the area around and within the survey area are core habitat for this species.

However, the lack of data for this species, prohibited the accurate habitat mapping across the entire survey area and it should be assumed that the amount (1223 ha) and distribution of habitat within the GVMDE, probably underestimates the overall area of habit used by this species within the GVMDE and larger survey area.

Northern Quoll

Of the 115 cameras deployed, 64 had observations of Northern Quoll with at least one record of a Northern Quoll from all bar one of the 21 sites. Given the distribution and frequency of the camera records and other observations within the survey area, the Northern Quoll is likely to occupy (including breeding) and hunt throughout the 1,346 ha of the MDE and 4815 ha of the GVMDE. according to DotE 2016 the core habitat areas of the GVMDE is 1637 ha (see Appendix F, Figure 8). However this is likely an under represented figure due to access issue with in the GVMDE area.

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Appendices

Appendix A – Bat call analysis methods

Bat call analysis and limitations

Craig Grabham (GHD) completed the analysis and presentation of all bat call data in this report.

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

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

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

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

Confidence ratings applied to calls

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

The semi-automated analysis process does not always capture all 'softer' Pilbara Leaf-nosed Bat (those calls with a lower amplitude) and Ghost Bat calls and sometimes calls with few

pulses. Noting these limitations the manual review of all files during step 3 of the analysis process each night ensured no emergence calls were missed. Furthermore random manual checking of data revealed that few if any Pilbara Leaf-nosed Bat calls were missed for the majority of the nights. Having said that both the Pilbara Leaf-nosed Bat and Ghost Bat need to be in close proximity to the bat detector to be recorded. The Ghost Bat call in particular is of low intensity making it difficult to detect with a bat detector therefore ultrasonic surveys should not be the primary means of surveying for this species.

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Appendix B – Remote camera location details

Site and Camera	mE	mN	Environment	Habitat	Deployed	Collected	Days Deployed
Site 1 - Python Gorge							
camera 10	713466.41	7643918.24	dry elevated gully	dry rocky drainage	9/05/2018	5/06/2018	27
camera 12	713412.01	7643893.7	small pool	Pilbara olive python present	9/05/2018	5/06/2018	27
camera 27	713231.13	7643856.19	dry elevated gully	small pool	9/05/2018	5/06/2018	27
camera 24	713146.77	7643817.87	bottom of dry gully	plunge pool	9/05/2018	5/06/2018	27
camera 8	713088.12	7643856.95	bottom dry gully	dry	9/05/2018	5/06/2018	27
Site 2 - Eastern Flank Gorge							
camera 5	714027.03	7643826.64	top dry gully	rocky overhangs	10/05/2018	6/06/2018	27
camera 16	714042.16	7643658.22	rocky ridge	above dry gully	10/05/2018	6/06/2018	27
camera 116	714148.75	7643507.53	dry rocky gully	top of drop off	10/05/2018	6/06/2018	27
camera 26	714224.24	7643493.92	dry rocky gully	drop off above plunge pool	10/05/2018	6/06/2018	27
camera ghd a	714235.8	7643489.67	dry rocky gully	dry pool, bottom of waterfall	10/05/2018	6/06/2018	27
camera sg 5	714383.61	7643451.18	dry creek	along valley	10/05/2018	6/06/2018	27
camera sg 8	714566.28	7643466.73	dry creek	quoll scat collected	10/05/2018	6/06/2018	27
camera sg 2	714682.27	7643408.06	dry creek	dry creek in rocks	10/05/2018	6/06/2018	27
camera sg 1	714928.78	7643551.01	small stony rise	between dry creek rocky ride	10/05/2018	6/06/2018	27
camera sg 9	714930	7643644.03	rocky steep gully	lots large boulders, dry	10/05/2018	6/06/2018	27
Site 3							
camera 15a	713940.59	7642923.06	head of grassy rocky gully	Euc amongst rock and triodia	10/05/2018	3/07/2018	54
camera 11	713864.11	7643035.48	dry gully creek junction	Euc amongst rock and triodia	10/05/2018	3/07/2018	54
camera 18	713735.59	7643000.72	dry gully	lots overhangs shallow caves at ground level	10/05/2018	3/07/2018	54
camera 29	713609.99	7642983.76	dry creek	creek bed, just dry	10/05/2018	3/07/2018	54
camera 14	713546.12	7642988.36	dry creek gully	creek bed, just dry	10/05/2018	3/07/2018	54
Site 4 -Column Cave drainage							
camera 7	714052.77	7645977.82	dry rocky gorge	at base of falls, dry	11/05/2018	5/06/2018	25
camera 25	714097.35	7645965.38	dry creek at base small fall	small pool water (seep) under rock in creek	11/05/2018	5/06/2018	25
camera 28	714434.95	7645919.55	dry creek	white gums, rocky outcrops both side	11/05/2018	5/06/2018	25
camera ghd b	714133.37	7646005.23	narrow rocky gorge base	small pool in drainage line, base of outcrop	11/05/2018	5/06/2018	25

camera 115	714080.64	7646029.06	mid way rocky gorge	near small seep amongst outcropping	11/05/2018	5/06/2018	25
Site 5 Breakaway Gully							
camera 2	713588.44	7646525.99	rocky ridge knoll	Breakaway above dry gully near plateau	11/05/2018	5/06/2018	25
camera 19	713403.98	7646279.21	rocky outcrop	top of slope above dry creek	11/05/2018	5/06/2018	25
camera 6	713392.6	7646123.1	dry creek	In dry creek	11/05/2018	5/06/2018	25
camera 1	713314.47	7646069.52	dry creek bed	surrounded by rocky hill gorge	11/05/2018	5/06/2018	25
camera 13	713259.01	7646011.54	rocky gorge western face	above small pool	11/05/2018	5/06/2018	25
Site 6 -Insane Gorge							
camera 31	713575.85	7644740.78	rocky dry creek	above dry pool	12/05/2018	5/06/2018	24
camera 23	713568.9	7644637.88	dry rocky creek	near dry pool	12/05/2018	5/06/2018	24
camera 4	713491.62	7644689.39	dry rocky gully	near confluence, steep rocky gully	12/05/2018	5/06/2018	24
camera ghd c	713276.88	7644658.63	rocky gorge	near pool	12/05/2018	5/06/2018	24
camera 21	713219.23	7644655.51	steep rocky gorge	near permanent pool	12/05/2018	5/06/2018	24
Site 7							
camera sg10	713047.25	7646506.35	near top of rocky outcrop	on Euc in rocky ridge near dry creek	12/05/2018	5/07/2018	54
camera sg6	713063.28	7646613.57	rocky outcrop dry water fall	next to dry creek on rocks	12/05/2018	5/07/2018	54
camera sg3	713039.89	7646682.87	top of outcrop breakaway	in small overhang	12/05/2018	5/07/2018	54
camera sg4	712913.05	7646675.88	dry creek in valley	creek bed	12/05/2018	5/07/2018	54
camera sg7	712860.07	7646537.58	rocky ridge	east slope small cave overhang	12/05/2018	5/07/2018	54
Site 8							
camera sg8	715415.2	7643823.48	rocky hills	rocky ridgeline on hill crest	6/06/2018	4/07/2018	28
camera sg1	715306.7	7643867.66	rocky hills	rocky ridgeline on hill crest	6/06/2018	4/07/2018	28
camera sg5	715301.32	7643893.2	rocky hills	rocky ridgeline on hill crest	6/06/2018	4/07/2018	28
camera sg2	715304.81	7643937.13	low rocky hills	rocky ridge and scree on slope	6/06/2018	4/07/2018	28
camera sg9	715514.36	7643771.01	low rocky hills, edge of plain	low quartz ridgeline	6/06/2018	4/07/2018	28
Site 9							
camera 19	715701.88	7645643.42	rocky hills on edge of plain	dry creek in valley	6/06/2018	4/07/2018	28
camera 27	715566.82	7645690.05	rocky hills	rocky scree on slope	6/06/2018	4/07/2018	28
camera 31	715403.35	7645667.62	rocky hills	dry creek in valley	6/06/2018	4/07/2018	28
camera 15a	715314.5	7645644.31	rocky hills	rocky scree on dry creek line	6/06/2018	4/07/2018	28
camera 14	715844.09	7645579.86	low rocky hills, edge of plain	dry creek in valley	6/06/2018	4/07/2018	28
Site 10							

camera 116	715278.53	7643423.04	low rocky hills, edge of plain	minor rocky ridgeline	6/06/2018	4/07/2018	28
camera 16	715449.69	7643399.96	plain with low hills	Dry creek bed	6/06/2018	4/07/2018	28
camera 26	715562.51	7643289.94	spinifex plain	Dry creek bed	6/06/2018	4/07/2018	28
camera ghda	715449.27	7643140.04	plain with low hills	on Eucalypt on low rocky hill	6/06/2018	4/07/2018	28
camera 5	715088	7643164.95	rocky hills	rocky ridgeline in gully	6/06/2018	4/07/2018	28
Site 11							
camera 18	713415	7643041	Gorge	on Euc in rocky gorge	3/07/2018	8/08/2018	36
camera 14	713306	7643149	Gorge	dry rock creek at base of small gorge on scarp	3/07/2018	8/08/2018	36
camera 15b	713332	7643270	Gorge	dry rock creek in small gorge	3/07/2018	8/08/2018	36
camera 29	713371	7643339	Gorge	positioned above water body	3/07/2018	8/08/2018	36
camera 11	713417	7643420	Gorge	on Euc on water body in gorge	3/07/2018	8/08/2018	36
Site 12 - Drop Off							
camera 8	713957	7642720	rocky hills	On Euc in rocky gully with breakaways	4/07/2018	8/08/2018	35
camera 1	714056	7642703	rocky hills	On Euc in rocky gully within dry creekline	4/07/2018	8/08/2018	35
camera 4	714192	7642713	rocky hills	Rocky gully in breakaways along dry creek, on rock ledge	4/07/2018	8/08/2018	35
camera 13	714220	7642699	rocky hills	On Euc in rocky ledge within dry creekline and waterfall	4/07/2018	8/08/2018	35
camera 6	714304	7642680	rocky hills	On Euc to ground at base of ridge	4/07/2018	8/08/2018	35
Site 13 -Turner River Tributary							
camera sg9	711645	7645195	Turner river Tributary	On Euc in dry river bed amongst triodia and River Gums	5/07/2018	9/08/2018	35
camera sg8	711687	7645379	Turner river Tributary	On Euc in dry river bed, triodia, River Gums, by Rocky ridgelines	5/07/2018	9/08/2018	35
camera sg5	711652	7645624	Turner river Tributary	On stump in dry river bed, triodia, River Gums, by Rocky ridgelines	5/07/2018	9/08/2018	35
camera sg1	711830	7645675	Turner river Tributary	Stump, rocky bank, dry river bed, triodia, River Gums	5/07/2018	9/08/2018	35
camera sg2	711972	7645742	Turner river Tributary	On rocky ridge where ridge and creek intersect, breakaways, Eucs	5/07/2018	9/08/2018	35
Site 14 - South Star Pool							
camera 26	712248	7645715	South Star Pool	On rocky ridge where ridge and creek intersect, breakaways, Eucs	5/07/2018	9/08/2018	35
camera 16	712454	7645649	South Star Pool	On rocky ridge above water body, breakaways and Eucs	5/07/2018	9/08/2018	35
camera 5	712556	7645649	South Star Pool	South side of pool in rocky ridge	5/07/2018	9/08/2018	35
camera 116	712542	7645691	South Star Pool	North side of pool in rocky ridge, next to series of caves	5/07/2018	9/08/2018	35

camera ghda	712580	7645681	South Star Pool	East side of pool above rocky waterfall	5/07/2018	9/08/2018	35
Site 15							
camera 27	713172	7645561	Gorge	mouth of small gorge near to water pool and seeps	5/07/2018	9/08/2018	35
camera ghdc	713145	7645493	Gorge	in small cave along ridgeline	5/07/2018	9/08/2018	35
camera 31	713158	7645402	Rocky ridgeline, western flank	small rocky ridgeline leading into small gully	5/07/2018	9/08/2018	35
camera 115	713246	7645432	Small gully	on Euc in small rocky gully amongst boulders	5/07/2018	9/08/2018	35
camera 19	713346	7645323	Small gully	head of small gully on Euc into small cave	5/07/2018	9/08/2018	35
Site 16							
camera sg6	714510	7644813	Large rocky gully	Rocky gully with dry creek bed, large rock faces with breakaway	6/07/2018	9/08/2018	34
camera sg4	714547	7644923	Large rocky gully	On Euc in rocky gully, facing onto rock face with lots of crevices	6/07/2018	9/08/2018	34
camera sg10	714538	7645006	Large rocky gully	On Euc in rocky gully, facing onto rock face	6/07/2018	9/08/2018	34
camera sg3	714474	7645207	Large rocky gully	Amongst boulders in dry creek bed	6/07/2018	9/08/2018	34
camera sg7	714478	7645259	Large rocky gully	Amongst boulders in dry creek bed	6/07/2018	9/08/2018	34
Site 5 Breakaway Gully repeat							
camera 14	713588.44	7646525.99	Repeat for camera 2	Breakaway above dry gully near plateau	22/01/2019	26/02/2019	32
camera 27	713403.98	7646279.21	Repeat for camera 19	top of slope above dry creek	22/01/2019	26/02/2019	32
camera GHDC	713392.6	7646123.1	Repeat for camera 6	In dry creek	22/01/2019	26/02/2019	32
camera 4	713314.47	7646069.52	Repeat for camera 1	surrounded by rocky hill gorge	22/01/2019	26/02/2019	32
camera 5	713259.01	7646011.54	Repeat for camera 13	above small pool	22/01/2019	26/02/2019	32
Site 6 -Insane Gorge repeat							
camera 2	713575.89	7644740.73	repeat for cam 31	above dry pool	22/01/2019	26/02/2019	32
camera 77	713491.64	7644689.37	repeat for cam 4	near dry pool	22/01/2019	26/02/2019	32
camera 115	713326.57	7644655.02	Under overhang	near confluence, steep rocky gully	22/01/2019	26/02/2019	32
camera 16	713227.22	7644660.00	Near pool	near pool	22/01/2019	26/02/2019	32
camera GHDA	713207.49	7644635.10	Near pool	near permanent pool	22/01/2019	26/02/2019	32
Site 17 Bore Road North							
camera 42	709287.19	7647310.51	Rocky ridgeline	flank ridgeline above dry creek	22/01/2019	26/02/2019	32
camera 41	709250.09	7647197.21	Rocky ridgeline	in rocks	22/01/2019	26/02/2019	32
camera 43	709319.58	7647115.00	Rocky ridgeline	flank ridgeline above dry creek	22/01/2019	26/02/2019	32
camera 44	709386.83	7646920.46	Rocky ridgeline	in rock onto of ridge	22/01/2019	26/02/2019	32
camera 45	709355.40	7646817.58	Rocky ridgeline	in rock behind large fig	22/01/2019	26/02/2019	32

Site 18 Ghost Bat Seep							
camera 15b	713150.99	7645095.00	base of gully	in rocks at the base of gully	22/01/2019	27/02/2019	33
camera 19	713207.53	7645086.74	overhang	opening to overhang and numerous small caves	22/01/2019	27/02/2019	33
Camera 21	713143.86	7645153.17	ridgeline	in rocks at the base of gully	22/01/2019	27/02/2019	33
camera GHDB	713174.46	7645201.04	base of gully	on tree next to small water body, but putrid water	22/01/2019	27/02/2019	33
camera 8	713198.10	7645200.21	overhang in GB seep	overhang in GB seep on fig	22/01/2019	27/02/2019	33
Site 19 Bore Road South							
camera 28	710584.04	7644808.89	low rocky ridgeline	on tree in low ridge 50% burnt	23/01/2019	26/02/2019	32
camera 1	710172.63	7645109.19	rocky ridgeline	in rock	23/01/2019	26/02/2019	32
camera 23	710113.70	7645127.67	rocky ridgeline	on ground in rock	23/01/2019	26/02/2019	32
camera 29	710081.32	7645274.81	rocky ridgeline	on tree to base termitaria	23/01/2019	26/02/2019	32
camera26	710017.81	7645608.28	rocky ridgeline	on tree to rocks	23/01/2019	26/02/2019	32
Site 14 repeat South Pool							
camera 24	712632.72	7645571.90	overhang	new location before waterfall under overhangs	23/01/2019	27/02/2019	34
camera 166	712573.16	7645684.56	waterfall	repeat for camera 5	23/01/2019	27/02/2019	34
camera 25	712546.73	7645683.43	south side of pool	repeat of camera 116	23/01/2019	27/02/2019	34
camera 20	712554.95	7645650.00	north side of pool	repeat of camera 5	23/01/2019	27/02/2019	34
camera 31	712496.28	7645648.97	down stream of pool	repeat of camera 16	23/01/2019	27/02/2019	34
						Total camera trap nights	**3760**

Appendix C – Fauna species list 2018 Survey

Species recorded over the project and seasons

Family	Genus	Species	Common Name	Status	Observed	Observed	Observed
Birds					May/June 2018	July/ August 2018	Jan/Feb 2019
Acanthizidae	*Smicrornis*	*brevirostris*	Weebill		X	X	
Accipitridae	*Accipiter*	*fasciatus fasciatus*	Brown Goshawk			X	
Accipitridae	*Accipiter*	*cirrocephalus*	Collared Sparrowhawk		X		
Accipitridae	*Aquila*	*audax*	Wedge-tailed Eagle			X	
Accipitridae	*Circus*	*assimilis*	Spotted Harrier		X	X	
Accipitridae	*Elanus*	*axillaris*	Black-shouldered Kite		X		
Accipitridae	*Haliastur*	*sphenurus*	Whistling Kite		X	X	X
Accipitridae	*Hamirostra*	*melanosternon*	Black Breasted Buzzard			X	
Accipitridae	*Hieraaetus*	*morphnoides*	Little Eagle			X	
Accipitridae	*Milvus*	*migrans*	Black Kite		X	X	
Aegothelidae	*Aegotheles*	*cristatus*	Australian Owlet-nightjar		X, camera	X, camera	
Ardeidae	*Ardea*	*pacifica*	White-necked Heron			X	
Artamidae	*Artamus*	*cinereus*	Black-faced Woodswallow		X, camera	X, camera	X
Artamidae	*Artamus*	*minor*	Little Woodswallow		X	X	
Artamidae	*Artamus*	*leucorynchus*	White-breasted Woodswallow		X		X
Artamidae	*Artamus*	*personatus*	Masked Woodswallow		X	X	
Artamidae	*Cracticus*	*tibicen*	Australian Magpie			X	
Artamidae	*Cracticus*	*nigrogularis*	Pied Butcherbird		X	X, camera	X, camera
Artamidae	*Cracticus*	*torquatus*	Grey Butcherbird		X	X	
Cacatuidae	*Cacatua*	*sanguinea westralensis*	Little Corella			X	
Cacatuidae	*Eolophus*	*roseicapilla*	Galah		X	X	X
Cacatuidae	*Nymphicus*	*hollandicus*	Cockatiel		X	X	
Campephagidae	*Coracina*	*novaehollandiae*	Black-faced Cuckoo-Shrike		X	X	X, camera
Campephagidae	*Lalage*	*sueurii*	White-winged Triller		X	X	
Columbidae	*Phaps*	*chalcoptera*	Common Bronzewing		X, camera	X, camera	X, camera
Columbidae	*Geophaps*	*plumifera*	Spinifex Pigeon		X, camera	X, camera	X
Columbidae	*Geopelia*	*cuneata*	Diamond Dove		X, camera	X, camera	X
Columbidae	*Geopelia*	*striata*	Peaceful Dove		X		
Columbidae	*Ocyphaps*	*lophotes*	Crested Pigeon		X	X	X
Corvidae	*Corvus*	*orru*	Torresian Crow		X, camera	X, camera	X, camera
Cuculidae	*Cacomantis*	*pallidus*	Pallid Cuckoo		X	X	
Estrildidae	*Emblema*	*pictum*	Painted Finch		X, camera	X, camera	X, camera

Family	Genus	Species	Common Name	Status	Observed	Observed	Observed
Estrildidae	*Taeniopygia*	*guttata*	Zebra Finch		X	X	
Eurostopodidae	*Eurostopodus*	*argus*	Spotted Nightjar		X		X
Falconidae	*Falco*	*cenchroides*	Nankeen Kestrel		X	X	
Falconidae	*Falco*	*berigora*	Brown Falcon		X	X	X
Falconidae	*Falco*	*longipennis*	Hobby Falcon			X	
Falconidae	*Falco*	*peregrinus*	Peregrine Falcon	OS	X		
Halcyonidae	*Dacelo*	*leachii*	Blue-winged Kookaburra		X		
Halcyonidae	*Todiramphus*	*pyrrhopygius*	Red-backed Kingfisher		X	X	
Halcyonidae	*Todiramphus*	*sanctus*	Sacred Kingfisher		X	X	X
Hirundinidae	*Petrochelidon*	*nigricans*	Tree Martin		X	X	X
Maluridae	*Amytornis*	*striatus whitei*	Striated Grasswren			X	X, camera
Maluridae	*Malurus*	*lamberti*	Variegated Fairy-wren		X	X	X, camera
Megaluridae	*Cincloramphus*	*cruralis*	Brown Songlark			X	
Megaluridae	*Cincloramphus*	*mathewsi*	Rufous Songlark		X		
Megaluridae	*Eremiornis*	*carteri*	Spinifexbird		X	X	X, camera
Meliphagidae	*Certhionyx*	*variegatus*	Pied Honeyeater		X	X	
Meliphagidae	*Epthianura*	*tricolor*	Crimson Chat		X	X	X
Meliphagidae	*Lichenostomus*	*keartlandi*	Grey-headed Honeyeater		X, camera	X, camera	X, camera
Meliphagidae	*Lichenostomus*	*plumulus*	Grey-fronted Honeyeater			X, camera	X, camera
Meliphagidae	*Lichenostomus*	*penicillatus*	White-plumed Honeyeater		X	X	X
Meliphagidae	*Lichenostomus*	*virescens*	Singing Honeyeater		X	X	X, camera
Meliphagidae	*Lichmera*	*indistincta*	Brown Honeyeater		X	X	X
Meliphagidae	*Manorina*	*flavigula*	Yellow-throated Miner		X, camera	X, camera	X, camera
Meliphagidae	*Sugamel*	*niger*	Black Honeyeater		X		
Meropidae	*Merops*	*ornatus*	Rainbow Bee-eater		X	X	X
Monarchidae	*Grallina*	*cyanoleuca*	Magpie-lark		X	X	X
Motacillidae	*Anthus*	*novaeseelandiae*	Australasian Pipit		X	X	X
Pachycephalidae	*Colluricincla*	*harmonica*	Grey Shrike-thrush		X, camera	X, camera	X, camera
Pachycephalidae	*Oreoica*	*gutturailis*	Crested Bellbird		X	X, camera	
Pachycephalidae	*Pachycephala*	*rufiventris*	Rufous Whistler		X	X	X
Pardalotidae	*Pardalotus*	*rubricatus*	Red-browed Pardalote		X	X	X
Podicipedidae	*Tachybaptus*	*novaehollandiae*	Australasian Grebe		X	X	X
Pomatostomidae	*Pomatostomus*	*temporalis*	Grey-crowned Babbler		X		
Psittacidae	*Barnardius*	*zonarius zonarius*	Port Lincoln Parrot		X	X	X
Psittacidae	*Melopsittacus*	*undulatus*	Budgerigar		X	X	X

Family	Genus	Species	Common Name	Status	Observed	Observed	Observed
Ptilonorhynchidae	*Ptilonorhynchus*	*guttatus*	Western Bowerbird		X	X, camera	
Rhipiduridae	*Rhipidura*	*leucophrys*	Willie Wagtail		X, camera	X, camera	X, camera
Strigidae	*Ninox*	*novaeseelandiae*	Boobook Owl		X		
Tunicidae	*Turnix*	*velox*	Little Button-quail		X	X	X
Reptiles							
Agamidae	*Amphibolurus*	*longirostris*	Long-snouted Water Dragon		X		X
Agamidae	*Ctenophorus*	*caudocinctus caudocinctus*	Ringtail Dragon		X	X	X
Boidae	*Antaresia*	*stimsoni*	Stimson's Python		X		
Boidae	*Antaresia*	*perthensis*	Pygmy Python		X		
Boidae	*Liasis*	*olivaceus barroni*	Pilbara Olive Python	Vu, Vu	X		X
Diplodactylidae	*Diplodactylus*	*conspiculatus*	Fat-tailed Gecko		X		
Elapidae	*Pseudechis*	*australis*	Mulga Snake			camera	
Gekkonidae	*Gehyra*	*punctata*	Spotted Dtella		X		X
Gekkonidae	*Gehyra*	*variegata*	Tree Dtella		X		
Gekkonidae	*Heteronotia*	*binoei*	Bynoe's Gecko		X		
Gekkonidae	*Heteronotia*	*spelea*	Desert Cave Gecko		X		
Gekkonidae	*Oedura*	*marmoratus*	Marble Velvet Gecko		X	X	
Pygopodidae	*Delma*	*elegans*	Pilbara Delma			X	
Pygopodidae	*Delma*	*pax?*	Peaceful Delma			X	
Scincidae	*Carlia*	*munda*	Striped Rainbow Skink			X	X
Scincidae	*Cryptoblephurus*	*ustulatus*	Russet Snake-eyed Skink		X	X	X
Scincidae	*Ctenotus*	*rubicundus*	Ruddy Ctenotus		camera	X, camera	
Scincidae	*Ctenotus*	*saxatalis*	Rock Ctenotus		X	X, camera	X
Scincidae	*Egernia*	*formosa*	Goldfield's Crevice Skink		camera	camera	X, camera
Scincidae	*Erimeascincus*	*richardsoni*	Broad Banded Sandswimmer		X		
Scincidae	*Menetia*	*greyii*	Common Dwarf Skink			X	X
Scincidae	*Morethia*	*ruficauda exquisita*	Fire-tailed Skink		X	X	
Typhlopidae	*Anilios*	*grypus*	Northern Beaked Blindsnake		X		
Varanidae	*Vananus*	*accanthurus*	Ridge-tailed Monitor		camera	camera	camera
Varanidae	*Vananus*	*giganteus*	Perentie		camera	camera	X, camera
Varanidae	*Vananus*	*panopties rubidus*	Yellow Spotted Monitor			camera	
Varanidae	*Vananus*	*pilbarensis*	Northern Pilbara Rock Monitor		camera	camera	camera
Varanidae	*Vananus*	*tristis tristis*	Racehorse Goanna			camera	camera
Mammals							
Bovidae	*Bos*	*taurus*	Cattle	intro	X	X	X

Family	Genus	Species	Common Name	Status	Observed	Observed	Observed
Camelidae	*Camelus*	*dromedarius*	Camel	intro	prints	prints	
Canidae	*Canus*	*lupis*	Dingo		X, camera	X, camera	camera
Dasyuridae	*Dasyurus*	*hallucatus*	Northern Quoll	En, En	X, camera	X, camera	camera
Dasyuridae	*Planigale*	*maculatus?*	Common Planigale		camera		
Dasyuridae	*Pseudantechinus*	*roryi or woolleyae*	False Antechinus		camera	camera	
Dasyuridae	*Sminthopsis*	*longicaudata*	Long-tailed Dunnart	P4			camera
Emballonuridae	*Taphozous*	*georgianus*	Common Sheathtail-bat		X, bat detector	X, bat detector	X, bat detector
Felidae	*Felis*	*catus*	Cat	intro	camera	camera	camera
Hipposideridae	*Rhinonicteris*	*aurantius*	Pilbara Leaf-nosed Bat	Vu, Vu	bat detector	bat detector	
Macropodidae	*Macropus*	*robustus*	Euro		X, camera	X, camera	camera
Macropodidae	*Petrogale*	*rothchildi*	Rothchilds Rock Wallaby		camera	camera	camera
Megadermatidae	*Macroderma*	*gigas*	Ghost Bat	Vu, Vu	X, bat detector	X, scats	Scats, X
Molossidae	*Chaerephon*	*jobensis*	Northern Freetail Bat		bat detector	bat detector	bat detector
Molossidae	*Tadarida*	*australis*	White-striped Freetail Bat		bat detector		
Muridae	*Zyzomys*	*argurus*	Common Rockrat		camera	camera	camera
Tachyglossidae	*Tachyglossus*	*aculeatus*	Echidna		camera	digs, camera	camera
Vespertilionidae	*Scotorepens sp.*	*greyii ?*	Little Broad-nosed Bat		bat detector	bat detector	bat detector
Vespertilionidae	*Vespadelus*	*finlaysoni*	Finlayson's Cave Bat		X, bat detector	X, bat detector	X, bat detector
Amphibia							
Hylidae	*Litoria*	*rubella*	Desert Tree Frog		X	X	
Hylidae	*Cyclorana*	*australis*	Giant Frog				X, camera
Myobatrachidae	*Uperoleia*	*saxatilis*	Pilbara Froglet			X	
Fishes							
Melanotaeniidae	*Melanotaenia*	*australis*	Western Rainbow Fish			X	X

Appendix D – Waterbodies

Appendix E – Remote camera results

Species Recorded on Camera from Sites 1 to 7

	Site 1 - Python Gorge					Site 2 - Eastern Flank Gorge										Site 3					Site 4 - Column Cave					Site 5 - Breakaway Gully					Site 6 - Insane Gorge					Site 7				
	c10	c12	c27	c24	c8	c5	c16	c116	c26	ca	csg5	csg8	csg2	csg1	csg9	c15a	c11	c18	c29	c14	c7	c25	c28	cb	c115	c2	c19	c6	c1	c13	c31	c23	c4	cc	c21	csg10	csg6	csg3	csg4	csg7
Birds																																							
Torresian Crow	3	1	3	2	2		3		2	4				2						2	1					2	1	2	1	1	3	4		2	4	4	5	4	3	9
Spinifex Pigeon	4	7			5															2														7						
Diamond Dove		1																						3				3							1					
Common Bronzewing																								1				1									1		1	
Painted Finch												1															2										1			2
Grey Shrike Thrush																		2								1			2		1					1			1
Willy Wagtail												3		3														2						1	1			1	
Spinifexbird																										1		1											
Striated Grasswren																																							
Variegated Fairy-wren																																							
Crested Bellbird																																							
Grey-headed Honeyeater																		1		1																			
Grey Fronted Honeyeater											1															1													
Singing Honeyeater																																							
Pied Butcherbird																										1													
Yellow Throated Miner																													1										1
Black-faced Woodswallow														1																									
Western Bowerbird																																							
Blace-faced Cuckoo-shrike																																							
Owlet Nightjar																																						2	
Reptiles																																							
Perentie	1														1					1														1					1	
Spotted Monitor																																							
Northern Pilbara Rock Monitor																											1												
Black-headed Monitor																																							
Ridge-tailed Monitor														1																									
Rock Skink																																							
Ruddy Ctenotus																												1											
Goldfield's Crevice Skink										2																													
Mulga Snake																																							
Mammals																																							
Northern Quoll		1		1			1	6		1	2	6			3		1			2	8						1		2	4		1?	2	1	1	1		1
Pseudantechinus sp.																																				4	1		
Planigale maculata?																																							
Sminthopsis longicaudata ?																																							
Echidna												1					1	1			1		2			1													
Common Rock Rat												4			1	1		4			2					3	1		1	1					7	2			6
Euro		2	1	3	3							1					1		3	1													3	1				
Rothchild's Rock Wallaby												1			2							4		1					3					2	1	2			1
Feral Cat												1					1	2	1	1		1	1			1		2	1	2	2	1			1			3	
Dingo	1																																						

Species Recorded on Camera from Sites 8 to 15

	Site 8					Site 9					Site 10					Site 11					Site 12 - Drop Off					Site 13 - Turner River Tributary					Site 14 - South Star Pool					Site 15				
	csg8	csg1	csg5	csg2	csg9	c19	c27	c31	c15a	c14	c116	c16	c26	ca	c5	c 18	c 14	c 15b	c 29	c 11	c 8	c 1	c 4	c 13	c 6	c sg9	c sg8	c sg5	c sg1	c sg2	c 26	c 16	c 5	c 116	c ghda	c 27	c ghdc	c 31	c 115	c 19
Birds																																								
Torresian Crow	1	5			4	9		2			5	7	1	4	4	1		1		1				2			2	1	1			3				4	3	3	3	
Spinifex Pigeon					5							2																					8							
Diamond Dove																											1	4												
Common Bronzewing																								1												1				
Painted Finch					1				5																				6									3		
Grey Shrike Thrush	2								1									2					6	9				1	3		3				3	1	2		
Willy Wagtail		1			2				3								6								1				2								1		
Spinifexbird																																							
Striated Grasswren																																							
Variegated Fairy-wren																																							
Crested Bellbird																													2										
Grey-headed Honeyeater																								1															
Grey Fronted Honeyeater																																							
Singing Honeyeater																																							
Pied Butcherbird																					1			1															
Yellow Throated Miner																																							
Black-faced Woodswallow					1																																		
Western Bowerbird																																							
Black-faced Cuckoo-shrike																																							
Owlet Nightjar																														1									
Reptiles																																							
Perentie																																							
Spotted Monitor																													1		1		2						
Northern Pilbara Rock Monitor																			1		1														1				
Black-headed Monitor																																	1		1				
Ridge-tailed Monitor																	1																						
Rock Skink																													1										
Ruddy Ctenotus																																							
Goldfield's Crevice Skink																							1																
Mulga Snake																							1	1															
Mammals																																							
Northern Quoll		1					3		1			1			3	4		18	1	4		3	2	4				1			7	4	3	1	2	1	1	2	2
Pseudantechinus sp.		2										1									1	1	1	1							1								
Planigale maculata?	1											1																											
Sminthopsis longicaudata ?																																							
Echidna									3								3	4						1													1		
Common Rock Rat	9	1			3	2			2		1	7			1	3	9	11			1	14	3	##					2		6	8		3		1	4	4		
Rodent sp.																	3					6		4	1														
Euro					1	1			3		2	4		2	3															2				1	1			1	5
Rothchild's Rock Wallaby							1		3							1		1					5	4						1	8	1		1			5	
Feral Cat						2	1		1	2?	1		1			1	2				1						4	2		2								1
Dingo											2			1																									

Species Recorded on Camera from Sites 16 to 22 (or there corresponding repeat site numbers)

	Site 16					Site 5 repeat					Site 6 repeat					Site 19 Bore Rd North					Site 20 Ghost Bat Seep					Site 21 Bore Rd South					Site 14 repeat South Pool				
	csg6	csg4	csg10	csg3	csg7	cghdc	c5	c27	c4	c14	cghda	cg16	c77	c2	c115	c42	c41	c43	c44	c45	c15b	c19	c21	cGHDB	c8	c28	c1	c23	c29	c26	c25	c166	c24	c20	c31
Birds																																		
Torresian Crow	1	3	3						1			1		4	3						3		1	2	1		1							
Spinifex Pigeon										1	7			7	7		1	1								3	16							
Diamond Dove											3																							
Common Bronzewing		1													2																			
Painted Finch					4												2										1							
Grey Shrike Thrush	1				1			2		1	1	3	5	1	1		1	1		3	2	1			1									
Willy Wagtail								1				1		3				1									2							
Spinifexbird																											3							
Striated Grasswren													1													1	1							
Variegated Fairy-wren																																1		
Crested Bellbird																																		
Grey-headed Honeyeater					3											1				1						1								
Grey Fronted Honeyeater						1																												
Singing Honeyeater																	1																	
Pied Butcherbird		1								3																								
Yellow Throated Miner		1						1		3																								
Black-faced Woodswallow																	2																	
Western Bowerbird			1																															
Black-faced Cuckoo-shrike																	1																	
Owlet Nightjar					1																													
Reptiles																																		
Perentie									1	1	1		1								1													
Spotted Monitor																																		
Northern Pilbara Rock Monitor		1							1																		1	1						
Black-headed Monitor																																1		
Ridge-tailed Monitor							4				1					1											13	1						
Rock Skink																																		
Ruddy Ctenotus																																		
Goldfield's Crevice Skink						1											1					1												
Mulga Snake																																		
Mammals																																		
Northern Quoll	7	12	5	10	7	2	1	1	2	2	1	2			1		1	3	4	6	3	4	1					5						
Pseudantechinus sp.																																		
Planigale maculata?																																		
Sminthopsis longicaudata ?																																1		
Echidna																							1											
Common Rock Rat	1		3	1	3					1						1			11								1							
Rodent sp.			2																															
Euro					2									1	4		1			1														
Rothchild's Rock Wallaby	1	1		1							1																	1						
Feral Cat					2	1		1						1					1															
Dingo											1			1																				
Amphibians																																		
Giant Frog																																1		

Appendix F – Figures (2 – 8)

680000 690000 700000 710000 720000 730000

7660000 7650000 7640000 7630000

Gillam Creek
Great Northern Hwy
Pippingarra Road
BHP RMT
Pipeline Access Road
Turner River
Chinaman Creek
Valley Road
Craigie Pass

Pool 1 BS
Pool 2 BS
Pool 3 BS
Nicko's Gorge pool (x2)
Fig pool
Artificial pools (office)
Pool 12
Artificial pool
Cow pool
Joe's Cave
Chateau Cave
Cave 13
South Star pool
Python Cave

LEGEND

- Cave
- Pool

DBCA

- Pilbara Leaf-nosed Bat
- Ghost Bat

FMG

- Ghost Bat
- Pilbara Leaf-nosed Bat
- Road/Major Track
- Minor Track
- Drill Line
- Haul Road
- River
- South Star and Glacier Valley Survey Extension
- MDE - South Star and Glacier Valley

Paper Size ISO A3

0 1 2 3 4 5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Database Searches

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

FIGURE 2a

\\ghdnet\ghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\61137156_002_Fig2a_FaunaSpeciesOfConservationSignificance_Rev0.mxd
Print date: 03 Feb 2020 - 07:50

Data source: FMG: Mine Development Envelope, Roads and Tracks (2018); GHD: Caves and Pools, Fauna Survey Data (2016); DBCA: Fauna Data (2018); Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

680000 690000 700000 710000 720000 730000

7660000 7650000 7640000 7630000

Great Northern Hwy
Gillam Creek
Pippingarra Road
BHP RMT
Pipeline Access Road
Turner River
Chinaman Creek
Craigie Pass
Valley Road

Pool 1 BS
Pool 2 BS
Pool 3 BS
Nicko's Gorge pool (x2)
Fig pool
Artificial pools (office)
Pool 12
Joe's Cave
Artificial pool
Cow pool
Chateau Cave
Cave 13
South Star pool
Python Cave

LEGEND

- Cave
- Pool

DBCA

- Pilbara Olive Python
- Northern Quoll

FMG

- Northern Quoll
- Pilbara Olive Python
- Road/Major Track
- Minor Track
- Drill Line
- Haul Road
- River
- South Star and Glacier Valley Survey Extension
- MDE - South Star and Glacier Valley

Paper Size ISO A3

0 1 2 3 4 5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Database Searches

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

FIGURE 2b

\\ghdnet\ghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\61137156_002_Fig2b_FaunaSpeciesOfConservationSignificance_Rev0.mxd
Print date: 03 Feb 2020 - 07:48

Data source: FMG: Mine Development Envelope, Roads and Tracks (2018); GHD: Caves and Pools, Fauna Survey Data (2016); DBCA: Fauna Data (2018); Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

710000

715000

7645000

LEGEND

Indicates absence of PLNB or Ghost Bat or extremely low detection rates within limitations

PLNB

- PLNB record
- PLNB - sheeting record

Ghost Bat

- Ghost Bat Diurnal Roost (maternity)
- Ghost Bat - sheeting record
- Ghost Bats recorded
- Ghost Bat scats
- Pool
- Cave
- MDE - South Star and Glacier Valley

Cow pool

Artificial pool

PLNB

Chateau Cave

Cave 13

2

4

23/1/19 (26-30 bats observed)
Maternity roost

16 10 10 10

6/07/2018 6:08:00 PM
7/07/2018 6:07:00 PM
17/07/2018 6:27:00 PM

South Star pool

7 24/06/2018 6:23:00 PM

7 26/06/2018 6:20:00 PM

11 8/07/2018 6:10:00 PM

17

18

15 7/07/2018 6:18:00 PM

13

12 6/07/2018 6:28:00 PM

5 14 9/05/2018 6:23:00 PM

Python Cave

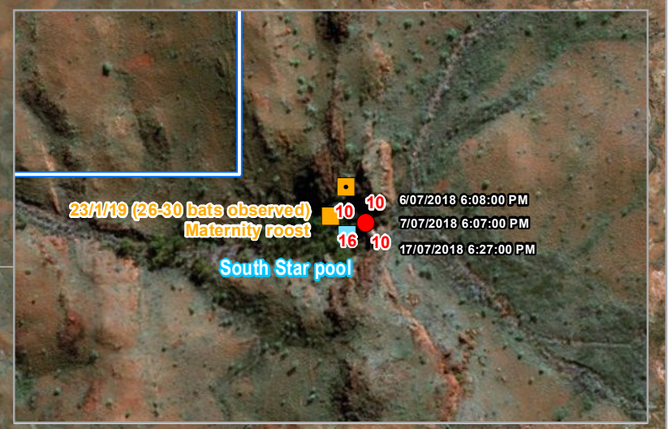
3

6

8

1

9



Paper Size ISO A3

0 200 400 600 800 1,000

Metres

N

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

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Bat detector and cave sheeting results

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

FIGURE 3

\\ghdnet\ghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\61137156_003_Fig3BatDetectorSurveyResults_Rev0.mxd
Print date: 03 Feb 2020 - 08:05

Data source: GHD: Bat Detector Effort - 20180821; FMG: MDE; Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

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7645000

LEGEND

- Camera location (2019)
- Camera location (2018)
- Pool
- MDE - South Star and Glacier Valley

Site 1 - Python Gorge

Site 2 Eastern Flank Gorge

Site 3

Site 4 - Column Cave Drainage

Site 5 Breakaway Gully

Site 6 Insane Gorge

Site 7

Site 8

Site 9

Site 10

Site 11

Site 12 - Drop Off

Site 13 - Turner River Tributry

Site 14 - South Star Pool

Site 15

Site 16

Paper Size ISO A3

0 200 400 600 800 1,000

Metres

N

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

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Remote camera survey effort

Project No. 61-37156
Revision No. 0
Date 3/02/2020

FIGURE 4

\\ghdnetghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\61137156_004_Fig4RemoteCameraSurveyEffort_Rev0.mxd
Print date: 03 Feb 2020 - 08:06

Data source: GHD: Camera Locations - 20180821; Landgate: Imagery; FMG: MDE; Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

710000

715000

7645000

LEGEND

Pool

Northern Quoll Records

Skull

Lower jaw in front of den area, scats present

Scat

Prints

Recorded from remote camera

MDE - South Star and Glacier Valley

South Star pool

Paper Size ISO A3

0 200 400 600 800

Metres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Northern Quoll Observations

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

FIGURE 5

\\ghdnetghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\61371 56_005_Fig5NorthernQuoll_Rev0.mxd
Print date: 03 Feb 2020 - 08:06

Data source: GHD: Northern Quoll Records, Northern Quoll Observations - 20180821; FMG: MDE; Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

710000

715000

7645000

7645000

LEGEND

- 4 foot animal in water body, Insane Gorge
- 4 foot animal in water body, Python Gorge
- Dead POP (skeleton) in narrow cave, estimated 6 feet long
- POP scat under over hang next to water body
- Approx 5 foot long POP
- Approx 8 foot long POP active in rocks in the morning
- Hatchling (about 2 weeks old approx 60 cm)

Pools

- Permanent
- Seasonal
- Semi perm
- MDE - South Star and Glacier Valley

Paper Size ISO A3

0 200 400 600 800

Metres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Pilbara Olive Python

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

FIGURE 6

\\ghdnetghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\61137156_006_Fig6PilbaraOlivePython_Rev0.mxd
Print date: 03 Feb 2020 - 08:09

Data source: GHD: Pools - 20181212, Pilbara Olive Python Observations - 20180821; FMG: MDE; Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.. Created by: ACJackson

710000

715000

7645000

7640000

7635000

Pool 12

Artificial pool

Cow pool

Chateau Cave

Cave 13

Fly Camp Access Road

Pipeline Access Road

Main Camp Access Road

Unknown

Comms Tower Access Road

Valley Road

Craigie Pass

Magazine Compound Road

South Star pool

Python Cave

LEGEND

- Potential Bat Cave Habitat
- Cave
- Pool (Seasonal)
- Pool (Semi Permanent)
- Pool (Permanent)
- Road/Major Track
- Minor Track
- Drill Line
- Haul Road
- Contours (10m)
- River
- South Star and Glacier Valley Survey Extension
- MDE - South Star and Glacier Valley
- Potential Roosting Habitat Location

Slope (Percent)

- >30
- 20 - 30
- <20

Elevation (mAHD)

460

140

Paper Size ISO A3

0 0.5 1 1.5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Pilbara Leaf-nosed Bat and Ghost Bat diurnal roost habitat

Project No. **61-37156**
Revision No. **0**
Date **3/02/2020**

FIGURE 7a

\\ghdnet\ghd\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\6137156_007_Fig7aHabitatMapPilbaraLeaf-nosedBatAndGhostBat_Rev0.mxd
Print date: 03 Feb 2020 - 08:01

Data source: FMG: Mine Development Envelope, Roads and Tracks (2018); GHD: Caves and Pools (2016); Landgate: 10m Contours, Hillshade, Elevation (2018); Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: ACJackson

705000
710000
715000
7650000
7645000
7640000
7635000

Fig pool
Artificial pools (office)
Northern Ramp
OPF Access Road
ROM Bypass Road
Tenberge Hill
Pool 12
Joe's Cave
Cow pool
Artificial pool
Chateau Cave
Cave 13
Pipeline Access Road
Valley Road
Craigie Pass
South Star pool
Python Cave

LEGEND

- Pool (Seasonal)
- Pool (Semi Permanent)
- Pool (Permanent)
- Cave
- Road/Major Track
- Minor Track
- Drill Line
- Haul Road
- River
- South Star and Glacier Valley Survey Extension
- MDE - South Star and Glacier Valley

Foraging habitat

- Gorges with pools (Priority 1)
- Gullies (Priority 2)
- Rocky outcrop (Priority 3)

Paper Size ISO A3

0 0.5 1 1.5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Pilbara Leaf-nosed Bat and Ghost Bat foraging habitat

Project No. **61-37156**
Revision No. **1**
Date **14/02/2020**

FIGURE 7b

N:\AU\Perth\Projects\61\37156\GIS\Maps\Working\Glacier Valley South Star\6137156_008_Fig7bHabitatMapPilbaraLeaf-nosedBatAndGhostBat_Rev1.mxd
Print date: 14 Feb 2020 - 11:11

Data source: FMG: Mine Development Envelope, Roads and Tracks (2018); GHD: Caves and Pools (2016), Foraging Habitats (2020); Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: tngavranic

710000

715000

7645000

7640000

7635000

South Star pool

LEGEND

- Pool
- River
- MDE - South Star and Glacier Valley
- South Star and Glacier Valley Survey Extension
- Northern Quoll Habitat

Paper Size ISO A3

0 0.5 1 1.5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Habitat Map - Northern Quoll

Project No. **61-37156**
Revision No. **1**
Date **2/28/2020**

FIGURE 8

G:\61\37156\GIS\Maps\Working\Glacier Valley South Star\6137156_009_Fig8HabitatMapNorthernQuoll_Rev1.mxd
Print date: 28 Feb 2020 - 10:09

Data source: GHD: Northern Quoll Habitat- 20200226; FMG: MDE; Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.. Created by: pjhernandez

710000

715000

7645000

7640000

7635000

South Star pool

LEGEND

- Pool (Seasonal)
- Pool (Semi Permanent)
- Pool (Permanent)
- River
- MDE - South Star and Glacier Valley
- South Star and Glacier Valley Survey Extension
- Pilbara Olive Python Habitat

Paper Size ISO A3

0 0.5 1 1.5

Kilometres

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

N

GHD

Fortescue Metals Group Ltd
Glacier Valley-South Star Fauna Assessment

Habitat Map - Pilbara Olive Python

Project No. **61-37156**
Revision No. **1**
Date **2/28/2020**

FIGURE 9

G:\61\37156\GIS\Maps\Working\Glacier Valley South Star\6137156_010_Fig9HabitatMapPilbaraOlivePython_Rev1.mxd
Print date: 28 Feb 2020 - 10:11

Data source: GHD: Pilbara Olive Python Habitat - 20200226; Landgate: Imagery; FMG: MDE; Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.. Created by: pjhernandez

GHD

Level 10
999 Hay Street
T: 61 8 6222 8222 F: 61 8 6222 8555 E: permail@ghd.com

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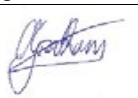
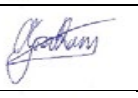
Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Rev A	C.Grabham G.Gaikhorst	R. Browne-Cooper		C.Grabham		11/12/2018
Rev B	C.Grabham G.Gaikhorst	J Tindiglia		C.Grabham		12/09/2019
Rev 0	G.Gaikhorst	G.Gaikhorst		C.Grabham		20/12/2019
Rev 1	G.Gaikhorst	C.Grabham		C.Grabham		14/2/2020

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