GLACIER VALLEY

TERRESTRIAL VERTEBRATE FAUNA ASSESSMENT

PREPARED FOR: IB OPERATIONS PTY LTD

Spectrum ECOLOGY

ABN 68 615 115 243
PO Box 314 Leederville
Western Australia 6902
Ph: (08) 9317 8233
Email: info@spectrumecology.com.au

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EXECUTIVE SUMMARY

IB Operations Pty Ltd (IBO) proposes to continue to develop the iron ore mining operations located at North Star (NS), approximately 100 km south of Port Hedland, in the Pilbara region of Western Australia (WA). IBO is a majority-owned subsidiary of Fortescue Metals Group Ltd (Fortescue), which owns and operates mining and infrastructure projects in the Pilbara. The Glacier Valley (GV) Survey Area (5767 ha) encompasses a proposed extension of NS that will likely involve mine pits, waste rock dumps and supporting infrastructure. Spectrum Ecology (Spectrum) was commissioned to undertake a two-phase Detailed (Level 2) fauna survey, short-range endemic invertebrate survey, targeted conservation significant vertebrate fauna surveys and regional critical habitat modelling for the Northern Quoll and Pilbara Olive Python. The environmental team at GHD were sub-contracted to complete targeted surveys and regional critical habitat mapping for the Ghost Bat and Pilbara Leaf-nosed Bat. The current assessment incorporates data collected during previous surveys completed adjacent to the Survey Area as part of the North Star Mine approvals process, regional fauna survey data, and previous data collected within the current GV Survey Area.

Both phases of the Detailed (Level 2) survey were completed as combined vertebrate and SRE invertebrate surveys. This report covers the vertebrate fauna component. The two phases were completed in autumn (May) and spring (October) during peak periods of fauna activity and in line with the EPA Technical Guidance (Environmental Protection Authority, 2020). Long-term motion cameras were installed during the May survey, the results of which were used to choose the locations of Northern Quoll trapping sites during the targeted survey in July. Additional surveys targeting Ghost Bat and Pilbara Leaf-nosed Bat were completed by GHD staff between August and October 2020 (Appendix G). All field surveys were completed as per the relevant government guidelines, species specific guidelines and Fortescue guidelines.

The following combined survey effort was completed at Glacier Valley during the field surveys:

- Four vertebrate fauna trapping grids were surveyed over two phases totaling 448 trap nights
- 16 hours were spent conducting 48 systematic bird surveys
- 26 hours of opportunistic searches recording all fauna observed
- 20,880 motion camera hours at 22 locations
- 288 hours of ultrasonic recordings from eight sites.

Targeted survey effort for conservation significant fauna species is as follows:

- Northern Quoll and Pilbara Olive Python:
  - 26 hours of opportunistic survey targeting both species
  - 420 trap nights targeting Northern Quoll across three sites
  - 20,880 hours of motion camera deployment at 22 sites
- Pilbara Leaf-nosed Bat and Ghost Bat (Appendix G):
  - A total of 25 trap nights spent harp trapping at four sites (one site within the Survey Area and three sites within the regional Study Area);
  - A total of 15 hours of roost emergence surveys were completed across four sites - one within the Survey Area and four within the regional Study Area. Surveys utilised one or two observers, one IR video camera (coupled with an IR lamp) and one ultrasonic recorder per site;
  - 1,958 hours of ultrasonic bat recordings from 27 sites (11 within the Survey Area and 16 within the regional Study Area) were analysed for threatened bat species calls;
  - 108 hours of acoustic recordings from three sites within the Survey Area were analysed for threatened bat species calls; and

  - 56 roost habitat surveys including two within the Survey Area.
- Fork-tailed Swift, Peregrine Falcon, and Grey Falcon:
  - 16 hours of systematic bird surveys
  - Opportunistic observations over 30 days of field survey

The key findings of the Glacier Valley vertebrate fauna assessment are as follows:

Four broad fauna habitat types were identified and defined from the Survey Area: Hills, Ranges and Plateaux; Rocky Escarpment; Gorges and Gullies; and Minor Drainage Lines. Analysis of aerial imagery, land system data, geological data, vegetation mapping and previous survey data indicates these habitat types are extensive in the wider region.

The combined field surveys identified 90 vertebrate fauna species within the Survey Area: one amphibian, 39 birds, 12 non-volant native mammals, three introduced mammals, six bats, and 32 reptiles. This total falls within the range of results recorded during previous surveys in the region and is comparable to total species counts achieved during surveys utilising similar sampling intensity within similarly diverse habitat types. Statistical analysis of systematically collected trapping and bird survey data suggests that the majority of species potentially occurring within the Survey Area have been recorded, though more species may be recorded with further survey effort. The overall total of 90 species is a combination of both systematically and opportunistically recorded species and exceeds the total species count predicted by the analysis.

The following species of conservation significance were recorded within the Survey Area during the current or previous surveys:

- Northern Quoll (*Dasyurus hallucatus*) - EPBC/ BC Act Endangered
- Ghost Bat (*Macroderma gigas*) - EPBC/ BC Act Vulnerable
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) - EPBC/ BC Act Vulnerable
- Pilbara Olive Python (*Liasis olivaceus barroni*) - EPBC/ BC Act Vulnerable
- Peregrine Falcon (*Falco peregrinus*) - BC Act Other Specially Protected Fauna

A further five conservation significant species were determined to have a medium or high likelihood of occurrence within the Survey Area.

- Fork-tailed Swift (*Apus pacificus*) EPBC/ BC Act Migratory
- Grey Falcon (*Falco hypoleucos*) - EPBC/ BC Act Vulnerable
- Western Pebble-mound Mouse (*Pseudomys chapmani*) DBCA Priority 4
- Long-tailed Dunnart (*Sminthopsis longicaudata*) DBCA Priority 4
- Gane's Blind Snake (*Anilios ganei*) DBCA Priority 1

The Rocky Escarpment and Gorges and Gullies habitat types were identified as critical habitat for Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python. The Hills, Ranges Plateaux and Minor Drainage Lines habitats may be used for foraging and dispersal by these species, although they do not represent denning, roosting, or breeding habitat. The Peregrine Falcon may utilise all habitat types within the Survey Area for foraging purposes though only the Rocky Escarpment habitat type represents potential breeding habitat.

Threatened fauna distribution modelling was completed within the regional Study Area (Survey Area plus 30 km buffer) for the Northern Quoll and Pilbara Olive Python based on the locations of 533 Northern Quoll records and 54 Pilbara Olive Python records. The initial model was ground-truthed at 50 locations within a 30 km regional Study Area and further refined to address errors. The results of the refined model were grouped into three categories in order to quantify the results and show total regional extents of critical/

breeding habitat (Cat 1), marginal/ foraging/ dispersal habitat (Cat 2) and areas not typically suitable as habitat (Cat 3). The Survey Area contains approximately 482 ha of modelled Cat 1 habitat for Northern Quoll and 533 ha of Cat 1 habitat for Pilbara Olive Python.

Habitat modelling for Pilbara Leaf-nosed Bat and Ghost Bat was completed by GHD (Appendix G). The results of the model identified four fauna habitat types comprising five priority levels. Habitat type 1 consists of critical roosting habitat as it was considered conducive to cave and overhang formations which provide roosting and refuge opportunities for both species. Habitat type 1 includes Priority 1 (gorges with pools, watercourses in upland areas) and Priority 3 (areas of exposed rock at top of rocky outcrops and mesa hills that contain caves and overhangs) habitat types. Approximately 1982 ha of Habitat 1 (711 ha of Priority 1 habitat; 1271 ha of Priority 3 habitat) was modelled to occur within the Study Area The entirety of the Survey Area is assumed to be foraging habitat for both bat species.

No significant limitations or constraints were experienced in association with this assessment. The current and previous regional assessments are comprehensive and give a detailed indication of the vertebrate fauna values of the Survey Area.

1. INTRODUCTION

1.1. Project Background

IB Operations Pty Ltd (IBO) proposes to continue to develop the iron ore mining operations located at North Star (NS) in the Pilbara region of Western Australia (WA). IBO is a majority-owned subsidiary of Fortescue Metals Group Ltd (Fortescue), which owns and operates mining and infrastructure projects in the Pilbara. Glacier Valley (GV) is a proposed extension of NS and will likely involve mine pits, waste rock dumps and supporting infrastructure, with the total area of the tenement covering 5767 ha.

The North Star (Stage 2 – magnetite) project is approved under Ministerial Statement 993 and comprises a mining area, slurry pipeline and infrastructure corridor, and Canning Basin borefield and water supply pipeline. The North Star project is located approximately 100 km south of Port Hedland and around 20 km east of the Fortescue Main Line Rail (

Map 1.1). The host to the magnetite mineralisation at GV is the main banded iron formation (BIF) member of the Pincunah Formation. The Pincunah Formation is one of several prominent BIF units within the greenstone belts of the Pilbara Craton which host primary magnetite mineralisation M45/1244 and M45/1226.

1.2. Scope of Work

To support the primary environmental approvals process, Spectrum Ecology (Spectrum) was commissioned to do a Detailed (Level 2) terrestrial vertebrate fauna assessment (including targeted conservation significant fauna survey) of the GV area, as this was required to assess potential environmental impacts and identify appropriate management strategies. The surveys built on previous ecological data collected from the GV area and surrounds, and assessed previously unsurveyed areas. The surveys comprised:

- A Detailed (Level 2) (two-phase) fauna survey within the GV Mine Development Envelope (MDE) and Extension Area (Survey Area) to identify the suite of fauna species that occur, validate existing information, and expand the area of fauna habitat mapping;
- Additional targeted conservation significant fauna survey as deemed appropriate within the Survey Area building on 2018/9 surveys, focusing on Northern Quoll, Pilbara Olive Python, Pilbara Leaf-nosed Bat and Ghost Bat;
- Regional critical habitat modelling for threatened vertebrate fauna species known or of high likelihood to occur within the GV MDE encompassing areas within 30 km of the Survey Area (Regional Survey Area); and
- Follow up ground-truthing and refinement of critical habitat mapping within the Regional Survey Area via appropriate active and remote sampling techniques.

1.3. Legislation & Guidelines

1.3.1. Threatened Fauna (EPBC Act)

Nationally threatened species (flora and fauna) and ecological communities are protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act provides for the identification and listing of species and ecological communities as threatened, development of conservation advice and recovery plans, development of a register of critical habitat, recognition of key threatening processes and the development of threat abatement plans. Listed threatened species and ecological communities are recognised under the EPBC Act as a matter of national environmental significance and must be referred to the Minister and undergo an environmental assessment and approval process if they are likely to be significantly impacted. The categories for listing under the EPBC Act are outlined in Appendix A.

1.3.2. Threatened Fauna (BC Act)

The Western Australian *Biodiversity Conservation Act 2016* (BC Act) provides for the conservation, protection and ecologically sustainable use of biodiversity and biodiversity components in Western Australia. Threatened species (both flora and fauna) and ecological communities that meet the conservation categories listed within the BC Act are protected and require authorisation by the Minister to take or disturb. Species listed as Threatened under the BC Act are publicly listed in the WA Government Gazette with the current list published on the 11 September 2018.

Fauna species may also be listed as being of special conservation interest if they have a naturally low population, restricted natural range, are subject to or recovering from a significant population decline or reduction of range or are of special interest, and the Minister considers that taking may result in depletion of the species. These are known as Specially Protected Species in the BC Act. The conservation categories covering State-listed threatened fauna species are aligned with those listed under the EPBC Act and are outlined in Appendix A.

1.3.3. Priority Fauna (DBCA)

Conservation significant species are listed by the Department of Biodiversity, Conservation and Attractions (DBCA) as Priority species where populations are geographically restricted or threatened by local processes, or where there is insufficient information to formally assign them to threatened fauna categories. Whilst Priority species are not specifically listed in the BC Act, they have a greater level of significance than other native species. The categories covering Priority Fauna species (DBCA 2019) are outlined in Appendix A.

1.3.4. Assessment Guidance

The terrestrial fauna assessment was conducted in accordance with the following Commonwealth and State legislation, as well as the Office of the Environmental Protection Authority (OEPA) requirements for environmental surveys, as outlined below. After the time the Detailed/Level 2 component of this assessment was conducted, the terminology for such surveys was changed from "Level 2" to "Detailed" (EPA 2020).

- *Biodiversity and Conservation Act 2016* (*BC Act*);
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- Technical Guidance: Sampling Methods for Terrestrial Vertebrate Fauna (EPA 2016b);
- Technical Guidance: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA 2020), and
- Technical Guidance: Terrestrial Fauna Surveys (EPA 2016c).

Relevant species-specific survey and assessment guidelines include:

- Survey Guidelines for Australia's Threatened Birds (DEWHA 2010b);
- Survey Guidelines for Australia's Threatened Mammals (DSEWPaC 2011b);
- Survey Guidelines for Australia's Threatened Reptiles (DSEWPaC 2011c);
- Survey Guidelines for Australia's Threatened Bats (DEWHA 2010a);
- Survey Guidelines for Australia's Threatened Frogs (DEWHA 2010c);
- Survey Guidelines for Australia's Threatened Fish (DSEWPaC 2011a);
- EPBC Act referral guideline for the endangered northern quoll *Dasyurus hallucatus* (DEC 2016), and
- Interim guideline for preliminary surveys of night parrot (*Pezoporus occidentalis*) in Western Australia (DPAW 2017).

Survey and other relevant guidelines as provided by IBO were also incorporated into the design of the assessment, as below:

- Terrestrial vertebrate fauna assessment guidelines 100-GU-EN-0006 (Fortescue 2014)
- Environmental Datasets – Data Governance 100-GU-EN-0020 (Fortescue 2012)
- Geographic Information Systems and Raw Data Guidelines 100-GU-EN-0009 (Fortescue 2011)
- Environmental Document Standard Terminology 100-GU-EN-0002 (Fortescue 2010)

600000
650000
700000
750000
800000
7750000
7700000
7650000
7600000
Port Hedland
Marble Bar
Nullagine

Legend

- Survey Area
- North Star Project Boundary
- North Star Stage 2 Area

N

0 5 10 15 20 25 km

Scale 1:720,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: DC Date: 25-06-2021

Survey Area Location

Glacier Valley Project

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IB Operations

MAP
1.1

2. EXISTING ENVIRONMENT

2.1. IBRA Bioregion

The Interim Biogeographic Regionalisation for Australia (IBRA) classifies Australia into regions based on dominant landscape, climate, lithology, geology, landform and vegetation (Thackway and Cresswell, 1995).

The Survey Area is in the Pilbara IBRA bioregion (Figure 2.1) located in the central west of Western Australia. The climate is classified as arid to tropical with very hot summers and mild or warm winters, and a mean average rainfall of between 250-350 mm each year (Kendrick, 2001). The bioregion is geologically complex with great mineral wealth and is also biologically special; there are high levels of species endemism and species-rich ecosystems including persisting populations of threatened and endangered species (McKenzie, May and McKenna, 2003).

The Pilbara Craton is made up of four subregions: the Chichester, Fortescue Plains, Hamersley and Roebourne. The Survey Area is in the northern section of the Pilbara bioregion within the Chichester subregion (Figure 2.1). The Chichester subregion is characterised by undulating Archaean granite and basalt plains with significant areas of basaltic ranges (Kendrick, 2001; McKenzie, May and McKenna, 2003). The plains of this subregion support hummock grasslands characterised by shrub steppe of *Acacia pyrifolia* over *Triodia pungens*. The ranges are dominated by *Eucalyptus leucophloia* tree steppes (Kendrick, 2001; McKenzie, May and McKenna, 2003).

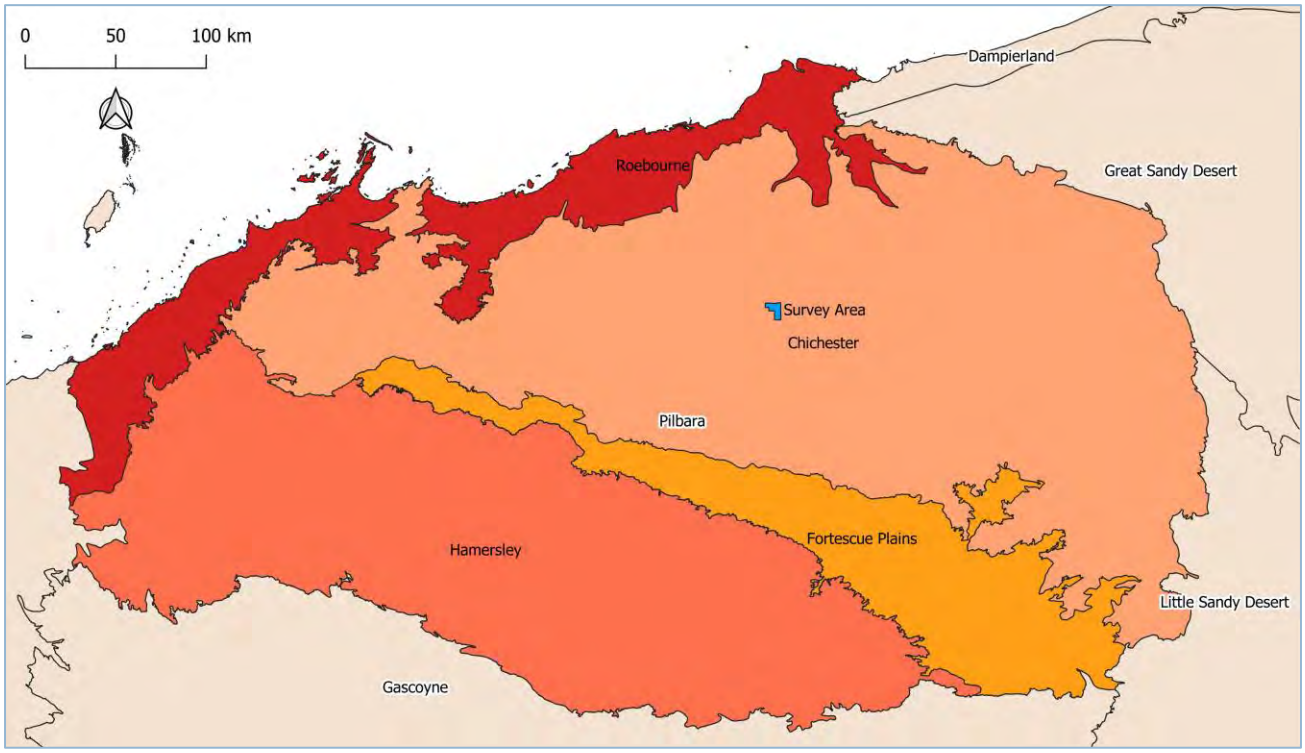

Figure 2.1: IBRA Bioregion

2.2. Climate

Two broad climatic zones occur across the Pilbara region. Semi-desert tropical climatic conditions occur in coastal areas as well as some higher rainfall inland areas, which experience 9-11 months of dry weather with hot humid summers and warm winters. Dry desert climatic conditions occur across the remaining inland areas, which typically experience higher temperatures and lower rainfall, with hot dry summers and mild winters and up to 12 months of dry weather, (Leighton, 2004). The Survey Area is within the dry inland area.

Annual rainfall is highly variable, but generally follows an inland to coastal and southern to northern increasing trend (Leighton, 2004). The driest months are in spring (September to October) with tropical cyclones and local thunderstorms producing much of the summer and early autumn rainfall (Mckenzie, Van Leeuwen and Pinder, 2009). Winter rainfall is also highly variable, generally decreasing from the coast through to inland areas (Leighton, 2004). The climate of the Chichester subregion is semi-desert tropical and receives an average of 300 mm of rain annually.

Monthly maximum temperatures in the Pilbara region range from an average of 25°C in July to 37°C in January, while minimum temperatures range between 12°C in July and 25°C in January (Mckenzie, Van Leeuwen and Pinder, 2009). December and January are the hottest months in inland areas (Leighton, 2004). According to the Köppen-Geiger climate classification, the Survey Area has a hot desert climate (Class BWh) (Peel, Finlayson and McMahon, 2007). This classification includes arid regions where annual evaporation exceeds annual precipitation, and with a mean annual temperate ≥18°C.

Long-term climate data recorded from the nearest Bureau of Meteorology (BOM) station (Marble Bar BOM station #4106) indicates that the Survey Area experiences hot wet summers and dry warm winter temperatures with high rainfall recorded January to March and very little rain consistently across the rest of the year (Figure 2.2). The total rainfall for the 12 months prior to the first and second phase of field survey was 393.6 mm (May to April) and 408.6 mm (October to September) respectively. This is very close to the long-term (2000-2020) annual average of 392.7 mm recorded at Marble Bar.

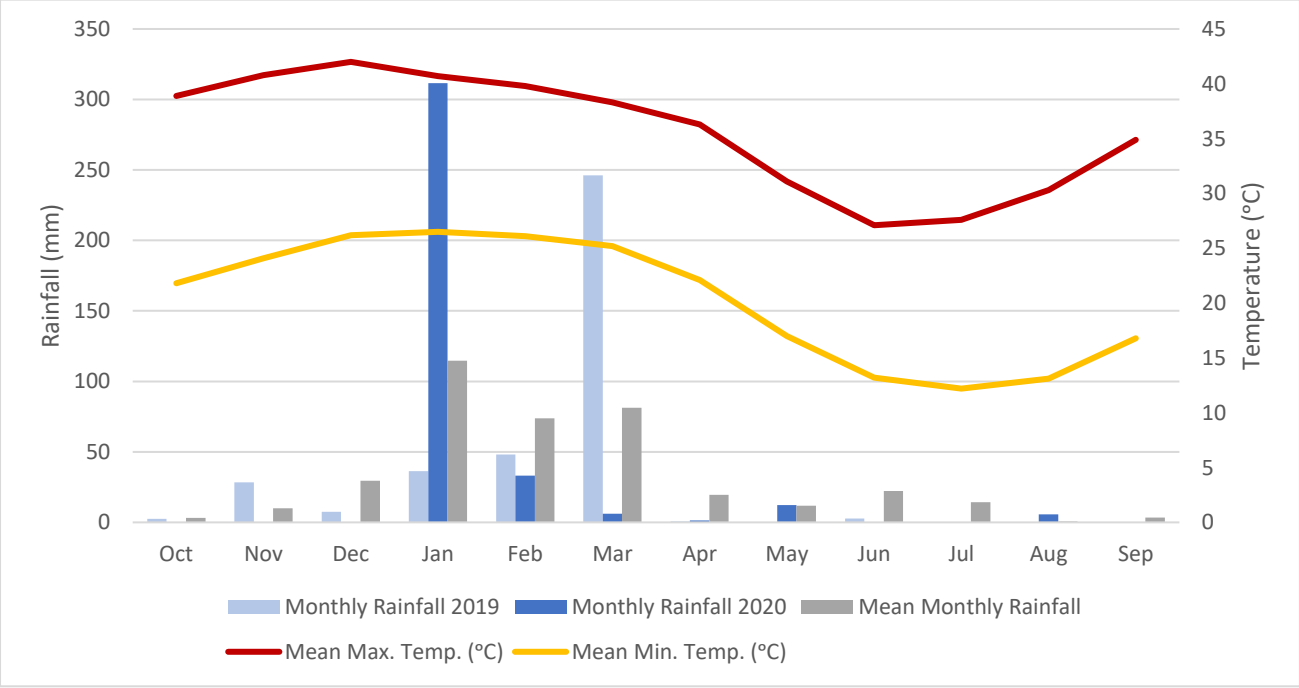

Figure 2.2: Rainfall and Temperature Data for the 12 Months Preceding the Survey (BOM 2020)

2.3. Land Systems

As part of the rangeland resource surveys, the biophysical resources of the Pilbara were comprehensively described and mapped together with an evaluation of the condition of the soils and vegetation (from an agricultural perspective) (Van Vreeswyk *et al.*, 2004). As part of this process, an inventory of land types, land systems and land units with particular use capabilities, habitats or conservation values were established to assist in land use planning. The land systems occurring within the Survey Area are listed in Table 2.1 and displayed in Map 2.1.

The Capricorn land system is the most common, occurring across 42% of the Survey Area. The Rocklea land system is the least well represented, accounting for 26% of the total area. The three land systems are extensive within the Pilbara region and the Survey Area represents less than 3% each of their total respective areas (Table 2.1).

Table 2.1: Land Systems Occurring within the Survey Area

Land System	Description	Area Within Survey Area (Ha)	Proportion of Survey Area (%)	Proportion of total LS Area (%)
Capricorn	Hills and ridges of sandstone and dolomite supporting shrubby hard and soft spinifex grasslands.	2,432	42	0.6
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands.	1,527	26	0.2
Talga	Hills and ridges of greenstone and chert and stony plains supporting hard and soft spinifex grasslands.	1,806	31	2.7

705000
708000
711000
714000
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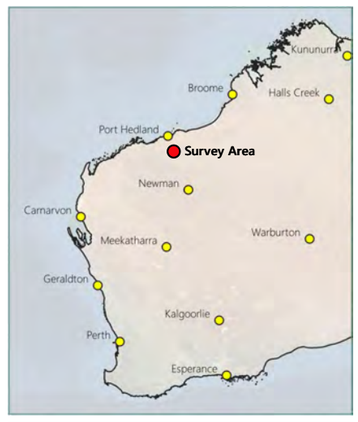
7644000
7641000
7638000

Legend

- Survey Area

Land System

- Capricorn
- Rocklea
- Talga
- Macroy



N

0 0.4 0.8 1.2 km

Scale 1:42,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum

Author: JV Approved: AH Date: 25-06-2021

Land Systems

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MAP
2.1

2.4. Pre-European Vegetation

Pre-European vegetation mapping was originally undertaken by Beard at various scales across the state, and has since been updated to be consistent with the National Vegetation Information System (NVIS) descriptions at a scale of 1:250,000 (DPIRD 2019).

The Survey Area is entirely located within vegetation sub-association 82.1, that is described as *Eucalyptus leucophloia* over *Triodia wiseana* var. *brevifolia* hummock grassland. The vegetation sub-association extents were extracted from the simplified State-wide Vegetation Statistics Report (DBCA 2019a), summarised in Table 2.2 and displayed in Figure 2.3.

Table 2.2: Vegetation Association Mapped within the Survey Area

Sub-association	Area in Survey Area (ha)	% of Survey Area	Pre-European Whole State (ha)	Current Extent State (ha)	% Remaining	% of Current Extent in DBCA Land
82.1	5,765	100	317,182.03	316,855.11	99.90	0

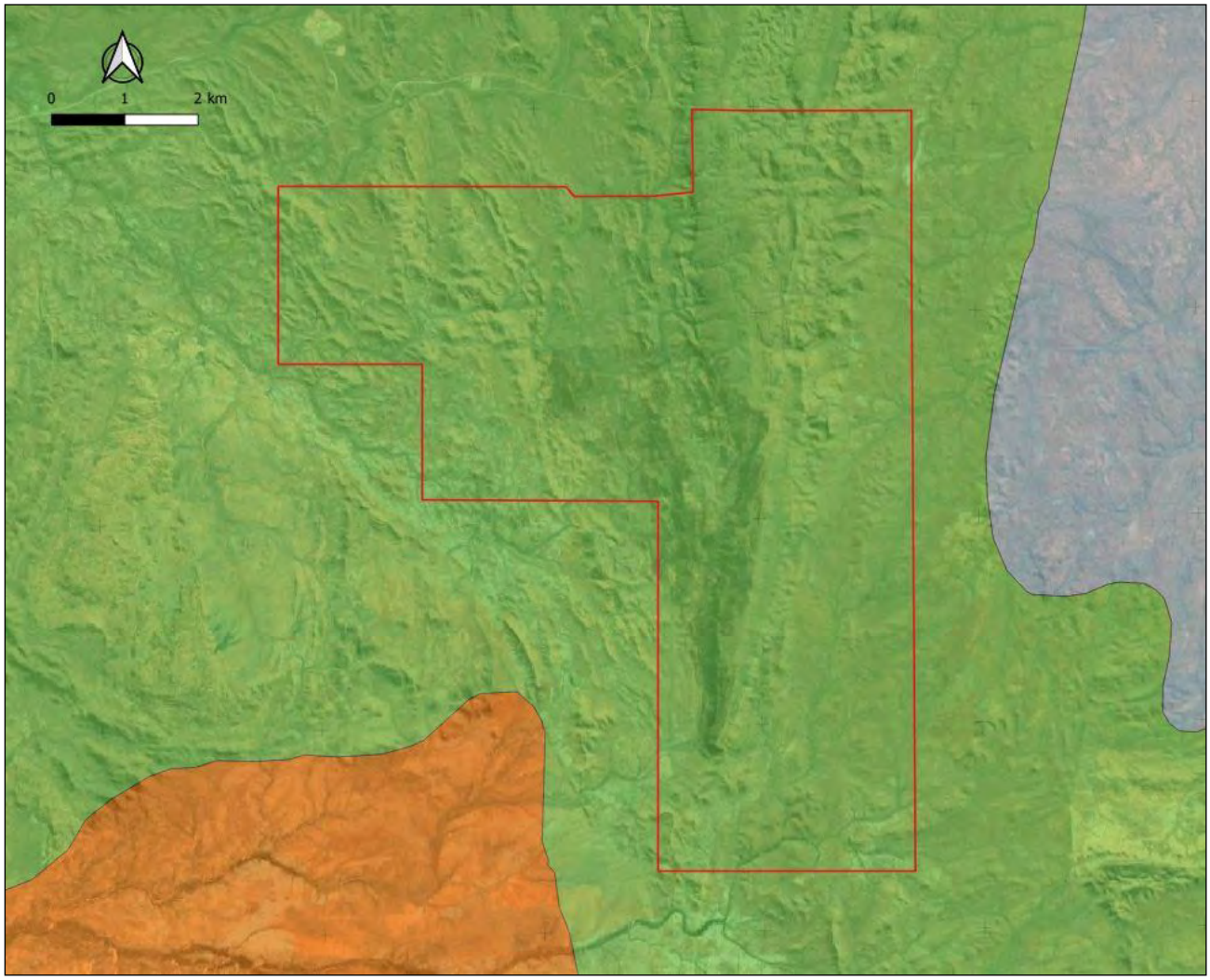

Figure 2.3: Pre-European Vegetation Units

2.5. Geology

The geology of Western Australia has been mapped at a scale of 1:50,000, 1:100,000, 1:250,000 and 1:500,000. The data for this assessment was extracted from the updated 1:500,000 scale dataset released this year by the Department of Mines, Industry Regulation and Safety (DMIRS 2020). The Survey Area consists of eight geological units, the most extensive of which is the Dalton Suite accounting for 22.2% of the total area. The Kangaroo Caves Formation and Leilira Formation compose 21.6% and 19.4% of the Survey Area respectively. Of note is the Leilira Formation that has 18.5% of its total Pilbara extent within the Survey Area. The geological units and their extents are listed in Table 2.3 and shown on Map 2.2.

Table 2.3: Geological Units of the Survey Area (1:500,000)

Formation	Unit	Description	Area in Survey Area (ha)	% of Survey Area	Total Pilbara Extent (ha)	% of Pilbara Extent within Survey Area
Corboy Formation	A-SOc-s	Siliciclastic sedimentary rocks; metamorphosed	139.4	2.4	27,536.4	0.5
Dalton Suite	A-DA-xo-a	Mafic and ultramafic intrusive rocks; metamorphosed	1,278.9	22.2	36,646.9	3.5
Kangaroo Caves Formation	A-SSc-xf-s	Felsic and mafic volcanic rocks, and siliciclastic sedimentary rocks; metamorphosed	1,245.6	21.6	17,519.5	7.1
Kunagunarrina Formation	A-SSk-b	Basaltic rocks with komatiitic basalt; minor komatiite, siliciclastic rocks and chert; metamorphosed	735.4	12.7	10,065.0	7.3
Leilira Formation	A-SSl-s	Siliciclastic sedimentary rocks, minor felsic volcanic rocks, and chert; metamorphosed	1,116.4	19.4	6,040.9	18.5
Pincunah Banded-Iron Member	A-SOap-ci	Banded iron-formation; jaspilitic; minor layered chert and shale; metamorphosed	788.9	13.7	7,479.6	10.5
Strelley Monzogranite	A-CEst-gm	Hornblende--biotite monzogranite and granophyric monzogranite; local diorite, dolerite, and gabbro; metamorphosed	277.0	4.8	18,043.0	1.5
Strelley Monzogranite	A-CEst-od	Dolerite and gabbro; metamorphosed	183.0	3.2	2,469.9	7.4

708000
711000
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7647000
7644000
7641000
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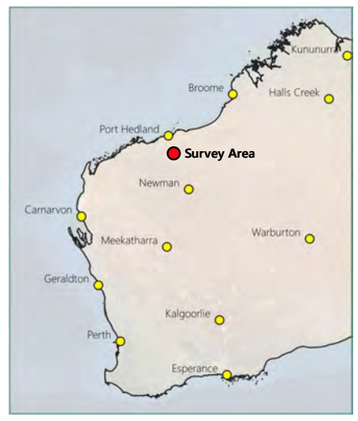
705000

Legend

Survey Area

Geological Units

- Corboy Formation: A-SOc-s
- Dalton Suite: A-DA-xo-a
- Kangaroo Caves Formation: A-SSc-xf-s
- Kunagunarrina Formation: A-SSk-b
- Leilira Formation: A-SSl-s
- Pincunah Banded-Iron Member: A-SOap-ci
- Strelley Monzogranite: A-CEst-gm
- Strelley Monzogranite: A-CEst-od



N

0 0.4 0.8 1.2 km

Scale 1:33,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum

Author: JV Approved: AH Date: 25-06-2021

Geological Mapping

Glacier Valley Project

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IB Operations

MAP
2.2

2.6. Environmentally Significant Areas

2.6.1. Threatened and Priority Ecological Communities

Ecological communities are defined as a naturally occurring group of plants, animals and other organisms interacting in a unique habitat. The complex range of interactions between the component species provide an important level of biological diversity in addition to genetic and species diversity (DBCA 2020). Ecological communities that are at risk are listed by the DBCA as Threatened (TEC) or Priority (PEC) under the EPBC and/or BC Act. The categories are listed and defined in Appendix A.

No TECs or PECs intersect the Survey Area or occur in the immediate region.

2.6.2. Conservation Estates and Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESA) are areas that are defined by the Department of Water and Environmental Regulation (DWER 2019) as:

- a declared World Heritage property as defined in s13 of the EPBC Act 1999;
- an area that is included on the Register of the National Estate, because of its natural heritage value under the Australian Heritage Council Act 2003;
- A defined wetland and the area within 50 m of the wetland;
- The area covered by vegetation within 50 m of Threatened flora, to the extent to which the vegetation is continuous with the vegetation in which the Threatened flora is located;
- The area covered by a TEC;
- A Bush Forever site;
- Areas covered by the Gnangara Mound Crown Land Policy and Western Swamp Tortoise Policy;
- Areas covered by lakes, wetlands and fringing vegetation of the Swan Coastal Plain Lakes Policy, including South West Agricultural Zone Wetlands Policy and Swan and Canning Rivers Policy; and
- protected wetlands as defined in the Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998.

No Conservation Estates or Environmentally Sensitive Areas intersect the Survey Area or occur in the immediate region. The closest Conservation Estate, which is also an ESA, is the Mungaroona Range Nature Reserve located 63 km south-west of the Survey Area.

2.6.3. Australian Wetlands Database

The Australian Wetlands Database includes nationally significant wetlands (as listed in the directory of important wetlands), wetlands listed under the Ramsar convention, wetlands that are representative, rare or unique, or wetlands that are considered of international importance (DoEE, 2019).

No significant wetlands intersect the Survey Area or occur in the immediate region. The Fortescue Marsh south of the Survey Area, and Leslie Saltfields System north of the Survey Area are both listed wetlands, although both are located over 100 km away.

3. METHODS

3.1. Desktop Assessment

Three public databases and a total of 16 previous survey reports were accessed to provide information to support the current assessment (Table 3.1). Several terrestrial fauna assessments, and ongoing conservation significant fauna monitoring projects have been completed in the region surrounding the Survey Area, which provide supplementary baseline data and regional context. Details of the completed database searches are listed in Appendix B. The vertebrate fauna values of the previous surveys are summarised in Table 4.1 and survey details are listed in Appendix C.

Table 3.1: Database Search Details

Custodian	Database	Species Group	Search Details
Department of Agriculture, Water and the Environment	Protected Matters Search Tool	EPBC Listed Vertebrate and Invertebrate Fauna Species	Date: 23/09/2020 Buffer: 40 km Coordinates: -21.31222 119.05583
Department of Biodiversity, Conservation and Attractions	NatureMap	Vertebrate Fauna Species	Date: 22/09/2020 Buffer: 40 km Coordinates: 119°03'23"E 21°18'44"S
	Threatened Fauna Database Search	Threatened and Priority Vertebrate and Invertebrate Fauna Species	Date: 25/03/2020 Buffer: 40 km of Survey Arrea

3.2. Conservation Significant Fauna

The results of the literature review (detailed in the regional fauna list – Appendix C) identified fauna species that are listed under current legislative frameworks. Three conservation lists have been developed at national (EPBC Act) and State level (BC Act and DBCA priority list) (Appendix A).

The likelihood of a conservation significant fauna species being present within the Survey Area was determined by examining the following:

- Suitability of fauna habitats known to exist within the Survey Area;
- Distribution of previously recorded conservation significant species;
- Frequency of occurrence of conservation significant species records in the region;
- Detectability of conservation significant species based on specific behavioural and ecological characteristics; and
- Temporal distribution of conservation significant species records, taking previous survey effort into consideration.

Each conservation significant species potentially occurring in the Survey Area, was assigned a likelihood of occurrence based on the below categories (Table 3.2). In accordance with the precautionary principal, the level of available information for each species was also taken into consideration so that species are not allocated a low likelihood of occurrence because of insufficient survey information.

Table 3.2: Criteria to Assess Likelihood of Occurrence

Likelihood	Criteria
Recorded	Species recorded within the Survey Area within the previous ten years.
High	Species recorded within or in proximity to the Survey Area within the previous 20 years. Suitable habitat occurs in the Survey Area.
Medium	Species recorded within or in proximity to the Survey Area more than 20 years ago. Species recorded outside the Survey Area but within 40 km. Suitable habitat occurs in the Survey Area.
Low	Species rarely or not recorded within 40 km of the Survey Area. Suitable habitat does not occur within or in proximity to the Survey Area.
Very Low	Species not recorded within 40 km despite multiple recent surveys. Suitable habitat does not occur within the Survey Area. Species considered locally extinct.

3.3. Determination of Survey Design

3.3.1. Previous Survey Effort and Timing

The desktop assessment identified 16 previous surveys of relevance. Of these, eight were completed close to (within 25 km) the Survey Area and the remaining eight were completed in the wider region. The results of these surveys were collated to generate a detailed inventory of the vertebrate fauna known to occur near the Survey Area and in the surrounding region. Details of each survey are provided in Appendix B.

Survey effort from three previous Detailed (Level 2), one Basic (Level 1) and four Targeted vertebrate fauna assessments that were completed within or adjacent to the Survey Area, were considered relevant to the current assessment. Of these, four previous vertebrate fauna survey areas overlap with the current Survey Area (Table 3.3), with survey effort consisting of nine opportunistic sites, two targeted Northern Quoll trapping sites, 119 motion camera sites and 36 bat recorder sites. Conservation significant fauna monitoring for Northern Quoll, Pilbara Olive Python and Pilbara Leaf-nosed Bat has been completed at the North Star Mine (2014-2020), immediately north of the Survey Area. Eight of the bat recorder sites, three long-term motion camera sites and two Northern Quoll trapping sites are also located within the northern section of the current Survey Area.

Two of the three Detailed (Level 2) trapping surveys were multi-phase, with surveys completed in both spring and autumn (post wet season) as per the Technical Guidance (Environmental Protection Authority, 2016a, 2016b, 2020). The remaining Detailed (Level 2) survey was single-phase, completed in spring (360 Environmental, 2016). The survey timing of the Basic (Level 1) and Targeted surveys also meet current terrestrial fauna assessment guidance (Environmental Protection Authority, 2016b, 2016a, 2020).

The locations of previous survey sites relevant to the current survey (where available) are shown on Map 3.1.

Table 3.3: Previous Survey Effort and Timing

Project / Report	Survey Type	Survey Timing	Site Type							
			Distance from Survey Area	Trapping Grid	Opportunistic Search	Targeted NQ Trapping	Targeted POP Search	Bird Survey	Motion Camera	Bat Recorder
North Star Project Targeted Conservation Significant Fauna Survey (ecologia 2011)	Targeted	29 March – 9 April 2011 5 – 7 July 2011 22 – 30 July 2011	Overlaps northern areas		14	17	17		34	25
Atlas Iron Limited Abydos DSO Project Terrestrial Vertebrate Fauna Baseline Survey (Outback Ecology, 2011a)	Level 2 (2 phase)	29 April – 10 May 2010 3 – 12 September 2010	16 km NNE	4	4			4		16
North Star Project Level 2 Terrestrial Vertebrate Fauna Assessment (ecologia 2012b)	Level 2 (3 phase)	29 March – 9 April 2011 10 – 21 October 2011 25 October – 5 November 2011	Adjacent N	16	27			16		16
FMG North Star Project Pilbara Leaf-nosed Bat Colony Survey (Bullen, 2013)	Targeted	7 – 13 April 2013	Overlaps northern areas							18
North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment (ecologia 2015c)	Level 1	22-26 August 2015	2 km E		19				13	

Project / Report	Survey Type	Survey Timing	Site Type							
			Distance from Survey Area	Trapping Grid	Opportunistic Search	Targeted NQ Trapping	Targeted POP Search	Bird Survey	Motion Camera	Bat Recorder
Pilgangoora Baseline Vertebrate Fauna Survey (360 Environmental, 2016)	Level 2 (1 phase)	8-18 March 2016	23 km NNW	6	25			6	20	
Conservation Significant Fauna Monitoring 2014-2018 (ecologia 2014a; Ecoscape 2016d, Ecoscape 2017a, Ecoscape 2018)	Targeted	2014-2018	Overlaps northern areas			8	8		18	24
Conservation Significant Fauna Monitoring 2018-2020 (Spectrum 2019a, Spectrum 2020d, Spectrum 2020c)	Targeted	2019-2020				4	8		58	4
Glacier Valley and South Star Fauna Surveys Fauna Survey Report (GHD, 2020)	Targeted	9-13 May 2018 5-7 June 2018 3-6 July 2018 8-10 August 2018 21-24 January 2019 26-28 February 2019	Overlaps northern areas		7				115	29

690000 700000 710000 720000 730000 740000

7670000 7660000 7650000 7640000 7630000

Legend

Survey Area

Pilgangoora Lvl 2 (360 Env 2016)
- Motion Camera
- Systematic Trapping Site

North Star Lvl 2 (ecologia 2011)
- Motion Camera
- Systematic Trapping Site

North Star Targeted (ecologia 2011)
- Motion Camera
- Bat Recorder
- Opportunistic Site
- Northern Quoll Trapping Site

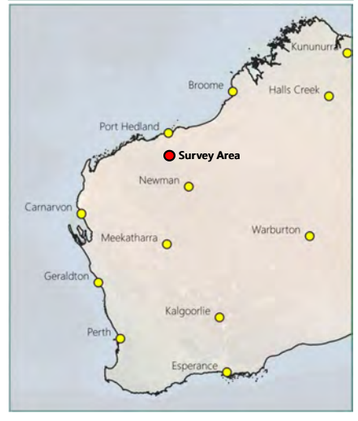
North Star Fauna Monitoring (ecologia 2014-2015, Ecoscape 2015-2018, Spectrum 2018-
- Long Term Motion Camera
- Bat Recorder
- Northern Quoll Motion Camera
- Pilbara Olive Python Site
- Northern Quoll Trapping Site (2014)
- Northern Quoll Trapping Site (2020)

North Star Targeted PLNB (Bullen 2013)
- Bat Recorder

North Star Aerodrome Lvl 1 (2015)
- Motion Camera
- Opportunistic Site

Glacier Valley Targeted (2018-2019)
- Motion Camera
- Bat Recorder
- Opportunistic Site

Abydos DSO Lvl 2 (2010)
- Bat Recorder
- Systematic Trapping Site



N

0 1 2 3 4 5 6 km

Scale 1:170,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: AH Date: 25-06-2021

Survey Effort - Previous Surveys

Glacier Valley Project

Prepared for
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MAP
3.1

3.3.2. Factors Likely to Influence Survey Design

Prior to the development of the survey methods, a review was undertaken of factors likely to influence the design and intensity of the field survey (Table 3.4).

Table 3.4: Factors Likely to Influence Survey Design

Factor	Relevance
Bioregion – level of existing survey/knowledge of the region and associated ability to predict accurately.	The Pilbara region has been extensively surveyed over the past decade with a general expansion in the detailed knowledge of the vertebrate faunal assemblages that occur in the region. The range associated with Glacier Valley and the Abydos Plain have been extensively sampled as part of mining and associated infrastructure environmental impact assessments. Much of the data is accessible online or via database search requests. The data is adequate to predict fauna assemblages and the likelihood of occurrence of conservation significant species.
Landform special characteristics/specific fauna/specific context of the landform characteristics and their distribution and rarity in the region.	The landforms of the Survey Area are typical of the region and consist of ranges and stony hills. Several minor drainage lines run through the Survey Area. All landforms are considered common throughout the surrounding region.
Lifeforms, life cycles, types of assemblages and seasonality (e.g. migration) of species likely to be present.	The Pilbara region is considered arid and most fauna life cycles are significantly influenced by rainfall. Population increases, the influx of nomadic species and the onset of breeding activity is directly affected by rainfall in many taxa. Temperature also influences activity levels, with reptiles and amphibians being most active during warm wet periods.
Level of existing knowledge and results of previous regional sampling (e.g. species accumulation curves, species/area curves).	The results of 16 vertebrate fauna surveys were available to provide regional context to the current assessment. Eight previous surveys have been completed within 25 km of the Survey Area, including three Detailed (Level 2) vertebrate trapping surveys. A comprehensive Detailed survey (three phases), Targeted conservation significant fauna surveys and ongoing fauna monitoring surveys have been completed as part of the North Star Project located immediately north of the current Survey Area. Some overlap of sites occurs with the current Survey Area. Regional and local knowledge for the area is detailed, highly comparable and available for inclusion.
Number of different habitats or degree of similarity between habitats within a study area.	Four fauna habitat types were initially identified based on staff experience with the region, previous habitat mapping, land systems and vegetation units.
Climatic constraints (e.g. temperature or rainfall that preclude certain sampling methods).	The Pilbara region experiences hot summers with occasional cyclonic rain events, followed by warm winters with little rain although rainfall is considered to be highly unpredictable. Field surveys are generally conducted in Autumn and Spring to avoid climatic events that may preclude sampling. No climatic constraints were expected to influence the field surveys, and extensive data from previous surveys provides information to cover any survey gaps experienced.
Sensitivity of the environment to the proposed activities.	The Survey Area contains habitat types which are well represented in the surrounding region. Highest impacts are associated with the areas of mining and associated infrastructure. Prior assessments completed as part of the North Star project provided broad baseline knowledge of the area.
Size, shape, and location of the proposed activities.	The Survey Area, located approximately 100 km south of Port Hedland, is part of a proposed extension of the North Star Mine currently in construction. The Survey Area is located south of North Star and occupies both the same ridge as the existing mine and areas of lower hills to the east, west and south.
Scale and impact of the proposal.	The Survey Area is part of a proposed extension of the approved North Star Mine located to the north. The impact of the extension will be associated with open pits, access roads, infrastructure, and waste dumps.

3.4. Field Survey Methods

Spectrum Ecology completed a two-phase Detailed (Level 2) terrestrial vertebrate fauna survey and a Targeted Northern Quoll survey as part of the current assessment. All methods followed the state and federal legislation and guidelines listed in section 1.3. Systematic sampling methods include standardised repeatable survey techniques that provide data that can be statistically analysed to measure survey adequacy. Opportunistic surveys include a selection of supplementary sampling techniques that can detect species that may not be detected during systematic sampling. The combination of sampling methods allows for the accurate identification of local fauna assemblages present at the time of sampling. Detailed descriptions for each sampling method are described below.

3.4.1. Systematic Sampling

3.4.1.1. Vertebrate Fauna Systematic Site

Fauna trapping sites include a suite of trapping techniques designed to detect the local terrestrial fauna assemblage. The trapping grids used during the field survey include the following:

- 20 L bucket and 50 cm PVC pipe pitfall traps: A trapping grid comprised of 10 alternating buckets and PVC pipes, dug into the ground to act as pitfall traps. A 10 m long, 30 cm high fence was also installed, passing across the top of each pit to direct fauna into it.
- Fraser-type funnel traps: Similar to yabbie traps, these were placed at the ends of each fence to capture fauna that are not readily caught in pitfall traps (20 per trapping grid). All funnel traps were covered with shades to reduce the likelihood of animals suffering from overheating.
- Elliott traps: Aluminium box traps were baited with 'universal bait' to attract and capture smaller mammals (10 per trapping grid) and re-baited as required. All Elliott traps were covered by shades to reduce the likelihood of animals suffering from overheating.
- Cage traps: Larger wire-frame box traps, also baited with 'universal bait', to capture medium-sized mammals (2 per trapping grid) and re-baited as required. All cage traps were covered by shades to reduce the likelihood of animals suffering from overheating.

The layout of each site is detailed diagrammatically in Figure 3.1. Trapping grids were set up in each major fauna habitat where possible, with each trapping grid surveyed over a seven-night period.

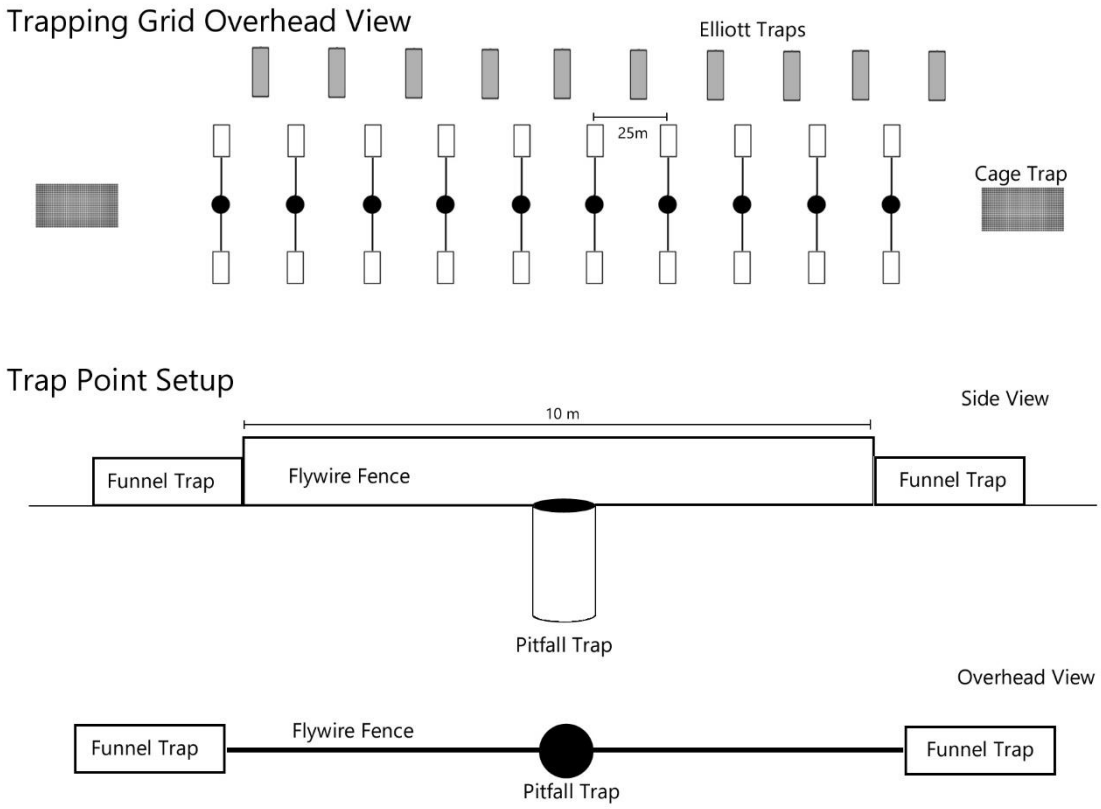


Figure 3.1: Diagram of standardised systematic fauna trapping grid layout

Bird Surveys: Area searches (20 minute set-time searches of 2 ha areas) were used to document the bird assemblage present at each of the systematic fauna trapping sites. During each area search an ornithologist recorded the number of individuals of each species observed while actively searching similar habitat within a 2 ha area surrounding the trapping site. Survey effort was concentrated within three hours of dawn or dusk, as these times are considered optimal for recording most bird species.

Bat Surveys: The SM4BAT device records the full spectrum of calls allowing greater accuracy and sensitivity when identifying bat species. Each SM4BAT device was programmed to record from 30 minutes pre-dusk to 30 minutes post-dawn for each night that was surveyed. Bat recorders were deployed in areas of suitable habitat at GHD's direction in an effort to locate Pilbara Leaf-nosed Bat and Ghost Bat roost caves. Further recorders were installed by GHD during the Targeted bat surveys, the recordings of which were analysed to identify the local bat assemblage.

3.4.2. Opportunistic Sampling

One limitation of systematic sampling sites is that some species are difficult to detect due to cryptic behaviours or other ecological considerations, such as fossorial or arboreal species. Systematic survey techniques were therefore supplemented with a suite of opportunistic sampling techniques that target specific species and habitats not normally covered by systematic trapping sites. Target groups and their associated active survey techniques are listed below:

- Reptiles and amphibians: Minimum 20 minute searches of 1 ha areas within the Survey Area by an experienced herpetologist. Microhabitats favoured by reptiles and amphibians were searched using various techniques including the raking of leaf litter and soil under shrubs, searching amongst rock piles, and searching under and inside fallen timber.
- Birds: Area searches (20 minute set-time searches of 2 ha areas) were used to document the bird assemblage present at bird-specific habitats, or habitats not already surveyed at systematic trapping sites. Bird species opportunistically observed inside the Survey Area that were not typically recorded during set time searches were also recorded, such as raptors, water birds and nocturnal species.
- Mammals: Mammals observed opportunistically within the Survey Area were also recorded. Tracks, scats and other traces of mammals were recorded and identified, where possible. Suitable cave structures and surface water pools were targeted using additional SM4BAT acoustic devices to record the potential presence of bat species.
- Motion cameras: Motion sensitive cameras capable of recording both normal (day) and infra-red (night) images were set up in areas of high fauna interest, such as caves, gorges, or near permanent water, to record cryptic species not typically observed during field surveys.

3.4.3. Conservation Significant Fauna

Several species listed under the EPBC Act and gazetted under the BC Act were identified during the desktop assessment as having a medium to high likelihood of occurrence in the Survey Area. These were specifically targeted using the following field survey techniques, whilst all other species were targeted using the methods mentioned above.

- Northern Quoll (*Dasyurus hallucatus*): Northern Quolls were previously recorded within the Survey Area and the areas immediately adjacent (ecologia Environment, 2011; GHD, 2020; Spectrum Ecology, 2020a). To target the species, Spectrum Ecology installed baited (non-food, fish-oil soaked cotton rope) long-term motion cameras (Reconyx HF2X & HP2X) and installed three cage trap sites (totaling 60 cages) within suitable habitat across the Survey Area. The cameras were deployed in May 2020 and retrieved during the Targeted survey in July 2020 (approx. six weeks post installation). The results of the motion camera survey were used to select the trapping sites that were installed to investigate population size present on site (including the presence or absence of a breeding population).
- Ghost Bat (*Macroderma gigas*) | Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*): Spectrum Ecology completed targeted searches for caves, and any found were assessed to determine their suitability as a roost site for each bat species (as per Cramer *et al.*, 2016). SM4BAT recorders were then deployed at selected sites as advised by GHD. A Targeted survey was also completed separately by GHD (Appendix G). The survey included habitat assessments, roost emergence surveys, bat call survey and analysis, and the use of harp traps.
- Pilbara Olive Python (*Liasis olivaceus barroni*): Pilbara Olive Pythons have been recorded from both within and immediately adjacent to the Survey Area, during previous surveys and Fortescue's ongoing conservation significant fauna monitoring program since 2011 (ecologia 2011; GHD, 2020; Spectrum 2020a). Searches for this species were conducted simultaneously with Northern Quoll searches, as these species typically occur in the same habitat (rocky gorges, escarpments, major drainage systems).
- Grey Falcon (*Falco hypoleucos*), Peregrine Falcon (*Falco peregrinus*) and Migratory Shorebirds: There is potential breeding and foraging habitat for the two Falcons which may occur within the Survey Area. In particular, the rocky ridges and associated cliffs represent potential breeding habitat for the Peregrine Falcon. The larger trees associated with drainage lines may also represent nesting habitat

for Grey Falcon, although the species is known to favour open plains rather than the ranges and hills that were found within the Survey Area. Migratory shorebirds prefer pools associated with wetlands, large rivers, and clay pans, but these habitats are not expected to be present within the Survey Area, even after significant rainfall. Conservation significant bird species were targeted during all surveys and any opportunistic sightings were recorded.

3.4.4. Site Selection

Prior to the current survey, information was considered from the previous three-phase Detailed (Level 2) vertebrate fauna survey completed as part of the North Star Mine approvals process (ecologia Environment, 2012b), as well as habitat and species data collected during ongoing conservation significant fauna monitoring (ecologia Environment, 2014a; Ecoscape (Australia), 2016d, 2017a, 2018; Spectrum Ecology, 2019b, 2020d, 2020c). The most likely broad fauna habitat types, and areas of interest for conservation significant fauna species were then selected, based on the results of the above assessments, to ensure adequate sampling of all habitats.

Survey sites were established across all habitat types. Systematic trapping sites were restricted to two of the four broad habitat types identified due to a combination of recent fire and an inability to install pit traps in areas with significant exposed bedrock and outcropping.

Site selection for the Targeted Northern Quoll survey was based on long-term motion camera results and the observations of Spectrum Ecology staff made while completing Targeted Northern Quoll surveys within the North Star survey area located north of Glacier Valley. Pilbara Olive Pythons were targeted via opportunistic surveys in areas of suitable habitat during the Targeted survey and both phases of Detailed (Level 2) survey.

Details and locations of all survey sites are listed in Appendix D and displayed on Map 3.2 and Map 3.3 as well as Appendix G.

3.4.5. Survey Effort

The vertebrate fauna survey outlined in this report was consistent with a Detailed (Level 2) survey as described in Technical Guidance: Terrestrial Fauna Surveys (EPA 2016c, EPA 2020) and Technical Guidance: Sampling Methods for Terrestrial Vertebrate Fauna (EPA 2016b). Four systematic vertebrate fauna trapping sites were surveyed over seven nights during both phases of the vertebrate fauna survey. A minimum of four systematic bird surveys (total of 2 hours) were also completed at each of the trapping sites during both phases.

A Targeted Northern Quoll trapping survey was also completed across three survey sites (20 cage traps per site) for 7 nights as per the referral guideline (DoE 2016). Pilbara Olive Pythons were surveyed at 15 general opportunistic sites during the Detailed (Level 2) surveys and a further three sites were searched during the Targeted survey. A Targeted survey for Pilbara Leaf-nosed Bats and Ghost Bats was completed (Appendix G), incorporating ultrasonic bat detectors at 11 sites within the Survey Area and 16 sites within the regional Study Area, acoustic bat recorders at three sites within the Survey Area, roost emergence surveys at one location within the Survey Area and three locations within the regional Study Area and harp trapping at one location within the Survey Area and three locations within the regional Study Area. Roost habitat surveys were conducted at two sites within the Survey Area and 54 locations in the regional Study Area. Results discussed in this report relate to activities within the Survey Area.

Although not specifically included in this report, SRE invertebrate fauna were simultaneously surveyed using six wet pitfall sites that remained open for approximately six weeks. Vertebrate by-catch from the wet pitfall trapping program was included in this assessment (Appendix E).

A summary of the survey effort undertaken is detailed in Table 3.5 with the survey effort completed in each fauna habitat type detailed in Table 3.6. During both phases of the Detailed (Level 2) surveys, the following survey effort was completed to determine the fauna assemblage present within the Survey Area:

- A total of four vertebrate fauna trapping grids were surveyed over two phases totaling 448 trap nights;
- 16 hours were spent conducting 48 systematic bird surveys;
- 26 hours of opportunistic searches;
- 20,880 motion camera trap hours at 22 sites; and
- 288 hours of bat recordings from eight sites were analysed.

A summary of targeted survey effort for conservation significant fauna species included, but was not limited to:

- Northern Quoll and Pilbara Olive Python:
  - 26 hours were spent opportunistically searching for individuals and secondary evidence in rocky habitats and along drainage lines.
  - Cage traps targeting Northern Quoll in Rocky Escarpments, and Gorges and Gullies habitat totaled 420 trap nights.
  - Baited (non-food, fish-oil soaked cotton rope) motion cameras were deployed at 22 locations over a total of 20,880 hours.
- Pilbara Leaf-nosed Bat/Ghost Bat:
  - Roost emergence surveys, bat recordings (ultrasonic and acoustic), harp trapping and roost habitat surveys were completed within the regional Study Area (Appendix G):
  - A total of 25 trap nights spent harp trapping at four sites (one site within the Survey Area and three sites within the regional Study Area);
  - A total of 15 hours of roost emergence surveys were completed across four sites - one within the Survey Area and three within the regional Study Area. Surveys utilised one or two observers, one IR video camera (coupled with an IR lamp) and one ultrasonic recorder per site;
  - 1,958 hours of ultrasonic bat recordings from 27 sites (11 within the Survey Area and 16 within the regional Study Area) were analysed for threatened bat species calls;
  - 108 hours of acoustic recordings from three sites within the Survey Area were analysed for threatened bat species calls; and
  - 56 roost habitat surveys including two within the Survey Area.
- Peregrine Falcon and Grey Falcon:
  - 16 hours of bird surveys were completed at the systematic trapping sites, although birds are opportunistically recorded at all sites and while traversing the Survey Area.

Table 3.5: Survey Effort Completed Within the Survey Area

Survey	Survey Timing	Person Days	Trap Nights					Survey Effort (hrs)				
			Pit Traps	Funnels	Elliotts	Cages	Harp Traps	Opportunistic Searches	Bird Surveys	Bat Ultrasonic and Acoustic Recorders	Dawn and Dusk surveys	Motion Cameras
Phase 1	14-25 May 2020	34	224	560	140	56	-	10	8	288	-	20,640
Targeted	7-18 July 2020	20	-	-	-	420	-	6	-	-	-	-
Phase 2	6-15 Oct 2020	20	224	560	140	56	-	10	8	-	-	240
Targeted Bats* (GHD)	19-25 Aug 2020 7-11 Sep 2020 22-29 Oct 2020	61	-	-	-	-	25	56	-	1,958	15	-
Total		135	448	1,120	280	532	25	92	16	2,246	15	20,880

* Includes survey effort completed in the regional Study Area

Table 3.6: Survey Effort by Habitat Type Completed Within the Survey Area

Habitat type	Trap Nights					Survey Effort (hrs)				
	Pit Traps	Funnels	Elliotts	Cages	Harp Traps	Opportunistic Searches	Bird Surveys	Bat Ultrasonic and Acoustic Recorders	Dawn and Dusk surveys	Motion Cameras
Hills, ranges and plateaux	336	840	210	84	-	13	12	988	-	5,160
Rocky escarpments	-	-	-	287	-	2	-	350	-	9,288
Gorges and gullies	-	-	-	133	8	8	-	856	7.5	5,400
Minor drainage lines	112	280	70	28	-	5	4	52	-	1,032
Total	448	1,120	280	532	8	28	16	2,246	7.5	20,880

708000
712000
716000
720000
7644000
7640000
7636000

Legend

Survey Area

Site Types

- Fauna Trapping Site
- Opportunistic Site
- Birding Site
- Motion Camera
- Northern Quoll Trap Location
- Targeted POP Site

* Habitat assessments conducted at all sites

N

0 0.5 1 1.5 km

Scale 1:42,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: NP Approved: AH Date: 28-02-2023

Survey Effort

Glacier Valley Project

MAP 3.2

Prepared for
IB Operations

708000
712000
716000
720000
7644000
7640000
7636000

Legend

Survey Area

Survey Methods

- Bat acoustic recorder
- Ultrasonic bat detector
- Emergence survey
- Harp Trap

N

0 0.5 1 1.5 km

Scale 1:42,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: NP Approved: AH Date: 25-06-2021

Survey Effort - Targeted Bat Survey

Glacier Valley Project

Prepared for
IB Operations

MAP
3.3

3.4.6. Survey Timing

The first phase of surveying was completed from the 14 – 25 May 2020, and the second phase from the 6 – 15 October 2020. A separate Targeted conservation significant fauna survey was also completed from the 7 – 18 July 2020. The targeted bat surveys were completed by GHD from 19-25 August 2020, 7-11 September 2020 and 22-29 October 2020 (Appendix G).

The Survey Area is located within the Eremaean Botanical Province, as described by Beard (Beard, 1980). The Technical Guidance (EPA 2016b, EPA 2020) recommends terrestrial fauna surveys in this region be completed between September and April (the period of highest reptile activity), preferably immediately after the heaviest rainfall events (the rain season) to coincide with peak amphibian and bird activity. There is no recommendation on survey timing for mammals.

Though the timing of the first phase of the survey fell just outside of the peak period of activity, the Technical Guidance also states that some compromise in timing may be required from a logistical or animal welfare perspective, to avoid the risk of extreme weather (e.g. flooding, high temperatures, cyclones). The second phase of the survey was completed during peak activity and within the recommended period, although high temperatures raised animal welfare concerns. To avoid the death or unnecessary stress of captured fauna, all traps were closed during the morning clearance and reopened in the afternoon once temperatures had dropped to a safe level.

3.4.7. Taxonomy and Nomenclature

Nomenclature for mammals, birds, reptiles, and amphibians followed the Western Australian Museum's *Checklist of the Vertebrates of Western Australia* (April 2020). Fauna species identifications were completed using the below references (Table 3.7).

Table 3.7: Species Identification References

Fauna Group	References
Mammals	Churchill (2009), Menkhorst and Knight , van Dyck and Strahan (2008)
Birds	Menkhorst *et al.* (2019), Simpson and Day (2017)
Reptiles & Amphibians	Wilson and Swan (2021), Cogger (2014), Tyler and Doughty (2009)

3.4.8. Bat Call Analysis

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:

- 1. Data files were downloaded from the units and saved to an external hard drive following the survey for processing and analysis
- 2. 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
- 3. For each night data was manually reviewed for bat calls using Kaleidoscope Pro or Anabat Insight from sunset onwards for approximately 45 mins 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 (see species descriptions below and McKenzie and Bullen 2009 and 2012).

- 4. Data was then processed using Wildlife Acoustic Kaleidoscope signal parameter batch processing. Further manual data review was also completed for validation purposes which was repeated several times to accurately identify species.
- 5. 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.

Steps 3 and 4 were completed for all nights for Pilbara Leaf-nosed Bats however due to the constraints associated with automating the analysis of Ghost Bat calls (due to complexity of vocalisations) additional validation was necessary. A sample of 14109 files from 15 sites was sent to an expert on Ghost Bat vocalisations (N. Hanrahan) for review, including files with possible Ghost Bat social calls derived from the above review process and a random number of files from a random selection of sites. Validation of these calls was aligned with the process detailed in Hanrahan *et al.*, (2021).

A call (pass) was defined as a sequence of three or more consecutive pulses of similar frequency and shape over a period of one second with the exception of the Pilbara Leaf-nosed Bat where at least one clear pulse 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 (Mills *et al.*, 1996; Duffy *et al.*, 2000) during the manual validation process (see Appendix G).

Pilbara leaf-nosed Bat: Echolocation calls are distinctive, having a CF-FM (constant frequency - frequency modulated) structure, and with a characteristic frequency between 117 and 125 kHz (DAWE 2020a). The mean characteristic frequency of the loudest (second) emitted harmonic is 121 kHz in the Pilbara, which is around 6 kHz higher than in the northern distribution of the species. Each pulse consists of a constant frequency tone of c. 8 milliseconds duration, followed by a very brief broadband downwards sweep through c. 20 kHz (Armstrong and Coles, 2007). It is possible to identify the species unambiguously from good quality echolocation calls

Ghost Bat: Ghost Bats make several social calls that are audible to humans ('chirps', 'squabbles' and 'twitters' (Kulzer *et al.*, 1984; Guppy, Coles and Pettigrew, 1985; Pettigrew *et al.*, 1986)). When free flying, echolocation calls are characterised by steep linear frequency modulated pulses at 45-56 kHz, of low intensity and short duration (0.8-2.3 ms) (Guppy, Coles and Pettigrew, 1985). Echolocation calls have up to four harmonics but most of the strength is in the 2nd or 3rd harmonic (Guppy, Coles and Pettigrew, 1985). More recently studies (Hanrahan, 2020; Hanrahan *et al.*, 2021) reviewed and revised the social vocalisations of the species as 'chirp-trill', 'squabble' and 'ultrasonic social'.

3.4.9. Animal Ethics

Any disturbance of animals caused by the various capture or sampling methods detailed in the previous sections followed the state and federal legislation and guidelines listed in section 1.3. The survey methods and animal handling protocols also followed the DBCA Standard Operating Procedures (SOPs) listed below (DBCA 2019b):

- Aluminium Box Traps for Capture of Terrestrial Vertebrates
- Cage Traps for Live Capture of Terrestrial Vertebrates
- Dry Pitfall Trapping for Vertebrates
- Funnel Trapping for Terrestrial Fauna
- Animal Handling and Restraint using Soft Containment
- Hand Capture of Wildlife

- Hand Restraint of Wildlife
- Transport and Temporary Holding of Wildlife

Survey timing is also a significant factor when considering animal welfare. The survey must be completed at a time when the target fauna groups are active and detectable though not during periods when extreme weather events are likely. High temperatures and flooding can lead directly to fauna stress and/ or death either directly or indirectly by restricting access to trapping sites. Vertebrate fauna was only handled as necessary for the purposes of species identification and the collection of morphometric data, where required.

3.4.10. Survey Team and Licenses

The project team members and their associated roles are detailed in Table 3.8. The field surveys were completed under Regulation 27 license BA27000255, and authorisation to take or disturb threatened species license TFA 2020-0071. GHD's Targeted bat surveys were completed with GHD Animal Research Authority approval (ARA 12517457) and the Department of Biodiversity, Conservation and Attractions, Authorisation to take of disturb threatened species (Authorisation number TFA 2020-0023).

Table 3.8: Project Team

Staff	Role	Years of Experience
Spectrum Ecology Staff		
Damien Cancilla	Reporting	14
Astrid Heidrich	Field assessment, reporting, data analysis	12
Jordan Vos	Field assessment, reporting, data analysis	10
Marcus Cosentino	Field assessment	10
Jesse Forbes-Harper	Reporting, data analysis	7
Dr Floyd Holmes	Field assessment, reporting, data analysis	7
Melinda Henderson	Field assessment, reporting, data analysis	2
Aleksa Marinovic	Field assessment	1
Ines Pereda	Threatened fauna distribution modelling (Northern Quoll and Pilbara Olive Python)	6
GHD Staff		
Craig Grabham	Field assessment, reporting, data analysis	21+
Glen Gaikhorst	Field assessment, reporting, data analysis	21+
Robert Browne-Cooper	Field assessment, reporting, data analysis	21+
Madison Roberts	Field assessment	3
Brad Maryan	Field assessment	21+
Lynette Greer	Field assessment	2

3.4.11. Survey Limitations

Survey limitations are unforeseen events that can limit the effectiveness of the field survey to achieve the required objectives. Overall, no significant limitations were experienced during the field survey. Specific potential limitations are addressed below in Table 3.9.

Table 3.9: Survey Limitations

Limitation	Constraint	Comment
Competency/experience of the consultant carrying out the survey.	No	Zoologists that completed the field survey were highly experienced at conducting terrestrial fauna surveys in the Pilbara region, more specifically the Chichester sub-region.
Scope (what faunal groups were sampled and were some sampling methods not able to be employed because of constraints such as weather conditions).	No	Sampling techniques were designed for a Detailed (Level 2) terrestrial fauna assessment. Most fauna groups were sampled, and no survey constraints were experienced that limited sampling of specific groups. Amphibian captures/ observations were predictably low due to the lack of rainfall during the Detailed surveys. This is a common outcome and not viewed as a significant constraint as amphibian diversity is low in the region and no conservation significant amphibian species are known from the Pilbara.
Proportion of fauna identified, recorded and/or collected.	No	All vertebrate fauna species encountered were identified in the field. No vertebrate fauna specimens were collected for vouchering with the WAM.
Sources of information.	No	Database searches and previous survey reports provided a significant level of information, adequate to guide field survey design and effort.
The proportion of the task achieved and further work which might be needed.	No	All components of a Detailed (Level 2) vertebrate fauna assessment were completed, in particular when considering previous survey effort within the Survey Area.
Timing/weather/season/cycle.	No	The survey was conducted during suitable seasonal conditions for a Detailed survey, and all dominant fauna groups, assemblages and major fauna habitat types were recorded. High temperatures during the second phase of survey resulted in daily trap closures though this is unlikely to have significantly impacted capture rates.
Disturbances (e.g. fire, flood, accidental human intervention) which affected results of survey.	No	No disturbances were recorded during the survey.
Intensity (in retrospect, was the intensity adequate).	No	The completed Detailed assessment was adequate to identify the fauna assemblages and habitat present within the Survey Area. Sufficient targeted searches for conservation significant fauna species were completed within areas of suitable habitat. Comprehensive previous Detailed (Level 2), Targeted, and conservation significant fauna monitoring surveys have also been completed in close proximity to the Survey Area.
Completeness (was the relevant area fully surveyed.	No	All major fauna habitat types were sampled and defined. Habitat types that may host conservation significant fauna species were adequately surveyed.

Limitation	Constraint	Comment
Resources (degree of expertise available in animal identification to taxon level).	No	The experience level of the zoologists present was sufficient to identify all species accurately. Resources available were adequate and did not compromise the outcome of the survey.
Remoteness and/or access problems.	No	Access to the eastern and south-eastern part of the Survey Area was limited. However, Spectrum staff have accessed this area previously and are familiar with the fauna habitats present. This, in combination with aerial imagery, vegetation mapping, land system data and geological data allowed for the prediction of habitat types by extrapolation.
Availability of contextual (e.g. biogeographic) information on the region.	No	Background information about the region was available and sufficient.

3.5. Fauna Habitat Mapping

Fauna habitat mapping identifies areas of vegetation and land features that are distinguishable from other areas. Typically, each fauna habitat supports a characteristic fauna assemblage that is adapted to the features of the fauna habitat. Fauna habitat types are identified and mapped based on the following information:

- General vegetation type (Shepherd, Beeston and Hopkins, 2001)
- Vegetation types mapped within the Survey Area
- Vegetation structure
- Landforms
- Geological units
- Soil substrate
- Aerial imagery
- Fauna assemblage
- Field observations

Fauna habitat assessments were completed at each survey site, opportunistically while traversing the Survey Area on foot, and when travelling between sites.

3.6. Threatened Fauna Distribution Modelling

3.6.1. Northern Quoll and Pilbara Olive Python

Maxent (Maximum Entropy) v.3.4.1 is a software package used to model species distributions by utilising a machine-learning approach to predict the probability of a species' occurrence based on a set of environmental parameters and occurrence records (Phillips, Dudík and Schapire, 2004). In this assessment, Maxent models were developed for the Northern Quoll and Pilbara Olive Python using the same geographic extent. This was selected to cover the majority of occurrence records for each species, to accurately predict their potential occurrence within the GV Survey Area and surrounding region (Study Area).

To ensure comprehensive sampling of known occurrences for each species, the occurrence records used to train the models were obtained from ongoing Fauna Monitoring records. The total number of occurrence records used to model species distributions were 533 for Northern Quoll and 54 for the Pilbara Olive Python.

Species Distribution Modelling identified areas that are more likely to provide suitable habitat for each species, both within the Survey Area and Study Area. This will assist field survey planning by identifying areas to target within the Project. It will also show likelihood of occurrence outside of the Survey Area, which can be useful to provide to regulators for impact assessment purposes.

Initial habitat modelling was ground-truthed in the field to determine accuracy. A total of 50 random regional sites were visited via helicopter and graded for suitability as Northern Quoll and Pilbara Olive Python habitat. Following this, additional environmental variable datasets were applied to further refine the model and ensure areas of suitable, marginal, and unsuitable habitat were represented accurately.

3.6.1.1. Methods

Environmental variables used in the Maxent analyses were based on land system, soil, surface geology and topography, and the distance to specific geological and hydrological layers most suitable for the species. As all variables are required to be at the same resolution, environmental layers were resampled at 30 x 30 m. Environmental variables are detailed in Table 3.10. The parameters used to cross-validate the model were replicated for up to 50 model runs, with a maximum of 10,000 iterations (per species).

A layer that accounted for the sampling bias was created from Kernel Density distribution for the records of each species. This bias layer prevented the model from overfitting the species occurrence to the species presences in areas where sampling efforts where higher.

Locations of records representing the target species were used as occurrence records to train the model, defining the environmental parameter preferences of the target species. Models were run using suitable parameters that are widely accepted in the scientific literature, and the outputs are expressed as probability of occurrence. Survey targets are categorised as 'high', 'medium', or 'low' potential for containing each species.

Models were summarised from 50 replicates using the subsample option. For each replicate, a randomised set representing 20% of occurrence records were withheld for testing model accuracy. The maximum number of iterations for each replicate was set to 10,000 to allow for adequate convergence of the model.

The accuracy of the models were assessed using the Area Under Curve (AUC) statistic, which measures how well the model fits the data by plotting the number of positive occurrences against the number of false positives (Fielding and Bell, 1997). The results of the variable performance for the model are presented as Percent Contribution and Permutation Importance. Percentage Contribution summarises the proportion that each variable contributed to the fitting of the model while the model is being trained, and identifies the

path taken to reach the optimal model (Phillips, 2008). Permutation Importance measures how dependent the final model is on a specific variable, by measuring the resulting decrease in AUC from the exclusion of that variable, using a jackknife test (Phillips, 2008). Maps of the model outputs were expressed as probability of occurrence, using Complementary Log-Log (cloglog) transformation, for each 30 x 30 m grid cell across the geographic extent of the model.

Table 3.10: Environmental Variables

Environmental Variable	Description
Digital Elevation Model (1 arc)	Height above sea level (US Geological Survey)
Topographic ruggedness	Topographic ruggedness calculated with SAGA-GIS from the Digital Elevation Model
MrVBF	Multi-resolution Valley Bottom Flatness identifies areas of deposited materials (CSIRO)
Soil Available Water Capacity	Computed plant-available water capacity of the soil at a depth of 0-5 cm (CSIRO) (CSIRO)
Soil Bulk Density	Bulk density of the whole soil (including coarse fragments) in mass per unit volume (CSIRO)
Soil Organic Carbon	Mass fraction of carbon by weight in the less than 2 mm soil material as determined by dry combustion at 900° C (CSIRO)
Soil pH (CaCl2)	pH of 1:5 soil/0.01M calcium chloride extract at a depth of 0-5 cm (CSIRO)
Geology (1:250,000)	Surface geology map of Western Australia (CSIRO)
Land systems	Soil Landscape Mapping - Best Available 027 (DPIRD)
Distance to Boolaloo landsystem	Euclidean Distance to the Boolaloo land system from the Land system layer (DPIRD)
Distance to waterholes	Euclidean Distance to waterholes (Geoscience Australia)
Distance to water courses	Euclidean Distance to watercourses (Geoscience Australia)

3.6.1.2. Ground truthing

The threatened fauna distribution model was based on the location of 533 Northern Quoll and 54 Pilbara Olive Python records from within 35 km of the Glacier Valley Survey Area. Ground-truthing was completed at 50 random locations within the 30 km regional Study Area, and subsequently identified errors with the model relating to potential Northern Quoll habitat. An area of granite outcrop associated with the Boolaloo land system was found to be suitable habitat, though the model represented the area as blue (Category 3). To further refine the model, 19 Northern Quoll records (recorded during FMG Main Line Rail fauna monitoring) from granite outcrop habitat 50 – 55 km north-west of the Survey Area were included. The model is reliant on confirmed species records, and as no Northern Quoll records existed from this habitat type in the initial dataset, the habitat was not recognised as suitable. Additional environmental variables were also applied relating to topographic ruggedness, land systems and specifically Euclidean distance to the Boolaloo land system. For both the Northern Quoll and Pilbara Olive Python habitat models, the Euclidean distance to water holes and water courses was also included to better define Categories 1 and 2.

Sampling bias was also identified as a potential issue with the original model. As part of Targeted conservation significant fauna surveys and monitoring associated with the North Star mine, over nine years (2011-2012, 2014-2020), extensive surveys for both Northern Quoll and Pilbara Olive Python have been conducted in the area immediately surrounding Glacier Valley. To correct for this, a bias layer was applied to prevent the model from overfitting each species' occurrence to the species' presence in areas where sampling effort was higher.

Granite outcrop as potential Northern Quoll habitat remains the most significant limitation to the current model. With the inclusion of the monitoring records associated with granite habitat, the model has identified similar areas within the regional Study Area as marginal dispersal and foraging habitat (Category 2),

although this habitat has the potential to be critical/ breeding habitat (Category 1). This is likely due to how few records were available from this habitat type in the region, as it's not typically associated with mineral resources or other large-scale developments requiring biological surveys. With further records to train and refine the model, these areas may then be considered Category 1 habitat. Unfortunately, Boolaloo is not the only land system associated with granite outcrops in the regional Study Area. An area of Granitic land system located east and north-east of the Survey Area has not been modelled as potential Northern Quoll habitat (currently Category 3), due to a lack of records corresponding with any of the associated environmental variables. This remains a limitation, and as such, estimations of total Category 1 and Category 2 habitat extents (Table 4.3) within the regional Study Area may be considered conservative.

3.6.2. Pilbara Leaf-nosed Bat and Ghost Bat

GHD completed an update on existing habitat modelling for Pilbara Leaf-nosed Bat and Ghost Bat within a 30 km radius of Cave 13 (Appendix G) whereby the area of foraging and roosting habitat was mapped and calculated.

The existing habitat modelling for bat species completed by GHD utilised the following layers:

- 10 m Contours (source: Landgate),
- Hillshade, Slope Analysis and Digital Elevation Model (source: GHD),
- Known roost sites, including elevation, aspect and geology,
- Aerial image (source: Landgate)
- Fortescue tenement boundaries and other mine tenement boundaries

Additional data was sourced to best model the extent of the priority roost and foraging habitat types as detailed in (Appendix G). The modelled output was then refined with additional data from the 2020 surveys. The key refinement was the reduction of the extent of Habitat Type 1 (priority 1). The preliminary results overestimated the area of this habitat, particularly areas between 280 and 300 m elevation. A combination of elevation, relief and slope data in combination with qualitative analysis of high-resolution satellite imagery was used to refine the extent of Habitat Type 1 (priority 1) and was ground-truthed using field survey data.

3.7. Fauna Survey Data Analysis

Only systematically collected data can be analysed because any mathematical comparison requires standardised sampling effort between variables. As such, only the data from the mammals, reptiles and amphibians caught in the trapping grids or set-time bird surveys were used for habitat analysis and survey adequacy tests. In this case, the variables are the seven trapping grid nights and four bird surveys that were completed at each of the 16 sites (eight per phase). The difference in systematic survey methods used between the trapping grids and bird surveys means that each of these data sets were analysed separately. Due to high variability in the bird abundance counts, the bird survey data was log transformed to reduce the impact of this variability on the data analysis. For both the habitat and SAC analyses, opportunistic records such as those from motion cameras or active searches were excluded, because the variables and sampling effort between sites are not standardised.

3.7.1. Habitat Analysis

Fauna habitat mapping enables the categorisation of each survey site into a specific habitat type, and analysis of this data provides insight into how distinct or similar the fauna assemblages in each habitat type are. One method is non-metric multidimensional scaling (non-metric MDS), which is based on a distance matrix computed with a range of distance measures, whereby an algorithm attempts to place the data points in a theoretical two- or three-dimensional coordinate system whilst preserving the ranked differences in terms of their Euclidean distance from others (Hammer and Harper and Ryan, 2001). In this case, the Bray-Curtis similarity algorithm was used because it appropriately quantifies the compositional similarity/dissimilarity between two sites with abundance data.

Another habitat comparison method is the use of cluster analysis, whereby a hierarchical clustering routine creates a dendrogram showing how survey site data are clustered and whether this matches the respective habitat types (Hammer and Harper and Ryan, 2001). The algorithm used (Bray-Curtis as an index) effectively joins clusters (or sites) together based upon the average distance between data in the two groups. A group can be a single site or several, and the level (or value) at which they join indicates how similar the two groups are, where an index value of 1 equals 100% similarity.

3.7.2. Survey Adequacy

Survey adequacy can, in part, be assessed by estimating species richness from sample data. Extrapolating Species Accumulation Curves (SACs), fitting parametric models or relative abundance and using non-parametric estimators (Bunge and Fitzpatrick, 1993; Colwell and Coddington, 1994; Gaston, 1996) are three generally accepted methods that achieve this. Species Accumulation Curves graphically illustrate the accumulation of species along a timeline, and this method was used to analyse the data from the current field survey. At the point the horizontal asymptote is reached, it is estimated that no new species are present. In an effort to eliminate the impact of random or periodic temporal variation, the sample order was randomised 1,000 times using EstimateS (Colwell, 2016). As a stopping-rule technique, a Michaelis-Menten enzyme kinetic curve was calculated to estimate the theoretical maximum number of species present at each systematic survey site.

4. RESULTS

4.1. Desktop Assessment

The desktop assessment identified a total of nine amphibian species, 152 birds (one introduced), 48 mammals (plus 10 introduced), 113 reptiles, and four fish that had previously been recorded in the region surrounding the Survey Area (Table 4.1). Of these, 29 species are listed as conservation significant (18 birds, nine mammals, and two reptiles).

GHD completed a series of Targeted fauna surveys during 2018 and 2019 within the Glacier Valley Survey Area (GHD, 2020). Five species of conservation significance were recorded:

- Northern Quoll (*Dasyurus hallucatus*): 49 records via observation and motion camera, eight scats;
- Ghost Bat (*Macroderma gigas*): four observations, two scats;
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*): 19 records from ultrasonic recordings,
- Pilbara Olive Python (*Liasis olivaceus barroni*): six observations, one scat; and
- Peregrine Falcon (*Falco peregrinus*): one observation.

The results of the DBCA Threatened Fauna Database search are shown on Map 4.1, and the locations of all previously recorded conservation significant fauna recorded within the Survey Area and from the surrounding region are shown on Map 4.2.

Table 4.1: Summary of Vertebrate Fauna Species Previously Recorded in the Region

Data Source	Reference in Appendices	Type	Amphibians	Birds	Mammals		Reptiles	Fish	Total Species
					Native	Introduced			
Survey Reports									
Field Survey for Conservation Significant Bats near Sulphur Springs, Pilbara (Molhar, 2007)	1	Targeted	0	0	1	0	0	0	**1**
Atlas Iron Limited Mt Dove DSO Project Vertebrate Fauna Assessment (Outback Ecology, 2011b)	2	Level 2 (2 phase)	1	40	17	6	30	0	**94**
North Star Project Targeted Conservation Significant Fauna Survey (ecologia 2011)	3	Targeted	2	5	7	0	1	0	**15**
Atlas Iron Limited Abydos DSO Project Terrestrial Vertebrate Fauna Baseline Survey (Outback Ecology, 2011a)	4	Level 2 (2 phase)	3	39	15	3	39	3	**102**
North Star Project Level 2 Terrestrial Vertebrate Fauna Assessment (ecologia 2012b)	5	Level 2 (3 phase)	5	81	19	3	74	4	**186**
North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment (ecologia 2012a)	6	Level 1	0	38	2	4	7	0	**51**
FMG North Star Project Pilbara Leaf-nosed Bat Colony Survey (Bullen, 2013)	7	Targeted	0	0	4	0	0	0	**4**

Data Source	Reference in Appendices	Type	Amphibians	Birds	Mammals		Reptiles	Fish	Total Species
					Native	Introduced			
FMG North Star Hematite Project EPBC Listed Threatened Fauna Monitoring Report 2014 (ecoliga 2014a)	8	Targeted	0	2	2	0	2	0	6
North Star Pilbara Olive Python Monitoring (Ecoscape 2015)	9	Targeted	0	2	2	1	17	0	22
North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment (ecologia 2015c)	10	Level 1	0	18	5	1	12	0	36
Conservation Significant Fauna Monitoring 2015-2016 (Ecoscape 2016d)	11	Targeted	0	9	6	2	5	0	22
Pilgangoora Baseline Vertebrate Fauna Survey (360 Environmental, 2016)	12	Level 2 (1 phase)	0	29	3	0	32	0	64
Corunna Downs Project: Terrestrial Vertebrate Fauna Survey (MWH, 2016)	13	Level 2 (2 phase)	4	70	25	5	66	0	170
Conservation Significant Fauna Monitoring 2017-2018 (Ecoscape 2018)	14	Targeted	0	0	0	0	0	0	0
Wodgina Gas Pipeline Targeted Fauna Survey (360 Environmental, 2018)	15	Targeted	0	0	5	1	0	0	6
Glacier Valley and South Star Fauna Surveys Fauna Survey Report (GHD, 2020)	16	Targeted	3	71	13	4	27	1	119
Public Databases									
NatureMap	-	-	8	125	37	7	97	0	274
DBCA Threatened Fauna Database	-	-	0	2	9	0	3		14
Protected Matters Search	-	-	0	20	4	9	1	0	35
Total Species	-	-	9	152	48	10	113	4	336

690000 700000 710000 720000 730000 740000

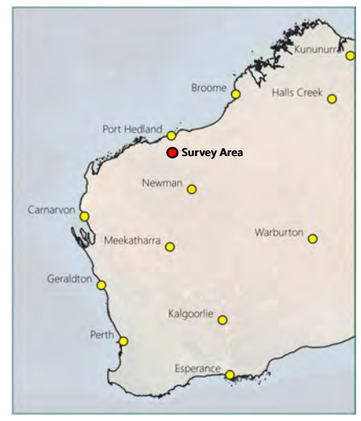
7660000 7650000 7640000 7630000 7620000

Legend

- Survey Area

DBCA database search results

- Northern Quoll (EN)
- Greater Bilby (VU)
- Pilbara Leaf-nosed Bat (VU)
- Ghost Bat (VU)
- Spectacled Hare-wallaby (P4)
- Long-tailed Dunnart (P4)
- Brush-tailed Dunnart (P4)
- Western Pebble-mound Mouse (P4)
- Short-tailed Mouse (P4)
- Fork-tailed swift (MI)
- Wood Sanpiper (MI)
- Pilbara Olive Python (VU)
- Pin-striped Fine-snout Skink (P1)
- Gane's Blind Snake (P1)



N

0 1 2 3 4 5 6 7 km

Scale 1:180,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: AH Date: 25-06-2021

DBCA Threatened Fauna Database Search Results

Glacier Valley Project

Prepared for
IB Operations

MAP
4.1

650000
675000
700000
725000
750000
775000
7700000
7675000
7650000
7625000
7600000

Legend

Conservation Significant Species (previous surveys)

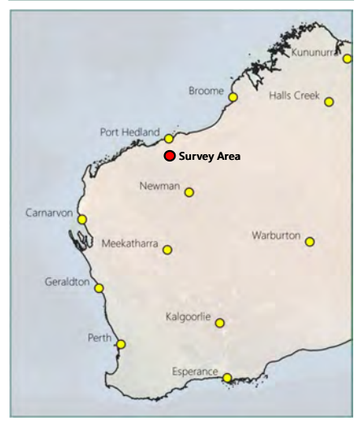
- Northern Quoll (EN)
- Ghost Bat (VU)
- Pilbara Leaf-nosed Bat (VU)
- Pilbara Olive Python (VU)
- Fork-tailed Swift (MI)
- Grey Falcon (VU)
- Peregrine Falcon (OS)
- Long-tailed Dunnart (P4)
- Spectacled Hare-wallaby (P4)
- Western Pebble-mound Mouse (P4)

FMG / IBO Supplied Fauna Records

- Northern Quoll (EN)
- Pilbara Olive Python (VU)

GHD Glacier Valley Records

- Northern Quoll (EN)
- Ghost Bat (VU)
- Pilbara Leaf-nosed Bat (VU)
- Pilbara Olive Python (VU)



N

0 5 10 15 km

Scale 1:450,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: DC Date: 25-06-2021

Previously Recorded Conservation Significant Fauna

Glacier Valley Project

MAP 4.2

Prepared for IB Operations

4.2. Fauna Habitats

Four broad fauna habitat types were recorded from the Glacier Valley Survey Area. The extent of each habitat type is detailed in Table 4.2 and shown on Map 4.3. The defining characteristics of these habitat types are described in the following section.

Table 4.2: Broad Fauna Habitat Types and Extents

Habitat Type	Fortescue Naming Convention	Extent (ha)	% of Survey Area
Hills, Ranges and Plateaux	Hills/Ranges/Plateaux	5,509.6	95.6
Rocky Escarpment	Rocky Escarpments (Ridges/Mesa/Cliffs/Outcrops/Breakaways)	99.1	1.7
Gorges and Gullies	Gorges/Gullys	41.5	0.7
Minor Drainage Line	Drainage Line/River/Creek (Minor)	117.6	2.0

4.2.1. Hills, Ranges and Plateaux

The Hills, Ranges and Plateaux habitat type within Glacier Valley covered 5,509.6 ha (95.6 %) of the Survey Area (Map 4.3). The habitat was characterised by exposed rocky hills, often with areas of rock outcropping. Tree cover on the hills, hillslopes and valley floors was typically limited to scattered *Corymbia hamersleyana*, *Eucalyptus leucophloia* and *Hakea chordophylla* over *Acacia inaequilatera*, *Acacia ptychophylla* and *Acacia adoxa* shrubs. The drainage depressions that dissected the hills and valleys were vegetated with thickets of *Grevillea wickhamii, Acacia acradenia* and *Acacia tumida*. In areas not recently burned, a dense layer of spinifex (*Triodia wiseana*) was present growing on skeletal soils (Plate 4.1). Wood and leaf litter was limited to small, shallow, pockets beneath areas of denser vegetation.

Plate 4.1: Hills, Ranges and Plateaux Fauna Habitat Type

4.2.2. Rocky Escarpment

The Rocky Escarpment habitat type accounted for 99.1 ha or 1.7 % of the Survey Area (Map 4.3). The defining features of this ridge habitat in the Glacier Valley area were its high elevation, steep gradient, and significant rock outcropping. The BIF and quartzite ridge lines and cliff faces offer abundant cracks, voids, and crevices that act as refugia for fauna. Due to its exposed nature, vegetation was limited to low trees, shrubs, herbs and grasses. Widely spaced *Ficus brachypoda* were present along the ridge amongst scattered *Acacia pruinocarpa*, *Grevillea wickhamii* and *Gossypium robinsonii* growing over spinifex (*Triodia wiseana*) and tussock grasses (predominantly *Cymbopogon* and *Eriachne* spp.) (Plate 4.2). Wood litter was very scarce though shallow pockets of leaf litter were present beneath *A. pruinocarpa* as well as deeper beds beneath *F. brachypoda*.

Plate 4.2: Rocky Escarpment Fauna Habitat Type

4.2.3. Gorges and Gullies

The Gorges and Gullies habitat type represented 41.5 ha (0.7 %) of the Survey Area (Map 4.3). It was characterised by steep (often vertical) edges and significant exposed bedrock and rock outcropping. The gorge or gully walls often hosted caves, cracks, crevices, and voids that act as shelter for fauna. The plant assemblage varied greatly, dependent on the depth of the landform and the shelter this depth provided. The upper and therefore more exposed areas were typically vegetated with scattered *Corymbia hamersleyana* and *Eucalyptus leucophloia* over thickets of *Acacia tumida* and *A. acradenia*. Spinifex (*Triodia* sp.) was abundant with tussock grasses (*Cymbopogon* sp.) often populating the gully floor. Deeper areas that experience a shorter photoperiod were vegetated with *Ficus brachypoda*, *Terminalia circumalata* and in areas with surface or shallow subsurface water, *Melaleuca* sp. and *Stemodia grossa*. Thickets of *A. tumida* were also present, with irregularly scattered tussock grasses (*Cymbopogon* and *Eriachne* spp.). Leaf litter was abundant in some areas, particularly in deeper sections beneath mature *Ficus* and *Terminalia* (Plate 4.3).

Plate 4.3: Gorges and Gullies Fauna Habitat Type

4.2.4. Minor Drainage Lines

Minor Drainage Lines habitat accounted for 117.6 ha, or 2.0 % of the Glacier Valley Survey Area. This habitat type was not observed to hold permanent surface water, which is likely to only be present after significant rainfall events. The vegetation lining the drainage edges consisted of widely spaced *Eucalyptus* sp. and *Corymbia hamersleyana* over moderately dense *Petalostylis labicheoides*, *Gossypium robinsonii* and *Grevillea wickhamii* shrubland. Herbs such as *Corchorus* and *Senna* spp. were abundant, particularly in recently burned areas. *Triodia wiseana* populated the upper banks and small patches of *Triodia longiceps* were present within the drainage lines themselves. Wood and leaf litter was scarce, although some small pockets existed beneath trees and shrubs. The substrate was a combination of smooth stones and coarse, loose sand (Plate 4.4).

Plate 4.4: Minor Drainage Lines Fauna Habitat Type

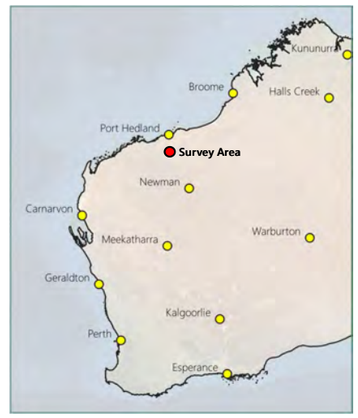
708000
711000
714000
717000
7647000
7644000
7641000
7638000

Legend

- Survey Area

Fauna Habitat Types

- Gorges and Gullies
- Hills, Ranges and Plateaux
- Minor Drainage Line
- Rocky Escarpment



N

0 0.5 1 1.5 km

Scale 1:41,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: AH Date: 24-06-2021

Fauna Habitat Types

Glacier Valley Project

MAP 4.3

Prepared for
IB Operations

4.3. Fauna Habitat Analysis

Fauna habitats were analysed in terms of both non-metric MDS scatter plots and cluster analyses, separately for fauna caught in trapping grids and for systematically sampled bird records. To simplify interpretation, for all four analyses the data recorded at each site was summed into a single variable. In Figures 4.1 – 4.4 below, orange represents the Hills, Ranges and Plateaux habitat whilst blue represents Minor Drainage Lines. Neither the Rocky Escarpment nor the Gorges and Gullies habitats could be included in the analyses given they were not systematically sampled (see section 3.4.4).

In the non-metric MDS scatter plots, the shaded areas (convex envelopes) are visual representations of all convex combinations of theoretical points in a bounded subset of each plane (coordinate 1 or 2), which then require three or more sites to create a shape. In other words, in the context of these particular theoretical coordinates, all data points recorded in each habitat should occur within a given convex envelope. Larger envelopes generally indicate that the data is more variable or less consistent between different sites of the same habitat for the given coordinates.

The scatter plot and cluster analysis of the trapping grid fauna data both indicate that the fauna assemblage of the Hills, Ranges and Plateaux habitat is distinct from that of the Minor Drainage Lines habitat (Figure 4.1, Figure 4.2). There is a small convex envelope, and minimal variation for sites in the Hills, Ranges and Plateaux habitat along coordinate 1 on the scatter plot, which are clearly distinct from site 2 at the other extreme of the same coordinate (Figure 4.1). Likewise, the cluster analysis shows that the three sites in the Hills, Ranges and Plateaux habitat are more similar to each other than they are to site 2 in the Minor Drainage Lines habitat, and share at least 50% similarity between them (Figure 4.2).

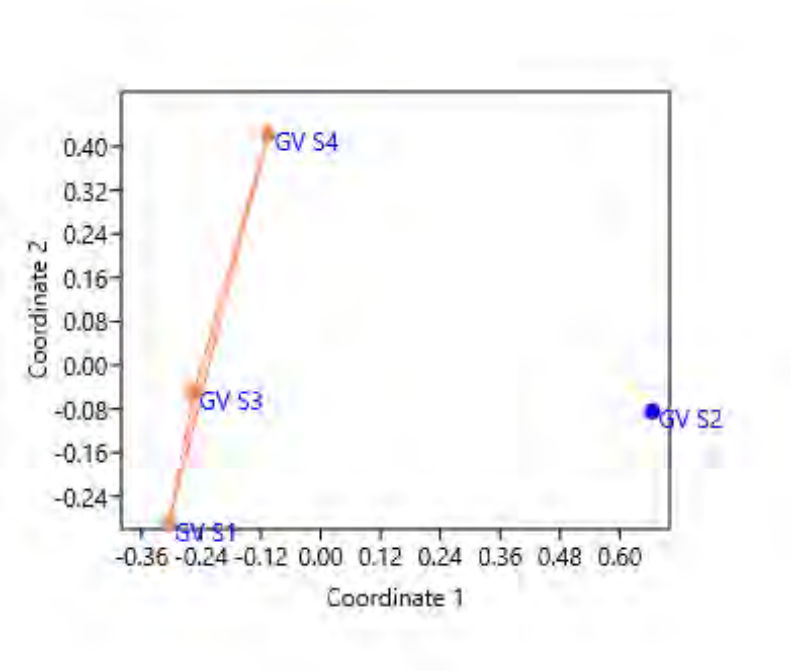


Figure 4.1: Non-metric MDS Scatter Plot of the Trapping Grid Fauna Data

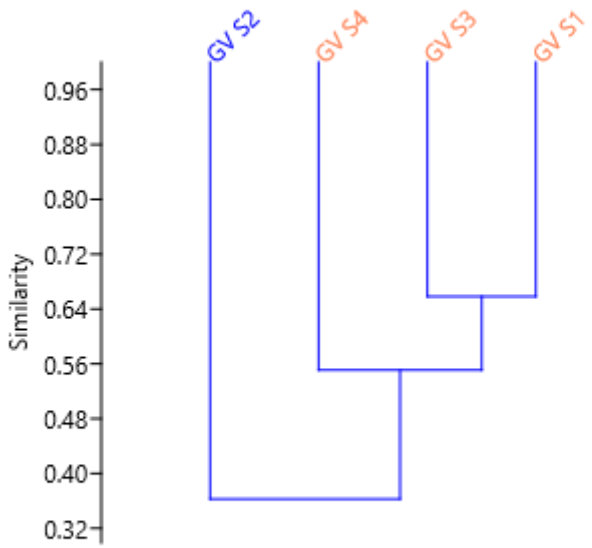


Figure 4.2: Cluster Analysis of the Trapping Grid Fauna Data

The results for the systematic bird survey data are not clearly defined like the trapping grid data results. There is a much larger convex envelope for the Hills, Ranges and Plateaux habitat in the scatter plot, and no clear distinction between the two habitats along either coordinate (Figure 4.3). The cluster analysis also does not differentiate between the two habitats, with at best only a 12% similarity between any two sites (Figure 4.4).

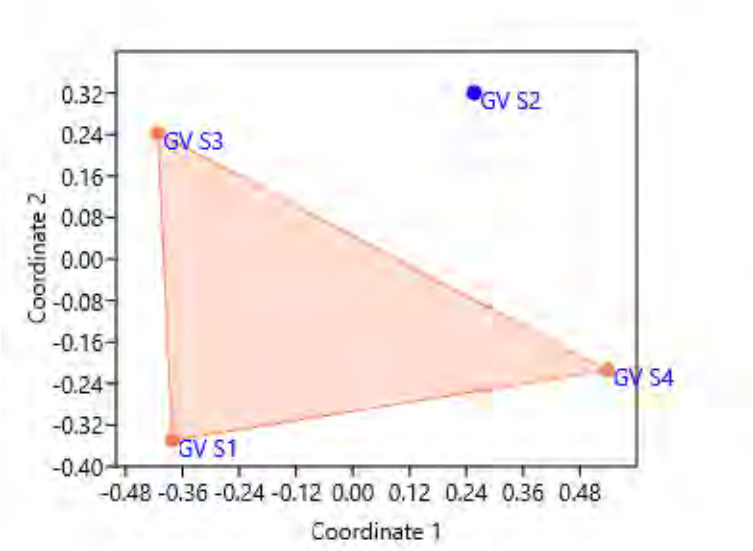


Figure 4.3: Non-metric MDS Scatter Plot of the Systematic Bird Survey Data

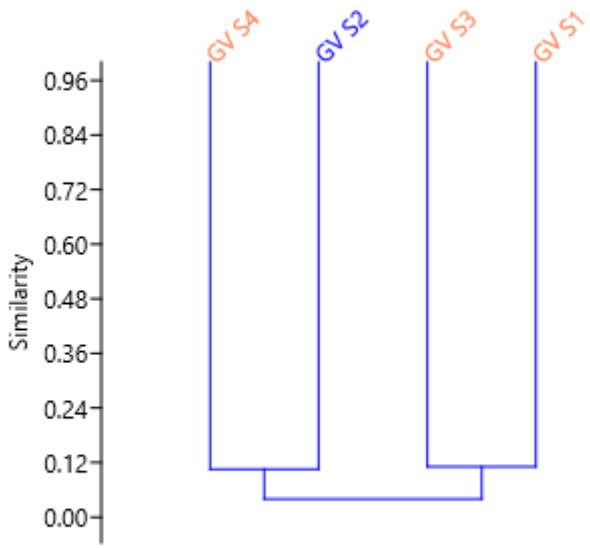


Figure 4.4: Cluster Analysis of the Systematic Bird Survey Data

4.4. Threatened Fauna Distribution Modelling

4.4.1. Northern Quoll

A total of 533 Northern Quoll records from the Baseline Fauna Assessment undertaken by ecologia in 2012, and ongoing fauna monitoring records since 2014 were used to train the model. Only records which were deemed as certain were used, such as trapping records. The number of records for Northern Quoll used in the analysis is well above the required 20 samples to provide high model accuracy (van Proosdij *et al.*, 2016).

The model's predictions are specifically categorised based on its ability to detect and highlight areas of rocky ridges, ranges and land systems with granite outcrops (e.g. Boolaloo Land System). The Pilbara population of Northern Quoll is associated with rocky habitats where the species finds refuge during the day in crevices, cracks and small caves. These critical denning habitats include rocky gorges, basalt hills, escarpments, mesas, plateaux, granite boulder piles, caves and adjacent cliff faces, but also along coastal fringes and beaches (Department of Agriculture Water and the Environment, 2020).

On the Northern Quoll modelled habitat map, areas highlighted in red indicate habitat of high quality and more probable use, whereas areas defined by blue are not considered quality habitat (Map 4.4). However, the species may still utilise areas defined in blue for dispersal and occasional movements outside of their territories. Major hotspots identified by the model are centred along the ridgeline running through the middle of the Survey Area in a north-south direction. The model also indicates two areas in the south-south-east and the north-east of the regional Study Area associated with smaller rocky gorges with the potential to hold water. Large areas of granite outcropping located in the west of the Study Area are also highlighted, which have been confirmed as suitable habitat during monitoring of the Main Line Rail (ecologia

Environment, 2014b; Ecoscape (Australia), 2015, 2016d, 2017a, 2018; GHD, 2015; Spectrum Ecology, 2019b, 2020b).

Drainage lines, creek lines and rivers are habitats utilised by the Northern Quoll for dispersal and foraging. The model's ability to detect these areas was improved by including calculations of distances to hydrological systems and land systems with granite outcrops (Boolaloo). These areas are defined in the model by the colours orange through to yellow (Map 4.4). Foraging can also occur across any adjacent habitat type that provides suitable cover and food resources, which can potentially be within areas defined as green to blue, although these areas are considered to be of lower quality for the species.

In an effort to quantify the results beyond a visual representation (Map 4.4 and Map 4.5), the results of the modelling were clustered into three categories for both the Northern Quoll and Pilbara Olive Python:

- Category 1 – Occurrence probability from 1 - 0.7
- Category 2 – Occurrence probability from 0.7 - 0.3
- Category 3 – Occurrence probably from 0.3 - 0

Category 1 represents critical/ breeding habitat; Category 2 represents marginal dispersal and foraging habitat, and Category 3 represents areas not typically utilised as habitat. The total extents of the three categories both within the Survey Area and the regional 30 km Study Area are detailed in Table 4.3.

4.4.2. Pilbara Olive Python

A total of 54 Pilbara Olive Python records were used to train the model, including those from the Baseline Fauna Assessment undertaken by Ecologia (ecologia Environment, 2012b), ongoing Fauna Monitoring records completed by Ecoscape (Ecoscape (Australia), 2015, 2016d, 2017a, 2018), and Spectrum Ecology (Spectrum Ecology, 2019b, 2020d, 2020c). The number of records for Pilbara Olive Python used in the analysis is well above the 20 samples required to provide high model accuracy (van Proosdij *et al.*, 2016), but is below that used for the Northern Quoll model. The model's evaluation is based on the accuracy of the data used to train and predict the probability of a species' occurrence. As only records which were deemed certain were used, such as trapping records, the accuracy of the model should not be impacted.

The model's predictions are specifically categorised based on its ability to detect and highlight rocky valleys on the western side of ranges, hills and ridges. Areas highlighted in red indicate habitat of high quality and more probable use, whereas areas defined by blue are not considered quality habitat (Map 4.5). The major drainage lines occurring through the central and eastern sections of the Study Area in a north-south direction are identified by the model as being higher quality habitat. These areas have the potential for water holes and other surface water features to be present.

Drainage lines may be used for foraging, with pythons also seeking refuge in tree hollows or under debris piles. This can include rocky gorge habitat as individuals may then also shelter in nearby caves and crevices. The model was improved to detect these areas by including topographic ruggedness and the Euclidean distances to water courses, represented by the colour's orange through to yellow (Map 4.5).

The habitat requirements of the Pilbara Olive Python are likely to vary throughout the year due to seasonal changes in specific habitats for feeding, breeding and mating. The species may still utilise areas defined in blue for dispersal and occasional movements outside of their known range. During the cooler dry season, studies have indicated that escarpments, mesas and other rocky habitat away from water are preferred habitats for breeding females, with males travelling along drainage lines and rivers in searches of receptive females (D. Pearson, pers. comm.).

Table 4.3: Habitat Category Extents – Northern Quoll and Pilbara Olive Python

Species	Category	Representative Colours on Map	Survey Area (ha)	Regional Study Area (ha)
Northern Quoll	1	Red – orange	482.0	8,754.387
	2	Light orange – yellow – light green	1,559.0	43,864.086
	3	Dark green – blue	3711.0	293,365.714
Pilbara Olive Python	1	Red – orange	533.5	4,250.7
	2	Light orange – yellow – light green	1,087.7	16,094.5
	3	Dark green – blue	4,129.7	325,640.5

4.4.3. Pilbara Leaf-nosed Bat and Ghost Bat

The potential distribution of roosting habitat for the Pilbara Leaf-nosed Bat and Ghost Bat was mapped into four habitat types (Map 4.6). There is approximately 1,982 ha of collective known and potential roosting habitat mapped (Habitat Type 1) for both species within the Survey Area and an additional 61,812 ha occurring within the regional Study Area (Table 4.4). Habitat Type 1 includes Priority 1 (gorges with pools, watercourses in upland areas) and Priority 3 (areas of exposed rock at top of rocky outcrops and mesa hills that contain caves and overhangs) habitat types. Both habitat types are conducive to cave and overhang formations which provide roosting and refuge opportunities for both species.

It is important to note that while there is a high likelihood of roosting and refuge formations occurring within Habitat Type 1, the modelling is not a quantitative estimate of potential roosting habitat as the specific requirements for each roost type for each species are not incorporated into the model (e.g., breeding roost compared to a temporary/occasional use diurnal roost and nocturnal refuge), nor does the model allow for the specific habitat requirements for each species at different times of the year (e.g., breeding and non-breeding periods).

The extent of foraging habitat for the Pilbara Leaf-nosed Bat and Ghost Bat was assessed using distribution records of both species, information on the habitats and movements in the nearby North Star area (e.g., recent radio tracking studies of the Pilbara Leaf-nosed Bat) and published information on the foraging behaviour of the Ghost Bat (Augusteyn *et al.*, 2018). It can be confidently assumed the entirety of the Survey Area is used as foraging habitat by Pilbara Leaf-nosed Bats and Ghost Bats.

Table 4.4 Habitat Category Extents – Pilbara Leaf-nosed Bat and Ghost Bat

Habitat Type	Representative Colours on Map	Survey Area (ha)	Regional Study Area (ha)
Habitat Type 1 (Priority 1) – gorges with pools in upland areas, sometimes with caves.	Orange	710.85	18,813.59
Habitat Type 1 (Priority 3) – rocky outcrops areas of exposed rock at top of rocky outcrops and mesa hills that contain caves and overhangs.	Green	1,271.02	42,117.03
Habitat Type 2 (Priority 2) – gullies with primary drainage with limited riparian development in upland rocky habitats.	Pink	18.81	416.63
Habitat Type 3 (Priority 4) – major watercourses with riparian vegetation on flat land plus main gravelly or sand channel of the riverbed.	Aqua	41.40	12,792.84
Habitat Type 4 (Priority 5) – open grassland woodland, dominated by Triodia, on lowland plains colluvial slopes and hilltops.	Blue	3,425.50	265,867

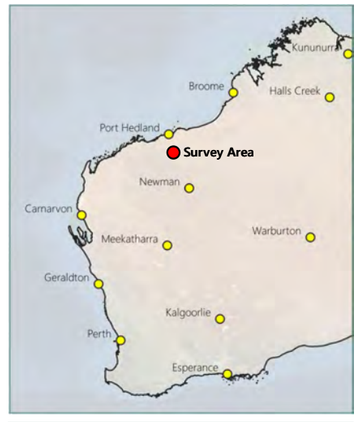
680000
700000
720000
740000
7660000
7640000
7620000

Legend

- Glacier Valley Survey Area
- Regional Study Area (30km buffer)

Northern Quoll Model (median)

- 0
- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1



N

0 2 4 6 8 10 km

Scale 1:258,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum Ecology • Spatial

Author: JV Approved: AH Date: 25-06-2021

Northern Quoll Modelled Habitat

Glacier Valley Project

Prepared for
IB Operations

MAP
4.4

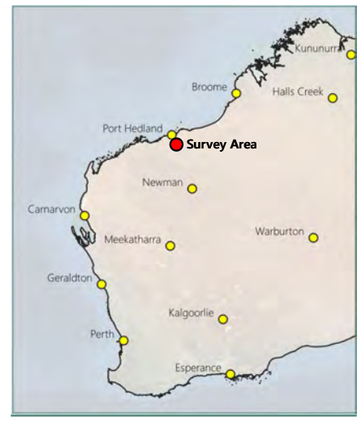
680000
700000
720000
740000
7660000
7640000
7620000

Legend

- Glacier Valley Survey Area
- Regional Study Area (30km buffer)

Pilbara Olive Python Model (median)

- 0
- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1



N

0 2 4 6 8 10 km

Scale 1:258,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum Ecology • Spatial

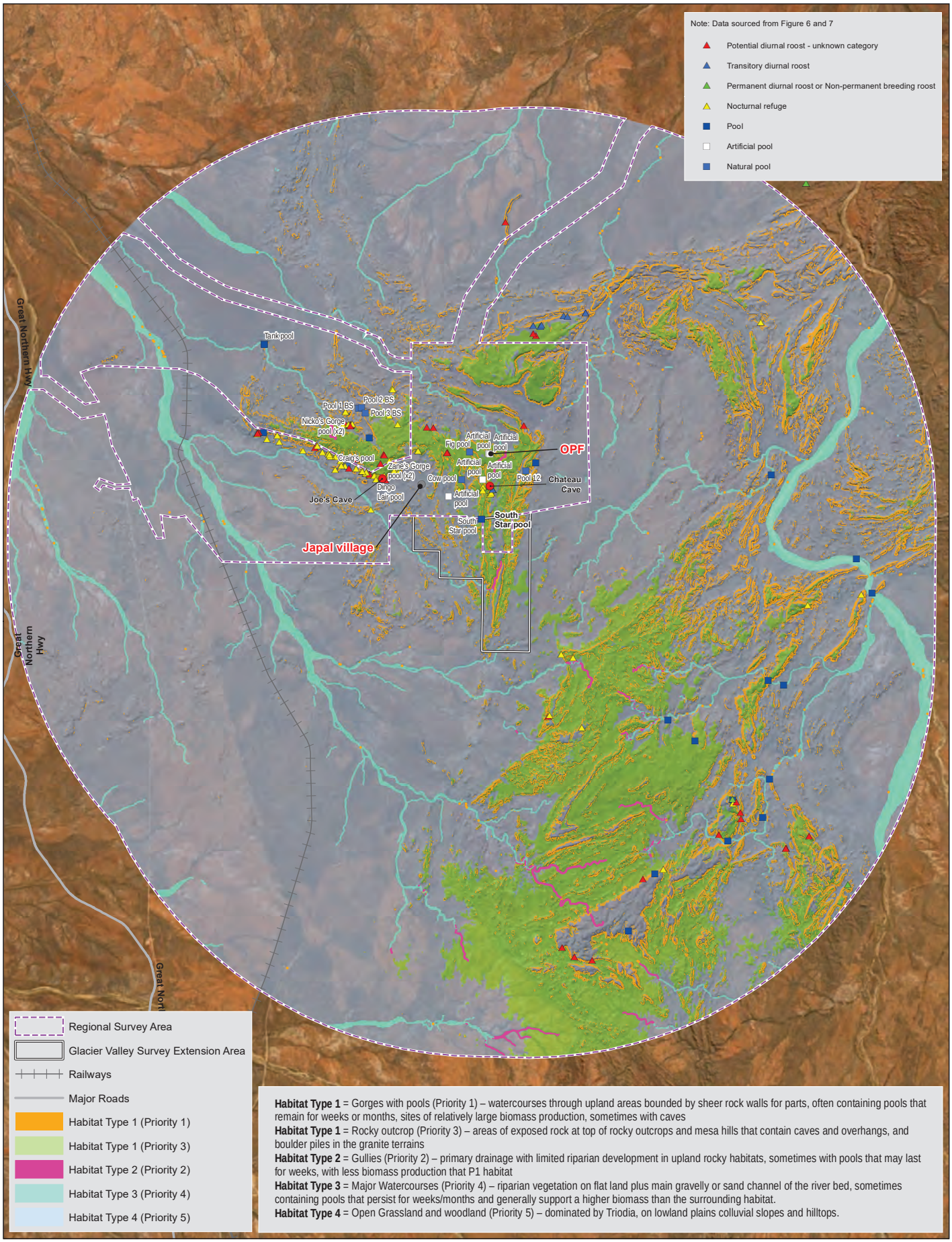
Author: JV Approved: AH Date: 30-06-2021

Pilbara Olive Python Modelled Habitat

Glacier Valley Project

Prepared for
IB Operations

MAP
4.5



Habitat Type 1 = 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
Habitat Type 1 = 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
Habitat Type 2 = 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
Habitat Type 3 = Major Watercourses (Priority 4) – 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.
Habitat Type 4 = Open Grassland and woodland (Priority 5) – dominated by Triodia, on lowland plains colluvial slopes and hilltops.

Paper Size A3
0 2.5 5
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Fortescue Metals Group Ltd

Job Number 12528008
Revision 0
Date 25 May 2021

Bat habitat and roost

Figure 4.6

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

Data source: GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS

4.5. Fauna Assemblage

During the two phases of Detailed (Level 2) and Targeted surveys, a total of 93 vertebrate fauna species were recorded:

- One amphibian
- Thirty-nine birds
- Twelve non-volant native mammals
- Six bats
- Three introduced mammals
- Thirty-two reptiles

A comparison of systematic data collected during the two phases of the Detailed survey shows a higher total species count recorded during the second phase (38 vs 47 species). Of these, 12 species were recorded only during the first phase of survey and 21 were recorded only during the second phase. Opportunistic searches and long-term motion cameras deployed during the first phase of the Detailed survey accounted for the remaining species that were recorded.

Systematic trapping capture rates were higher during the second phase of survey (73 vs 99 individuals). This can be attributed primarily to one species, the Pilbara Ningaui (*Ningaui timealeyi*), with an increase from three to 21 captures. Systematic bird survey observations were also higher during the second phase (37 vs 139 counts) with the Grey-headed Honeyeater, Painted Finch, Pied Butcherbird and Galah recorded more frequently when compared to all other species recorded during the first phase.

Plate 4.5: A *Morethia ruficauda exquisita* and *Demansia rufescens* Captured During Systematic Trapping

4.6. Conservation Significant Fauna

Four conservation significant fauna species were recorded during the two phases of the Detailed survey and the Targeted surveys:

- Northern Quoll (*Dasyurus hallucatus*) – EPBC / BC Act Endangered
- Ghost Bat (*Macroderma gigas*) – EPBC / BC Act Vulnerable
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) – EPBC / BC Act Vulnerable
- Pilbara Olive Python (*Liasis olivaceus barroni*) – EPBC / BC Act Vulnerable.

Eight Northern Quolls were captured during the Targeted trapping survey, with a further 14 records obtained via motion cameras. Of these, 12 motion camera records were made at locations that were later utilised for trapping sites during the Targeted survey. As such, it is likely that many of these records represent multiple repeated captures of a smaller group of individuals. The two remaining records were made to the west of

the Glacier Valley ridge during the second phase of the Detailed (Level 2) survey in Hills, Ranges and Plateaux, and Minor Drainage Line/Gorges and Gullies habitat, adjacent to two minor drainage lines. A single male Pilbara Olive Python was also recorded during the Targeted survey from within the proposed Glacier Valley disturbance footprint.

A Ghost Bat diurnal roost cave was recorded from Python Cave, in the south of the Survey Area. The latter is also used by the Pilbara Leaf-nosed Bat as a transitory diurnal roost site (Appendix G). Chateau Cave is a permanent breeding roost of the species, however this cave is located north of the Survey Area.

The locations of all conservation significant fauna records made during the three field surveys combined are detailed in Table 4.6 and displayed on Map 4.7.

4.6.1. Targeted Northern Quoll and Pilbara Olive Python Survey

A total of eight Northern Quoll were captured during the survey, including six males and two females. Further details specific to each capture are detailed in Table 4.5. Trapping site descriptions are presented in Appendix F and site-specific captures are detailed below.

Plate 4.6: Two Northern Quolls Captured via Cage Trap and Motion Camera

4.6.1.1. Northern Quoll Site 1 (GV NQ S1)

Six Northern Quolls were captured at GV NQ S1, located within the Rocky Escarpment habitat type. Four males and two females were captured with multiple recaptures recorded (Table 4.5). All the animals processed appeared to be in good physical condition with no obvious signs of injury, weight loss or parasites. The females were small and had undeveloped pouches suggesting they were not reproductive at the time of survey.

4.6.1.2. Northern Quoll Site 2 (GV NQ S2)

Northern Quoll Site 2 was located within the Rocky Escarpment habitat type. No original Northern Quoll captures were recorded from GV NQ S2. However, a male (#991003000174887) originally captured at GV NQ S1 on 9/07/20 was recaptured at GV NQ S2 on 14/07/20 (Table 4.5).

4.6.1.3. Northern Quoll Site 3 (GV NQ S3)

Northern Quoll Site 3 was located within the Gorges and Gullies habitat type. Two male Northern Quolls were captured at GV NQ S3; one animal was recorded once, the other recorded seven times during the survey (Table 4.5). Traps were closed near where the individual was recaptured to avoid further recaptures, though this had little effect, with the animal instead moving further up or down the trap line to access other cages. Both males appeared to be in good physical condition with no obvious signs of injury, weight loss or parasites.

4.6.1.4. Opportunistic Pilbara Olive Python Observations

A single adult male Pilbara Olive Python was observed laying in a semi-permanent water pool in a deep gorge within the proposed Glacier Valley disturbance footprint (site GV POP2). Further details can be found in Table 4.5 and all conservation significant fauna record locations are displayed on Map 4.7.

Plate 4.7: Recorded Pilbara Olive Python and Associated Habitat

4.6.2. Targeted Pilbara Leaf-nosed Bat and Ghost Bat Surveys

The Survey Area was identified as an area of high Pilbara Leaf-nosed Bat and Ghost Bat activity (Appendix G). Evidence from roost habitat surveys identified Python Cave as a diurnal roost for both Pilbara Leaf-nosed Bats and Ghosts Bast. Three Pilbara Leaf-nosed Bats were observed roosting inside the cave, while fresh and historical Ghost Bat scat was recorded. There was no evidence at the South Star Pool complex to suggest the site was occupied as a Ghost Bat breeding roost during this survey, however a previous survey completed by GHD in 2019 suggests that the cave complex at South Star Pool is likely a maternity roost (Appendix G). No bats were captured during harp trapping within the Survey Area.

Pilbara Leaf-nosed Bats were recorded on bat detectors on 84 nights at 12 sites within the Survey Area (Table 4.6). At four of these sites calls were recorded within 20 minutes of civil twilight near dusk (CT PM). Of particular interest were two sites with calls on consecutive nights including moderate and high activity nights:

- South Star Pool (cave 3): Timing of records (e.g., some within 10 and 15 minutes of CT PM) with some records occurring over consecutive nights suggests Pilbara Leaf-nosed Bats may have been using cave 3 of the South Star Pool complex as a diurnal roost for up to six nights of the survey period. Placement of the detector unit inside the cave indicates records originate from inside the roost rather than Chateau Cave located approximately 2.4 km from the site.
- Python Cave: Timing of records and positive confirmation of roosting bats during the August survey indicates Pilbara Leaf-nosed Bats were using Python Cave (Map 4.7.) as a diurnal roost for up to three nights during the survey period. Placement of the detector unit inside the cave indicates records originate from inside the roost rather than Chateau Cave located approximately 4.1 km from the site.

Ghost Bats were confirmed from bat recorders on six nights at five sites within the Survey Area. Potential Ghost Bat calls were recorded at a further four sites within the Survey Area (Table 4.6).

Table 4.5: Conservation Significant Fauna Recorded During the Survey (excluding bats)

Species	Sex	Microchip #	Date	Capture Locations	Coordinates*		Weight (g)	Caudal Width (mm)	Short Pes (mm)	Total Length (mm)
					Easting	Northing				
Dasyurus hallucatus	M	991003000174887	9/07/2020 14/07/2020	GV NQ S1C4 GV NQ S2C2	713510 714240	7638301 7642208	690	16.3	39	N/A
Dasyurus hallucatus	M	900113001715476	9/07/2020 10/07/2020 12/07/2020 13/07/2020 15/07/2020	GV NQ S1C5 GV NQ S1C8 GV NQ S1C16 GV NQ S1C17 GV NQ S1C12	713506 713481 713399 713401 713450	7638256 7638110 7638076 7638126 7637913	750	21	36.5	N/A
Dasyurus hallucatus	M	900113001715477	9/07/2020 10/07/2020 11/07/2020 12/07/2020 13/07/2020 14/07/2020 15/07/2020	GV NQ S3C13 GV NQ S3C14 GV NQ S3C17 GV NQ S3C15 GV NQ S3C18 GV NQ S3C15 GV NQ S3C14	713276 713264 713205 713242 713188 713242 713264	7643873 7643856 7643852 7643858 7643848 7643858 7643856	800	20	39	N/A
Dasyurus hallucatus	F	900113001715468	10/07/2020	GV NQ S1C14	713395	7637982	390	14.5	29.9	N/A
Dasyurus hallucatus	M	991003000174878	10/07/2020	GV NQ S3C11	713310	7643884	720	18.2	38	N/A
Dasyurus hallucatus	F	900113001715480	13/07/2020 14/07/2020	GV NQ S1C4 GV NQ S1C5	713510 713506	7638301 7638256	365	15	32	N/A
Dasyurus hallucatus	M	900113001715478	13/07/2020	GV NQ S1C16	713399	7638076	640	16.8	37	N/A
Dasyurus hallucatus	M	900113001715475	14/07/2020	GV NQ S1C17 GV NQ S1C17	713401	7638126	490	17	35	N/A
Liasis olivaceus barroni	M	-	15/07/2020	GV POP2	713287	7644667	-	N/A	N/A	2000 (approx.)

*All coordinates given are GDA94 Z50

Table 4.6: Conservation Significant Bats Recorded During the Survey

Species	Survey	Date	Time of First Call	Location	Coordinates*		Comment
					Easting	Northing	
Macroderma gigas	Roost habitat survey	-	-	Python Cave	713259	7643858	Diurnal roost
Rhinonicteris aurantia	Roost habitat survey	-	-	Python Cave	713265	7643868	Diurnal roost
Rhinonicteris aurantia	Bat detector	18/05/2020 20/05/2020	11:21:00 PM 7:01:00 PM	GVBAT1 6282	713542	7638404	Feeding visitor
Rhinonicteris aurantia	Bat detector	19/05/2020 20/05/2020 21/05/2020	11:49:00 PM 12:25:00 AM 2:22:00 AM	GVBAT3 6174	714098	7642647	
Macroderma gigas	Bat detector	19/05/2020 20/05/2020	6:14:00 PM 6:20:00 AM	GVBAT3 6174	714098	7642647	
Rhinonicteris aurantia	Bat detector	19/05/2020 21/05/2020	9:09:00 PM 6:54:00 PM	GVBAT4 6272	713887	7641529	
Macroderma gigas	Bat detector	20/05/2020#		GVBAT5 6269	713423	7644685	
Rhinonicteris aurantia	Bat detector	20/05/2020 21/05/2020 22/05/2020	6:21:00 PM 7:25:00 PM 6:22:00 PM	GVBAT5 6269	713423	7644685	
Macroderma gigas	Bat detector	21/05/2020 22/05/2020#		GVBAT6 6256	713231	7643867	
Rhinonicteris aurantia	Bat detector	21/05/2020 22/05/2020 23/05/2020	7:32:00 PM 5:55:00 PM 7:01:00 PM	GVBAT6 6256	713231	7643867	
Macroderma gigas	Bat detector	21/05/2020#		SSP Cave 1	712521	7645693	
Rhinonicteris aurantia	Bat detector	21/05/2020 22/05/2020 23/05/2020	6:25:00 PM 6:18:00 PM 6:28:00 PM	SSP Cave 1	712521	7645693	

Species	Survey	Date	Time of First Call	Location	Coordinates*		Comment
					Easting	Northing	
Macroderma gigas	Bat detector and emergence survey	22/08/2020#		SSP Cave 5	712635	7645570	
Rhinonicteris aurantia	Bat detector and emergence survey	22/08/2020 23/08/2020 30/08/2020 31/08/2020 01/09/2020 03/09/2020 05/09/2020 07/09/2020	7:37:00 PM 8:11:00 PM 7:13:00 PM 6:57:00 PM 7:21:00 PM 7:16:00 PM 9:40:00 PM 7:05:00 PM	SSP Cave 5	712635	7645570	
Macroderma gigas	Bat detector and emergence survey	21/05/2020 22/08/2020# 27/08/2020#		SSP Cave 3	712543	7645698	
Rhinonicteris aurantia	Bat detector and emergence survey	21/05/2020 22/05/2020 23/05/2020 22/08/2020 – 21/09/2020 (recorded daily) 09/10/2020 – 14/10/2020 (recorded daily)	6:17:00 PM 6:12:00 PM 6:40:00 PM 6:43:00 PM 6:45:00 PM	SSP Cave 3	712543	7645698	
Macroderma gigas	Bat detector	15/10/2020		Python Cave	713264	7643860	

Species	Survey	Date	Time of First Call	Location	Coordinates*		Comment
					Easting	Northing	
Rhinonicteris aurantia	Bat detector	10/09/2020 – 17/09/2020 (recorded daily) 13/10/2020 – 18/10/2020 (recorded daily)	6:35:00 PM 4:13:00 AM	Python Cave	713264	7643860	
Rhinonicteris aurantia	Bat detector and emergence survey	25/08/2020 26/08/2020 27/08/2020 28/08/2020 28/10/2020	6:40:00 PM 6:35:00 PM 6:50:00 PM 6:45:00 PM 6:50:00 PM	SSP Cave 2	712521	7645693	
Macroderma gigas	Bat detector	28/08/2020		SSP Cave 2	712521	7645693	
Macroderma giga[#]	Emergence survey	28/10/2020[#]		SSP Cave 3	712529	7645698	
Rhinonicteris aurantia	Emergence survey	28/10/2020	7:02:00 PM	SSP Cave 3	712545	7645694	

*All coordinates given are GDA94 Z50

Possible recording

708000
711000
714000
717000
720000
7647000
7644000
7641000
7638000

South Star Pool
Python Cave
South Star Pool
Python Cave

Legend

- Survey Area
- Significant location

Current Survey Records

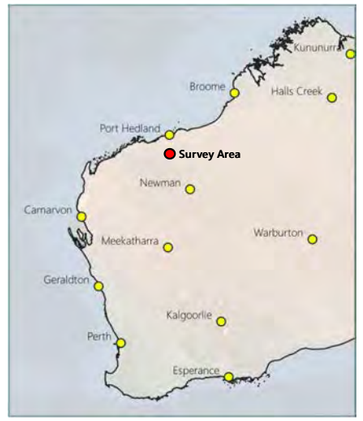
- Northern Quoll (EN)
- Pilbara Olive Python (VU)
- Ghost Bat (VU)
- Pilbara Leaf-nosed Bat (VU)
- Ghost Bat - Diurnal Roost
- Pilbara Leaf-nosed Bat - Transitory Diurnal Roost

FMG / IBO Supplied Previous Records

- Northern Quoll (EN)
- Pilbara Olive Python (VU)

Previous GHD Records (2018-2019)

- Northern Quoll (EN)
- Ghost Bat (VU)
- Pilbara Leaf-nosed Bat (VU)
- Pilbara Olive Python (VU)
- Peregrine Falcon (OS)



N

0 0.5 1 1.5 km

Scale 1:41,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: DC Date: 28-02-2023

Conservation Significant Fauna Recorded

Glacier Valley Project

Prepared for
IB Operations

MAP
4.7

4.7. Survey Adequacy

Analyses of both the vertebrate trapping grid and bird data produced flattening species accumulation curves approaching the horizontal asymptote. The graphs below display two data sets; species observed during the survey (S(est)) and the Michaelis-Menten curve (MM Means) that serves as an estimator of total species richness. Comparison of these two curves shows that approximately 76 % of the estimated total number of combined mammal and reptile species (Figure 4.5), and 80 % of the potential bird species (Figure 4.6) were sampled. These results indicate that, with further trapping effort, an additional 10 mammal or reptile species may be detected, and another 6 bird species. No amphibians were recorded during systematic sampling and as such did not contribute to the analysis.

The trapping grid data includes records from both phases of survey (56 trapping events). The analysed bird survey data was also collected over both phases, with a total of 32 set-time surveys completed.

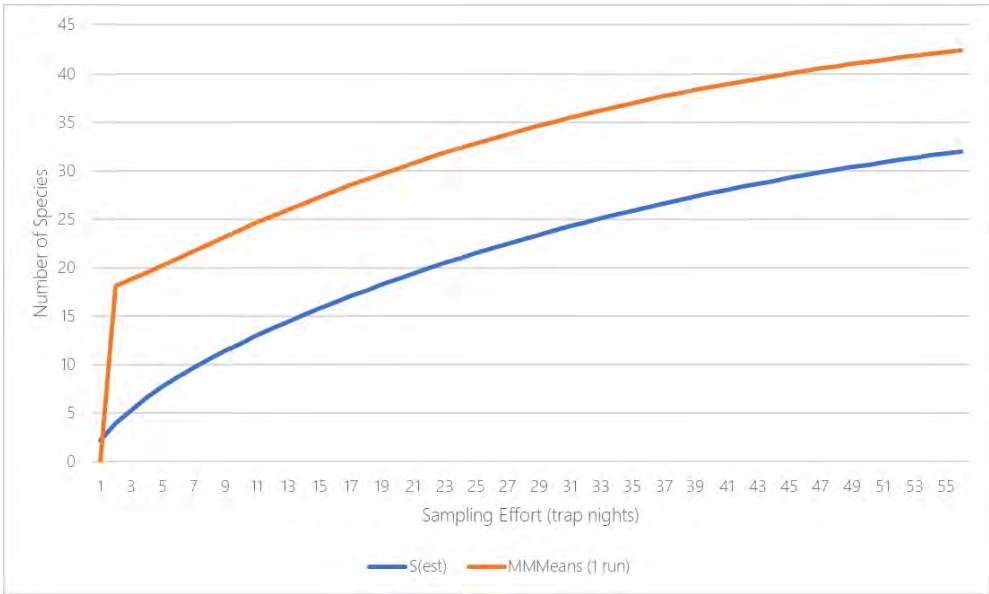


Figure 4.5: SAC Based on Systematic Trapping Data

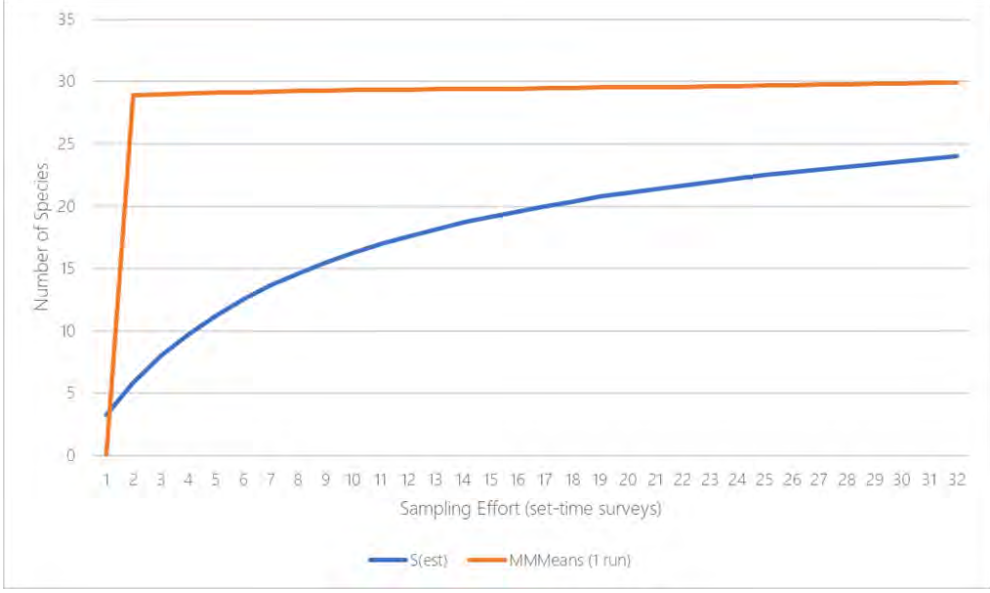


Figure 4.6: SAC Based on Systematic Set-time Bird Surveys

5. DISCUSSION

5.1. Desktop Assessment

5.1.1. Vertebrate Fauna

The desktop assessment identified nine amphibians, 152 bird species (including one introduced), 48 native mammals (plus ten introduced), 113 reptiles and four fish that have been recorded from the region surrounding the Survey Area. This is significantly higher than the results of any single vertebrate fauna survey completed in the region, including the current survey. This is to be expected, as the desktop draws data from a wide range of sources that were collected over different time periods and seasons, as well as more types of fauna habitats than those present within a single survey area. A suitable example of this is the large number of shorebird and other water bird species reported only by NatureMap. NatureMap also has the potential to include vagrant species and those only present in the region during and/or following significant rainfall events and the resource boom that follows. These records may also be incorporated via museum collection trips, public specimen collections/ observations and DBCA surveys, as well as from the DBCA fauna survey returns database which includes data from private sources.

The data reported by NatureMap, the DBCA Threatened Fauna Database, the Protected Matters Search Tool as well as previous survey reports all provide a useful indication of regional vertebrate fauna assemblages. Whilst many species recorded during the desktop assessment have the potential to occur in the Survey Area, the fauna assemblage that typically utilises all the habitats found within the Survey Area forms a much smaller subset of species. Variations in population distributions and the availability of microhabitats within each area also limit the species that may occur. However, the accumulated data provided by the desktop assessment is invaluable during survey planning to ensure all major fauna assemblages are sampled and any conservation significant species that may occur are targeted appropriately.

5.2. Fauna Habitats

5.2.1. Hills, Ranges and Plateaux

The Hills, Ranges and Plateaux habitat type was the most extensive in the Survey Area, with the highest degree of variation in vegetation type and structure. Amphibians are typically in low density and lacking diversity in this habitat type due to the lack of water, soft substrate (for burrowing species) and cool, moist refugia to shelter in during dry periods.

The avifauna of this habitat type is typically comprised of generalist species that can also be found in a variety of other habitats. Zebra Finch, Spinifex Pigeon and Crested Pigeon can be found foraging for seeds amongst the *Triodia* sp., and honeyeater species such as the Grey-headed Honeyeater feed on flowering trees and shrubs. Some less-frequently observed birds such as the Rufous Grasswren and the Rufous-crowned Emu-wren can be found on hilltops and slopes where they hide between and within mature spinifex hummocks.

Some examples of mammals found in the Hills, Ranges and Plateaux habitat are the Euro (*Osphranter robustus*), Pilbara Ningaui (*Ningaui timealeyi*) and Planigale (*Planigale* sp.). These and other similar species will all utilise the cracks, crevices, and caves typically found in this habitat for shelter.

An assortment of saxicoline herpetofauna species such as the Ring-tailed Dragon (*Ctenophorus caudicinctus*), Rock Ctenotus (*Ctenotus saxatilis*), Lined Firetail Skink (*Morethia ruficauda exquisita*) and the Spiny-tailed Monitor (*Varanus acanthurus*) inhabit the Hills, Ranges and Plateaux habitat.

Conservation significant fauna species potentially occurring in this habitat type include the Long-tailed Dunnart (*Sminthopsis longicaudata*) and Western Pebble-mound Mouse (*Pseudomys chapmani*). The Northern Quoll (*Dasyurus hallucatus*) may also utilise this habitat infrequently for foraging purposes or for shelter in areas with suitable rocky shelter adjacent to foraging and denning habitat.

5.2.2. Rocky Escarpments

The Rocky Escarpments habitat type included some of the most vertical features in the Survey Area such as cliffs and breakaways. Amphibians are typically absent or in low density in this habitat type due to the lack of water and exposure to high temperatures.

The avifauna of this habitat type is typically not diverse and is comprised of generalist species that can also be found in adjacent habitat types (such as Hills, Ranges and Plateaux). Little Woodswallows and birds of prey such as Australian Kestrels may roost and nest on ledges, and the nocturnal Australian Owlet-nightjar may be found sheltering in caves and overhangs during the day.

Some examples of mammals found in the Rocky Escarpments habitat are Rothschild's Rock-wallaby (*Petrogale rothschildii*), Common Rock-rat (*Zyzomys argurus*) and Woolley's Pseudantechinus (*Pseudantechinus woolleyae*) which all utilise cracks, crevices, and caves for shelter. A variety of bat species including the Common Sheath-tailed Bat (*Taphozous georgianus*) and Finlayson's Cave Bat (*Vespadelus finlaysoni*) can be found occupying overhangs, crevices and caves along the ridges and cliffs.

An assortment of saxicoline herpetofauna species such as the Western Marbled Velvet Gecko (*Oedura fimbria*), Pilbara Cave Gecko (*Heteronotia spelea*), Spotted Dtella (*Gehyra punctata*) and the Pygmy Python (*Antaresia perthensis*) can be found occupying cliff faces and their associated cracks, crevices and caves.

Threatened fauna species such as the Northern Quoll (*Dasyurus hallucatus*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*), Ghost Bat (*Macroderma gigas*), Pilbara Olive Python (*Liasis olivaceus barroni*) and Long-tailed Dunnart (*Sminthopsis longicaudata*) are all associated with the typical rocky ridges, outcropping, cliffs and caves found in this habitat type. High ledges along cliffs may also provide nesting habitat for the Peregrine Falcon (*Falco peregrinus*).

5.2.3. Gorges and Gullies

Gorges and Gullies forms suitable habitat for a large variety of terrestrial species due to increased resources such as moisture, shelter, and food. The Little Red Treefrog (*Litoria rubella*) may utilise this habitat when surface water is present in small permanent pools or after rainfall events.

The avifauna of this habitat type are relatively sparse and unique. Species such as the Western Bowerbird and Grey Shrike-thrush prefer gorge habitat, where they forage for fruit and insects. Nocturnal birds such as the Australian Owlet-nightjar often shelter in small overhangs during the day and forage on insects during the night. This habitat occasionally features small waterholes that attract a variety of birds during the day. Grey-headed Honeyeaters, Black-chinned Honeyeaters, Painted Finches, Spinifex Pigeons and Common Bronzewings can be seen flying in from surrounding areas to drink from small rock pools.

The Rothschild's Rock-wallaby (*Petrogale rothschildi*) is active in this habitat at night and shelters in caves and crevices during the day. The Common Rock-rat (*Zyzomys argurus*) is a regularly encountered rodent species that lives in the Gorges and Gullies habitat. The Lesser Long-eared Bat (*Nyctophilus geoffroyi*) and

Gould's Wattled Bat (*Chalinolobus gouldii*) can be recorded foraging for insects at night and shelters in caves and crevices during the day.

The herpetofauna typical for the Gorges and Gullies habitat include rock- and crevice-dwelling species that are generally not found away from significant rock structures. The Goldfields Crevice-skink (*Egernia formosa*), Russet Snake-eyed Skink (*Cryptoblepharus ustulatus*), Pygmy Python (*Antaresia perthensis*) and Pilbara Rock Monitor (*Varanus pilbarensis*) are common examples of crevice-dwelling species.

Due to the higher moisture levels in Gorges and Gullies habitat and the availability of shelter in the form of crevices, caves and overhangs, several threatened fauna species can be found utilising this habitat type. The Northern Quoll (*Dasyurus hallucatus*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*), Ghost Bat (*Macroderma gigas*), Pilbara Olive Python (*Liasis olivaceus barroni*) and Long-tailed Dunnart (*Sminthopsis longicaudata*) may all use Gorges and Gullies for both denning/roosting and foraging.

5.2.4. Minor Drainage Lines

Minor Drainage Lines is the most densely vegetated habitat type within the Survey Area. Amphibians such as the Little Red Tree Frog (*Litoria rubella*) and Main's Frog (*Cyclorana maini*) can be found in the creekbeds where the substrate holds moisture, and in large numbers after rainfall events when surface water is present.

The avifauna utilising Minor Drainage Lines are most diverse after significant rainfall when *Acacia* and *Grevillea* spp. shrubs are flowering. Honeyeater species such as Brown Honeyeater, White-plumed Honeyeater and Singing Honeyeater are most common during these flowering events. In good conditions, when abundant nectar-producing blooms are available, Black, Pied and White-fronted Honeyeaters can also be common. Other species likely to occur include Crested Bellbird, Weebill, Willie Wagtail, Red-capped Robin, Grey-crowned Babbler, and White-winged Triller, some of which are more sedentary and rely less on post-rainfall flowering events.

Mammal species occupying Minor Drainage Lines include generalists such as the Pilbara Ningaui (*Ningaui timealeyi*), Sandy Inland Mouse (*Pseudomys hermannsburgensis*), and Delicate Mouse (*Pseudomys delicatulus*). These species utilise burrows, spinifex grasses, wood litter and leaf litter beneath shrubs for shelter and foraging.

The herpetofauna of the Minor Drainage Lines habitat is comprised of generalist species such as the Tree Dtella (*Gehyra variegata*), Common Dwarf Skink (*Menetia greyii*), Shaded-litter Rainbow-skink (*Carlia munda*), slider species of the genus *Lerista*, and legless lizards such as the Peace Delma (*Delma pax*). Specialist species such as the Flat-shelled Turtle (*Chelodina steindachneri*) inhabit areas where ephemeral pools form after rain, whereas the Long-nosed Dragon (*Gowidon longirostris*) can be found within the surrounding riparian vegetation.

The Minor Drainage Lines habitat type does not typically provide critical habitat for any conservation significant species. However, the Northern Quoll (*Dasyurus hallucatus*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*), Ghost Bat (*Macroderma gigas*), Pilbara Olive Python (*Liasis olivaceus barroni*) and Peregrine Falcon (*Falco peregrinus*) may use this habitat type for foraging and/or dispersal purposes.

5.3. Fauna Habitat Analysis

The results of the fauna habitat analysis confirm that, especially for vertebrates caught in the trapping grids (mammals and reptiles), the fauna assemblage of the Hills, Ranges and Plateaux habitat is distinct from that of the Minor Drainage Lines. This is to be expected given the categorical differences in vegetation and landform between the two and indicates that the fauna present are generally restricted to these habitats. There also appears to be minimal variation between the fauna recorded at each of the three sites in the Hills, Ranges and Plateaux habitat, suggesting this habitat is somewhat homogenous across the Survey Area.

However, in terms of the bird data, there appears to be only a loose distinction between the two habitats in the scatter plot, and none in the cluster analysis. This is likely because birds are much more mobile and generally less restricted to a given habitat, so that for example they might be recorded in Hills, Ranges and Plateaux habitat whilst moving between trees in Minor Drainage Lines habitat. This means the effect size, or measurable difference in bird fauna assemblage between habitats, is much smaller than for the trapping grid fauna. This issue is conflated and amplified by the fact that there were very few birds recorded systematically during the survey (conditions were very hot and windy; also see Appendix E), resulting in poor representation of the population and lower statistical power.

5.4. Fauna Assemblage

During the two phases of field work at the Survey Area, a total of 93 vertebrate fauna species were recorded: one amphibian, 39 bird species, 12 species of native non-volant mammals, six species of bats, three introduced mammals, and 32 reptiles. This is a relatively low total compared to that recorded during previous surveys in the region (Table 4.1). This is likely due to the relatively small number of fauna habitats present within the Survey Area. Furthermore, although the survey timing of the first phase (early May) was suitable for each species group, strong winds at the time limited bird activity. Likewise, during the second phase of the survey, dry conditions with strong winds and hot temperatures (daily maximum of 41°C) were recorded, which also negatively impacted fauna activity levels (particularly birds and amphibians). Reptiles are typically more active during warm temperatures; however, due to the temperatures exceeding 38°C, traps were closed between mid-morning and mid-afternoon to avoid trap deaths. This reduced the accessibility of the traps and consequently the number of animals that could enter them. The Targeted survey was completed during optimal timing for the relevant species, so the results of this survey were not affected by adverse weather conditions.

A comparison of systematically collected data (trapping and bird survey results) shows that vertebrate fauna captures were higher during the second phase of the survey (110 vs 238). Despite the post wet season survey typically being considered the preferred survey timing due to more suitable conditions, the timing of rainfall events in relation to the field surveys was unlikely a contributing factor in this case. It is more likely that the delayed effect of rainfall, such as increased food resources (insects, nectar, seeds etc.) provided by the rainfall events during the wet season, resulted in increased vertebrate fauna abundance and activity. This is apparent in the mammal capture results and bird counts, which were almost four times higher during phase 2. Whilst using systematic survey techniques, increased bird counts were noticed across the granivores such as Galahs, Spinifex Pigeons and Painted Finches, insectivorous species (Pied Butcherbird), and also nectarivores like the Grey-headed Honeyeater (Appendix E).

The increase in mammal abundance was almost solely due to the number of Pilbara Ningaui captured during phase 2, which was significantly higher in October 2020 than during the first phase in May. This is likely due to their life cycle, with population sizes typically peaking in September (Dunlop and Sawle, 1982). A small increase across other small dasyurids and rodents (Delicate Mouse, Desert Mouse, Sandy Inland

Mouse and Common Rock-rat) contributed to the overall higher number of captures. In particular, Pilbara rodents are known to undergo boom and bust cycles with up to 40- to 50-fold population increases, with peaks in population size recorded up to 18 months after the first heavy post-drought rainfall event (How and Cooper, 2002). This is consistent with the increased mammal activity recorded during the second phase, which was completed 19 months after a peak rainfall event in March 2019, when a total of 622.8 mm of rain was recorded during a single month (Fortescue rainfall data presented in Spectrum (Spectrum Ecology, 2019b, 2020b)).

Reptile captures (based on systematic trapping results) were comparable between the two phases (67 vs 69 captures). When comparing systematic species counts, there was an increase between phase 1 and phase 2 (12 vs 20). Three gecko species, one legless lizard, three skinks, one varanid and four snakes were only captured during the phase 2 survey. This is likely due to the warmer temperatures during the second phase compared with the first phase (Figure 2.2), during which the temperatures were certainly cool enough to have had a negative effect on reptile activity.

5.5. Conservation Significant Fauna

The literature and database review identified a total of 27 conservation significant species listed as either Threatened (EPBC Act, BC Act Schedule) or Priority (DBCA Priority list) fauna that could potentially occur within the Survey Area. This includes eight mammals, 16 birds and three reptiles.

An assessment of their likelihood of occurrence was completed, based on the categories outlined in Table 3.2. Relevant information for each species, including a consideration of known habitats and previous survey effort, is summarised in Table 5.1.

Of the 27 species, 10 (three birds, five mammals and two reptiles) have a medium to high likelihood of occurrence, or have been recorded inside the Survey Area, and are discussed in further detail in sections 5.5.1-5.5.3. The remaining 17 species have a low to very low likelihood to occur based on the lack of habitats within the Survey Area (e.g. waterbirds) and/or scarcity of records in the region.

Table 5.1: Likelihood of Occurrence Criteria for Conservation Significant Species

Species	Conservation Status			Preferred Habitats	Previous Records	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA			
Birds						
Night Parrot *Pezoporus occidentalis*	EN	EN		Recorded from long unburnt, ring-forming *Triodia* grasslands in association with low-lying saline lakes and drainages hosting chenopods/samphire (Jackett *et al.*, 2017).	Protected Matters Search Tool (PMST) only with no specific record information.	**Low** No nearby records and limited suitable habitat present.
Oriental Plover *Charadrius veredus*	MI	MI		Open grasslands and sparsely vegetated plains. During hottest parts of the day, collects in large flocks on wet ground. Associated with wetlands though often found far from water (Pizzey and Knight, 2012).	PMST only with no specific record information or historically recorded (NatureMap).	**Low** The species has been rarely recorded in the wider region. Small areas of suitable habitat are present near creeklines.
Curlew Sandpiper (*Calidris ferruginea)* Eastern Curlew (*Numenius madagascariensis*) Australian Painted Snipe (*Rostratula australis*) Common Sandpiper (*Actitis hypoleucos*) Pectoral Sandpiper (*Calidris melanotos*) Oriental Pratincole (*Glareola maldivarum*) Osprey (*Pandion halieatus*) Common Greenshank (*Tringa nebularis*)	MI	MI		Drainage lines, waterways and pools along rivers (Pizzey and Knight, 2012).	Mostly only listed by PMST as potentially occurring, with no specific record information. Some scattered records from along the Main Line Rail to the W of the Survey Area.	**Very Low** No nearby records or suitable habitat.

Species	Conservation Status			Preferred Habitats	Previous Records	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA			
Barn Swallow (*Hirundo rustica*) Grey Wagtail (*Motacilla cinerea*) Western Yellow Wagtail (*Motacilla flava*)	MI	MI		Open country with low vegetation, farmlands and meadows (Department of the Environment, 2020) Fast-flowing watercourses, lakes, ploughed fields and creeks (Pizzey and Knight, 2012) Damp and wet habitats with low vegetation including meadows, marshes and waterside pastures (Birdlife International, 2020)	PMST only, with no specific record information. Not recorded during previous surveys.	**Very Low** No previous records and suitable habitat is very limited on-site.
Fork-tailed Swift *Apus pacificus*	MI	MI		Nomadic, almost entirely aerial lifestyle over a variety of habitats; associated with storm fronts (Australian Government & Department of Agriculture Water and the Environment, 2020)	A single record 7 km to the NW of the Survey Area in 2011 (DBCA 2020). Six NatureMap records within approx. 40 km.	**Medium** Recorded during the baseline survey at North Star. Species is rarely recorded due to its aerial lifestyle.
Grey Falcon *Falco hypoleucos*		VU		Arid and semi-arid grasslands, plains and wooded watercourses (Olson and Olson, 1986; Schoenjahn, 2013)	Three records from 2012-14 within 36 km of the Survey Area (NatureMap). A family of four was recorded in 2012 from within 12 km W of the Survey Area. Additional records from the FMG Main Line Rail during annual monitoring.	**High** Recorded from within the region. Some habitat for foraging and nesting present within the Survey Area.
Peregrine Falcon *Falco peregrinus*		OS		Widespread but uncommon; a variety of habitats including open woodlands, grasslands with trees, lakes, wooded watercourses and urban areas (Pizzey and Knight, 2012)	Two records from 2000-02 within 38 km of the Survey Area (NatureMap). Species was recorded on-site during a previous survey (GHD 2020)	**Recorded** Previous records from near and within the Survey Area. Some suitable habitat for foraging and breeding occurs.

Species	Conservation Status EPBC Act	BC Act	DBCA	Preferred Habitats	Previous Records	Likelihood of Occurrence
Mammals						
Northern Quoll *Dasyurus hallucatus*	EN	EN		Most common on dissected rocky escarpments, gorges and boulder piles. Typically prefers rocky areas with suitable denning sites and access to surface water. Major drainage lines and wooded creek lines may be used for movement and dispersal (DoE 2016).	357 records to the N and the SW within 24 km of the Survey Area since 2001 (DBCA 2020), including records from within the Survey Area.	**Recorded** Species recorded from the Survey Area during previous and current surveys. Suitable denning and foraging habitat present.
Greater Bilby *Macrotis lagotis*	VU	VU		A variety of habitats with suitable soil substrates and plant species that are fed on directly or host insect larvae. Habitats can include spinifex hummock grassland, acacia shrubland, open woodland and cracking clays (Dziminski and Carpenter, 2016, 2018)	365 records from the sandplain habitat to the west of the Survey Area within 30km since 2001 (DBCA). Naturemap lists 403 records west of the Survey Area also within 35 km, most of which are likely a duplicate of the DBCA records.	**Low** No suitable habitat exists within the Survey Area, despite the species being frequently recorded within 20 km west where sandplain habitat is present.
Pilbara Leaf-nosed Bat *Rhinonicteris aurantia* (Pilbara form)	VU	VU		Dissected rocky escarpments with suitable roost caves with high humidity (85 - 100% RH) and stable temperatures (28 - 32°C). Forages in a variety of habitats, particularly along water bodies and riparian vegetation (Armstrong, 2001; Cramer *et al.*, 2016)	253 records within the Survey Area and within 17 km, in particular to the north (DBCA 2020). Maternity roost caves also recorded from the north (ecologia Environment, 2012b; GHD, 2015; Spectrum Ecology, 2020a).	**Recorded** The species was recorded during previous surveys and is known to breed within areas adjacent to the north of the Survey Area. A transitory diurnal roost was recorded from Python Cave.

Species	Conservation Status			Preferred Habitats	Previous Records	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA			
Ghost Bat *Macroderma gigas*	VU	VU		A variety of habitats, including caves, rock piles and abandoned mines, may be utilised as transient roosts. Maternity/ breeding roosts require dark, warm and humid (>80% RH) microclimates (Armstrong and Anstee, 2000). Will travel up to 2 km from a roost to hunt, and will utilize other structures such as culverts, rock overhangs and trees for feeding roosts (Tidemann *et al.*, 1985).	22 records to the N and the SW within 24 km of the Survey Area, between 2001 and 2018 (DBCA 2020), and 62 records within 40 km (NatureMap). Species has been recorded during several previous surveys from immediately north of the Survey Area (ecologia Environment, 2012b; GHD, 2015; Spectrum Ecology, 2020a).	**Recorded** Recorded from the current and previous surveys from within the Survey Area. A breeding roost (to be confirmed) was recorded from South Star Pool, and a diurnal roost was recorded from Python Cave. Suitable foraging and roosting habitat present.
Brush-tailed Mulgara *Dasycercus blythi*			P4	Sandy, loamy and sometimes stony/ gibber plains vegetated with spinifex and/ or tussock grasses. Has a preference for flats rather than the dune crests preferred by its congener *D. cristicauda* (Pavey *et al.*, 2011).	Three historical and 16 recent records, most recently recorded along the Fortescue Main Line Rail in 2018 approx. 18 km west of the Survey Area (DBCA 2020). 69 records within 30 km (NatureMap).	**Low** No suitable habitat is present within the Survey Area. Records are limited to the sandplain habitat to the west of the Survey Area.
Western Pebble-mound Mouse *Pseudomys chapmani*			P4	Rocky ranges and hills where suitably-sized pebbles are available for mound construction. Most common on the lower slopes of ridges vegetated with spinifex hummock grassland (Dunlop and Pound, 1981)	Ten records within 20 km of the Survey Area (DBCA 2020), 53 records from NatureMap within 40 km of the Survey Area. Previous surveys to the North recorded the species along continuous habitat (ecologia Environment, 2012b).	**High** Potential to occur based on recent records in proximity to the Survey Area, and suitable habitat is present.
Long-tailed Dunnart *Sminthopsis longicaudata*			P4	Rocky hills, ranges and escarpments with open woodland and/or shrubland over spinifex (Pavey, 2006)	Two records within 6 km north of the Survey Area during a previous survey in 2011 (DBCA 2020, NatureMap).	**High** Potential to occur based on recent records in proximity to the Survey Area, and suitable habitat is present.

Species	Conservation Status			Preferred Habitats	Previous Records	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA			
Short-tailed Mouse *Leggadina lakedownensis*			P4	Spinifex and tussock grassland on cracking clays. Also acacia shrubland, samphire, woodlands, and stony ranges in northern Australia (Kutt and Kemp, 2005).	One record from 15 km south-west of the Survey Area.	**Low** No suitable habitat present, very few records in the region.
Reptiles						
Pilbara Olive Python *Liasis olivaceus* subsp. *barroni*	VU	VU	VU	Inhabits gorges, gullies, stony ranges, rock piles and along watercourses. Often associated with permanent or temporary water bodies, but is not restricted to them (DSEWPaC 2011c)	52 records located within 11 km of the Survey Area along the rocky escarpments to the north, from 2011-2017 (DBCA 2020, previous surveys), 42 records within 38 km of the Survey Area (NatureMap).	**Recorded** The species was recorded during previous surveys and the current survey, and is also known from continuous habitats to the north of the Survey Area. Suitable habitat is present.
Gane's Blind Snake *Anilios ganei*			P1	A variety of habitats; thought to prefer moist gorges, though habitat data is limited (Aplin, 1998). Its cryptic nature and predominantly subterranean lifestyle reduce the likelihood of recording this species during fauna assessments.	One recent record (2018) approximately 11 km north of the Survey Area (DBCA 2020, NatureMap). Another record from 2014 from north of the Survey Area (ecologia Environment, 2014a). Metadata indicates that these records represent a single record.	**Medium** Recently recorded nearby with suitable habitat occurring throughout the Survey Area. Previous record represents a range extension.
Pin-striped Fine-snout Skink *Ctenotus nigrilineatus*			P1	Spinifex plains adjacent to granite outcrops and watercourses in hilly interior of Pilbara (Wilson and Swan, 2017).	A single record to the south-west of the Survey Area in 2001 (DBCA 2020), four records within 25 km to the south-west pre-2001 (NatureMap)	**Low** No recent records of the species and little suitable habitat present within the Survey Area.

5.5.1. Birds

5.5.1.1. Fork-tailed Swift (*Apus pacificus*)

- EPBC Act – Migratory
- BC Act – Migratory

Distribution, Habitat and Ecology: The Fork-tailed Swift is a terrestrial migratory visitor to Australia from Asia, occurring across all states. Within Western Australia, observations are highest along the coast and in the south-west, Pilbara, and Kimberly regions. Records are most sparse inland, especially in the wheatbelt (DAWE 2020). This medium-sized swift is characterised by its forked tail and white rump, with back-swept wings that taper to a fine point and a tail that is deeply forked when spread (Menkhorst *et al.*, 2019). The species is known to be highly nomadic and rarely lands, spending much of its time foraging in large flocks high above the ground. The species is known to be insectivorous, but its food source is relatively unknown within Australia (Menkhorst *et al.*, 2019).

Likelihood of Occurrence – Medium: The Fork-tailed Swift was recorded from 7 km to the north-west of the Survey Area in 2011 (ecologia 2012b). The species is likely to overfly the Survey Area in association with thunderstorms, but is unlikely to land or utilise the habitats of the Survey Area due to its almost entirely aerial lifestyle.

5.5.1.2. Grey Falcon (*Falco hypoleucos*)

- BC Act: Vulnerable

Distribution, Habitat and Ecology: The Grey Falcon is the rarest falcon in Australia, with an estimated population size of <1000 individuals (Schoenjahn, 2011). They occur very sparsely in a wide variety of arid and semi-arid zones that make up an area of about 5 million km^2 (Archer *et al.*, 2002; Schoenjahn, Pavey and Walter, 2020). Currently, there do not appear to be any vegetation types that Grey Falcons are particularly associated with, however that may be due to an insufficient understanding of their fine-scale environmental requirements (Schoenjahn, Pavey and Walter, 2020). Neither do climatic characteristics (temperature and rainfall) appear to strongly influence the distribution of the species. Breeding habitat appears to be localised in zones with the highest annual average temperatures, and areas with persistently dry and winter drought climatic conditions (Schoenjahn, 2013). Grey Falcons, like most falcons, typically use the nests of other large birds (often corvids and other raptors) in trees or on human infrastructure such as repeater towers or power-line pylons. Nests are often used over several years and can be in close proximity to nests of other falcons or raptor species (Schoenjahn, 2013). The Grey Falcon forages in open landscapes such as rocky plains with hummock grasslands, low shrublands, and small drainage lines, where they predominantly feed on birds, mainly pigeons (*Columbidae*) and parrots (*Psittaciformes*) (Schoenjahn, 2013).

Likelihood of Occurrence – High: A family of Grey Falcons was recorded from approximately 12 km west/south-west of the Survey Area during the North Star Level 2 baseline survey in 2011 (ecologia 2012b). The species has also been recorded along the Fortescue Main Line Rail (ecologia 2015a; Spectrum 2019b). The Grey Falcon is likely to use the Survey Area for foraging on an infrequent basis, and breeding sites may also be present along the Minor Drainage Lines habitat; however, nests are also built in artificial infrastructures such as repeater towers. Development of powerline infrastructure may increase the availability of nesting sites. The Grey Falcon has been given a medium likelihood of occurrence as it is has been previously recorded in the region, and is a widely dispersed species, occurring in low numbers across the north of Australia (Olson and Olson, 1986; Schoenjahn, Pavey and Walter, 2020).

5.5.1.3. Peregrine Falcon (*Falco peregrinus*)

- BC Act: Other Specially Protected Fauna

Distribution, Habitat and Ecology: The Peregrine Falcon is one of the most widespread birds in the world, breeding on all continents except Antarctica (Olsen *et al.*, 2006). It occurs across most of Australia, although they are an uncommon species and are rare across all states and territories (Birdlife Australia, 2012). They are known to be both a nomadic and sedentary species, and are uncommon in the Kimberley, Hamersley and Darling Ranges. They inhabit cliffs, coastal habitats, rivers, wooded water courses and lakes, as well as urban environments. Peregrine Falcons usually nest by making a scrape on a high cliff-edge, but will also use stick nests of other large birds and tree hollows in some areas (Olsen *et al.*, 2006). Hunting is mainly done during the day and feeding is primarily on small- to medium-sized birds caught in flight, often above drainage lines and rivers. Favoured prey species include the Galah (*Eolophus roseicapilla)* and Sulphur-crested Cockatoo (*Cacatua galerita*) (Birdlife Australia, 2012).

Likelihood of Occurrence – Recorded: Previous biological surveys have recorded the Peregrine Falcon from the region and from within the Survey Area (GHD, 2020). Hunting habitat is present within the western Survey Area in the Minor Drainage Lines habitat type. The Rocky Escarpments habitat in the eastern section also provides potential breeding habitat for the species. The species typically occurs in low densities and is likely to only occur infrequently.

5.5.2. Mammals

5.5.2.1. Northern Quoll (*Dasyurus hallucatus*)

- EPBC Act: Endangered
- BC Act: Endangered

Distribution, Habitat and Ecology: The Northern Quoll is the smallest of the four quoll species occurring in Australia (Oakwood, 2008). The species formerly occurred all across the northern parts of Australia. Since the arrival of the Cane Toad (*Rhinella marina*) the Northern Quoll's distribution has declined significantly, especially in the more arid parts of its range (DAWE 2020). The species' diet varies widely, fluctuating based on available habitats and environmental conditions. The Northern Quoll is an opportunist feeder that mostly consumes insects, fruit, vegetation and molluscs, but also a large number of vertebrate species (mammals, birds, reptiles and frogs) (Dunlop, Rayner and Doherty, 2017). The Pilbara population is associated with rocky habitats where the species finds refuge during the day in crevices, cracks and small caves. These critical denning habitats include rocky gorges, basalt hills, escarpments, mesas, plateaux, granite boulder piles, caves and adjacent cliff faces, but also along coastal fringes and beaches (DAWE 2020). Foraging can occur across any adjacent habitat type that provides suitable cover and food resources. Drainage lines and rivers are used by the species for dispersal and foraging. The species is adaptable and has also been recorded in artificial habitat such as rock armour underneath bridges (Ecoscape 2018), in quarries (DMP 2013), camp sites (ecologia 2012b) and along breakwaters (Ecoscape 2016a, Ecoscape 2016b).

Likelihood of Occurrence – Recorded: The species was recorded from the Survey Area during previous surveys and monitoring events over several years (ecologia 2011, ecologia 2014a; Ecoscape 2016d, Ecoscape 2017a; Spectrum 2019b, Spectrum 2020d). A total of eight individuals (six males, two females) were captured during the current Targeted survey in the eastern section of the Survey Area, which indicates that breeding occurs on site. Additional records were made from 14 motion cameras in the western and eastern sections of the Survey Area (Gorges and Gullies; Rocky Escarpments; and Minor Drainage Lines habitat types). Breeding activities are known from north of the Survey Area, with females being repeatedly captured up to three consecutive years. Suitable habitat for denning is present within the Survey Area along the Gorges and Gullies, and the Rocky Escarpments habitats (Map 5.1). Foraging and dispersal habitat is present along the Minor Drainage Lines habitat. Some dispersal of young may also occur across the Hills, Ranges and Plateaux habitat, however this habitat is not considered critical for the survival of the species.

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- Survey Area

Northern Quoll Habitat

- Denning Habitat (Gorges & Gullies, Rocky Escarpment)
- Foraging and Dispersal Habitat (Minor Drainage Line)

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Scale 1:41,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: AH Date: 28-06-2021

Critical Habitat for the Northern Quoll

Glacier Valley Project

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IB Operations

MAP
5.1

5.5.2.2. Ghost Bat (*Macroderma gigas*)

- EPBC Act: Vulnerable
- BC Act: Vulnerable

Distribution, Habitat and Ecology: The Ghost Bat is a large, specialist carnivorous bat and is the sole survivor of its genus (Hoyle, Pople and Toop, 2001; Worthington Wilmer *et al.*, 2008). Historically, it was widely distributed across Australia, but the species is now only recorded from isolated locations across northern Australia, including the Pilbara region (Armstrong and Anstee, 2000).

The Ghost Bat is a predator and feeds on other bats, rodents and birds. Prey detection is completed by a combination of passive listening, vision and some echolocation, where detection through movement is thought to be the primary stimulus (Pettigrew *et al.*, 1988). Studies undertaken by Boles (Boles, 1999) have shown that Ghost Bats often take roosting birds and small rodents. During the wet season, grasshoppers, beetles and cicadas are heavily preyed upon (Toop, 1985; Pettigrew *et al.*, 1986).

Ghost Bats utilise a range of cave structures for a variety of purposes, ranging from short-term transient feeding roosts through to maternity roosts (DoE 2018). Short-term transient feeding roosts can include overhangs, small shallow caves, granite boulders, and even rail culverts (Armstrong and Anstee, 2000; Ecoscape 2017b, Ecoscape 2018). These sites have microclimates that are similar to ambient conditions. Maternity roosts, however, require a more stable, warm and humid climate with a relative humidity of over 80%. They are usually deep, complex or large-domed caves (or mine adits) with an ideal isothermal zone (23-26°C), and a cavern size large enough for the species to manoeuvre in (Pettigrew *et al.*, 1986; Hall *et al.*, 1997). Medium-sized caves with suitable microclimates are used for a variety of activities from brief visits to consume prey to long-term roosting. Caves that provide complete darkness are reported to be preferred for roosting (Schulz and Menkhorst, 1986).

Likelihood of Occurrence – Recorded: Ghost Bats were recorded during previous surveys (ecologia 2011, ecologia 2012b; GHD, 2020) and from the current survey (Map 4.2). A diurnal roost was recorded from Python Cave in the south of the Survey Area (Appendix G). Records appear to be concentrated around the ranges associated with the Wodgina and North Star projects. Suitable cave structures for the Ghost Bat are present along the Gorges and Gullies, and Rocky Escarpment habitat types in the eastern section of the Survey Area. The Minor Drainage Lines habitat type is likely used for foraging habitat in addition to the two roosting habitats above (Map 5.2).

5.5.2.3. Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*)

- EPBC Act: Vulnerable
- BC Act: Vulnerable

Distribution, Habitat and Ecology: The Pilbara Leaf-nosed Bat is the Pilbara form of the Orange Leaf-nosed Bat, a small orange coloured bat, that occurs across the north of Australia (Armstrong, 2006). The two separate populations of the Orange Leaf-nosed Bat, one in the Pilbara and the other one in the Kimberley region, have been separated for approximately 30,000 years. The two populations differ both in morphological features and the frequency of their echolocation calls (Armstrong, 2001, 2003).

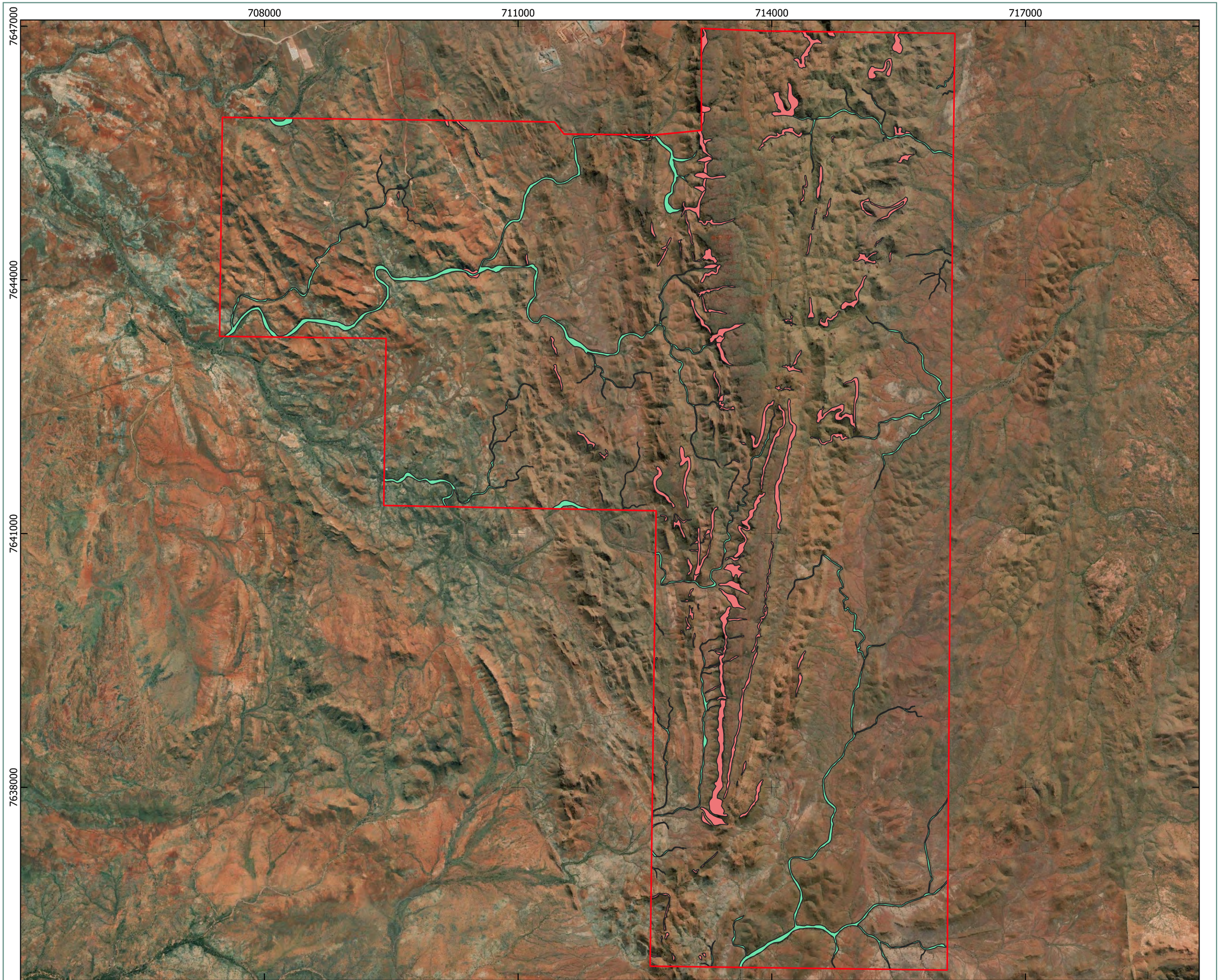
Pilbara Leaf-nosed Bat feed on insects, with a large proportion of their diet consisting of moths, termites and beetles. The bats emerge from their nocturnal roost shortly after dusk and typically after other species of bats have left the roost, travelling along rock faces, rocky gullies, gorges, and creeklines (Churchill, 2009; DoE 2018). In particular, water holes will be visited for a drink and to feed on insects. The Pilbara Leaf-nosed Bat is vulnerable to the loss of body heat and moisture, and therefore requires a stable, warm microclimate. Their breeding cycle stretches over a 9-month period, with mating taking place in July and the dispersal of independent young in February/ March (Churchill, 2009; DoE 2018).

The Pilbara Leaf-nosed Bat roosts during the day in deep, warm and humid caves and adits (horizontal mining tunnels). Some caves are used all year round, whereas others are only visited for a variety of purposes, including specific maternity roost caves (Churchill, 2009; DoE 2018). A standardised nomenclature for the different roost types has been established and includes four types of roosts:

- Permanent diurnal roost
- Non-permanent breeding roost
- Transitory diurnal roosts
- Nocturnal refuge

Permanent diurnal roosts are occupied all year and likely include activities such as mating and rearing of young. Non-permanent breeding roosts are also used during parts of the 9-month breeding cycle. Transitory diurnal roosts are occupied outside the breeding season, which enables the species to undertake long-distance dispersal. The first three roost types are considered critical for the survival of the species, whereas the fourth type (Nocturnal refuge) is used only during the night for resting and feeding, and is considered important for the persistence of the species on a local level (Churchill, 2009; DoE 2018). Foraging habitats include shallow gullies, rocky gorges, creeks and rivers with surface water, and amongst granite boulders, whilst the entrance of the diurnal roost cave can also be used to catch insects (DoE 2018).

Likelihood of Occurrence – Recorded: The Pilbara Leaf-nosed Bat has been recorded from within the Survey Area during previous surveys (ecologia 2011, ecologia 2012b; GHD, 2020) and during the current survey (Map 4.2). A transitory diurnal roost was recorded from Python Cave (Appendix G). A breeding roost cave is known from Chateau Cave, north of the Survey Area (Appendix G). Pilbara Leaf-nosed Bat roosts have been recorded from the ranges associated with the Wodgina and North Star projects (ecologia 2015b; GHD, 2015; Ecoscape 2016c). Records within the Survey Area are mostly associated with the ridges in the eastern section of the Survey Area. Gorges and Gullies, and Rocky Escarpment habitats provide suitable structures for roost caves, as well foraging habitats. The Minor Drainage Lines across the Survey Area may also be used for hunting (Map 5.2).

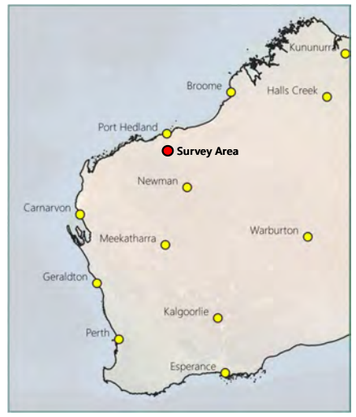


Legend

- Survey Area

Ghost Bat and Pilbara Leaf-nosed Bat Habitats

- Potential Cave Structures (Gorges & Gullies, Rocky Escarpment)
- Foraging Habitat (Minor Drainage Line)



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Scale 1:41,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: AH Date: 28-06-2021

Critical Habitat for the Ghost Bat and Pilbara Leaf-nosed Bat

Glacier Valley Project

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MAP
5.2

5.5.2.4. Western Pebble-mound Mouse (*Pseudomys chapmani*)

- DBCA: Priority 4

Distribution, Habitat and Ecology: The Western Pebble-mound Mouse is native to, and only occurs in, Western Australia. Western Pebble-mound Mice is one of four species in Australia that are known to build large pebble mounds (Van Dyck and Strahan, 2008). They are known to occur in areas with pebbled soil on the gentle slopes of rocky ranges, with hard spinifex and scattered outcropping acacia shrubs. Though this habitat is patchy, it is widespread and has been recorded from across the central and southern Pilbara, and extends into the ranges of the Little Sandy Desert (Van Dyck and Strahan, 2008). Western Pebble-mound Mice have a complex social structure and are known to occur in social groups of up to 12 animals (Anstee, Roberts and Shea, 1997). Each family may use several mounds, whilst male home ranges were found to be considerably larger than those of females, in particular during the breeding season (Anstee, Roberts and Shea, 1997).

Likelihood of Occurrence – High: The Western Pebble-mound Mouse was recorded through secondary evidence during previous surveys to the north of the Survey Area (ecologia 2012b). The activity at the three mounds recorded ranged from recently active, to inactive. The species is expected to occur throughout the the Survey Area, mostly occupying the Hills, Ranges and Plateaux habitat.

5.5.2.5. Long-tailed Dunnart (*Sminthopsis longicaudata*)

- DBCA: Priority 4

Distribution, Habitat and Ecology: The Long-tailed Dunnart is a small, nocturnal, white-grey marsupial and is the only Dunnart species with a tail more than twice the length of its body, including a small terminal tuft of long hairs at the end. It occurs in the Pilbara, Murchison, north-eastern Goldfields, Ashburton and Gibson Desert regions. In Western Australia, populations have been found to be relatively isolated which indicates a very poor dispersal capability. The Long-tailed Dunnart feeds on a range of invertebrates including grasshoppers, beetles, ants, cockroaches and spiders (Van Dyck and Strahan, 2008).

The Long-tailed Dunnart is often found in rocky landscapes, such as lateritic plateaux, flat-topped hills and mesas, as well as breakaways. The vegetation is often dominated by low, open woodland or mixed shrubland of *Acacia* spp. over *Triodia* grassland (Government of Western Australia, 2018). It is a specialist rock-dwelling species that has great agility climbing between rocks, using its striated foot pads and long tail for balance.

Likelihood of Occurrence – High: The Long-tailed Dunnart occurs across the Pilbara region, although it has rarely been recorded during biological surveys. The species was recorded from the baseline survey in 2011, north of the Survey Area (ecologia 2012b). The species has been allocated a high likelihood of occurrence because the habitat from the 2011 record to the north (Hills, Ranges and Escarpments) extends into the Survey Area.

5.5.3. Reptiles

5.5.3.1. Pilbara Olive Python (*Liasis olivaceus barroni*)

- EPBC Act: Vulnerable
- BC Act: Vulnerable

Distribution, Habitat and Ecology: The Pilbara Olive Python is a large python species, growing up to 4.5 m in length, and is considered to be one of the largest snake species in Australia (Wilson and Swan, 2017). The Pilbara Olive Python is a subspecies of the Olive Python and is geographically separated by the Great Sandy Desert from populations in the Kimberley region, Northern Territory and Queensland (Wilson and Swan, 2017), whilst the subspecies occurs widely across the Pilbara. Pilbara Olive Pythons are ambush predators, which is why they are often seen positioning themselves next to or inside water pools where they wait for prey to approach to drink (Pearson, 2003; ecologia 2012b). Juveniles prey on birds, rodents and bats, whereas adults feed on larger birds and mammals such as Rothschild's Rock-wallabies (Ellis, 2010; Wilson and Swan, 2017). Male Pilbara Olive Pythons travel up to 3 km during the winter months (June to August) in search of females to mate with. Some studies suggest that home ranges can be up to 450 hectares (Pearson, 2003). When temperatures start to warm up in September and October, eggs are laid in a rocky incubation site. As with other pythons, the females will protect and warm the clutch, and during this period the females cease feeding (D. Pearson, pers. comm., 2017). The young hatch at the start of the wet season, between December and January when activity patterns and foraging conditions for reptiles are ideal. During the wet season, females recommence feeding and the young disperse. Based on radio tracking studies, it is unlikely that breeding takes place annually, because females require a certain level of body condition. This may take up to five years to regain due to their sporadic feeding activities after breeding (D. Pearson, pers. comm., 2017).

Habitat requirements of the Pilbara Olive Python are likely to vary throughout the year based upon changes in temperature and breeding activities. Pearson (Pearson, 2003) suggests that, during the wet season, the species disperses across rocky habitats that support water sources, drainage lines with waterholes, and other surface water features utilised for hunting. When present, pools of surface water along rocky gorge habitat are preferred, as individuals can then shelter in nearby caves and crevices after feeding. Major rivers and other drainage lines can also be used for foraging, with pythons seeking refuge in tree hollows or under debris piles. During the cooler dry season, studies have indicated that escarpments, mesas and other rocky habitat away from water are the preferred habitats for breeding females, with males travelling along drainage lines and rivers in search of receptive females. Females then lay eggs in suitable rocky crevices (D. Pearson, pers. comm., 2017).

Likelihood of Occurrence – Recorded: The Pilbara Olive Python has been recorded from the Survey Area during the current survey and additional records exist from continuous habitat to the north (Ecoscape 2015, Ecoscape 2017a, Ecoscape 2018; Spectrum 2019b, Spectrum 2020a). The ongoing presence of the species, and records of juveniles from the region indicate that a viable breeding population is present. Suitable habitat for nesting is present along the Rocky Escarpments, and Gorges and Gullies habitat types (Map 5.3). Foraging and dispersal is likely along the Minor Drainage Lines habitat, with occasional dispersal potentially occurring across the Hills, Ranges and Plateaux habitat (which is not critical for the survival of the species).

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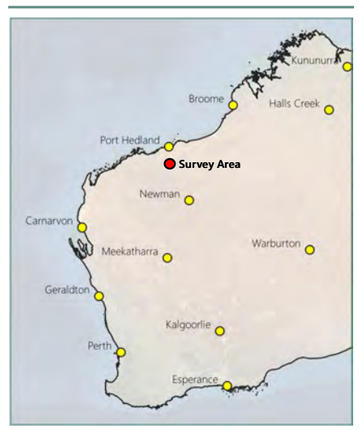
- Survey Area

Pilbara Olive Python Habitats

- Nesting Habitat (Gorges & Gullies, Rocky Escarpment)
- Foraging and Dispersal Habitat (Minor Drainage Line)



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Scale 1:41,000 @ A3

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Units: Meter

Spectrum ECOLOGY

Author: JV Approved: AH Date: 28-06-2021

Critical Habitat for the Pilbara Olive Python

Glacier Valley Project

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5.3

5.5.3.2. Gane's Blind Snake (*Anilios ganei*)

- DBCA: Priority 1

Distribution, Habitat and Ecology: The Gane's Blind Snake is an elusive, moderately robust Blind Snake that lives underground. Due to its subterranean lifestyle, the species is rarely recorded and relatively little is known of its ecology. The Gane's Blind Snake has a rounded snout that is greyish on the upper side and cream on the underside (Wilson and Swan, 2017). Its distribution is limited to the Pilbara region between Newman and Pannawonica (Wilson and Swan, 2017; DBCA 2021). The species is likely to enter social insect nests to feed on termites and ants, as well as their eggs and pupae. The Gane's Blind Snake is thought to be associated with moist gullies and gorges, though little published information exists (Aplin, 1998). A single specimen was recorded in the Hamersley Range from a stony clay-loam valley floor vegetated with *Triodia* sp., suggesting that the species may utilize moist gullies and gorges, although is not restricted to them.

Likelihood of Occurrence – Medium: Due to its cryptic nature, the Gane's Blind Snake has rarely been recorded, and has not been recorded within the Survey Area. It has been allocated a medium likelihood of occurrence as suitable habitat occurs within the Survey Area in the form of Gorges and Gullies. A record was made from 10 km north/north-east in similar rocky gully habitat to that of the Survey Area (Ecologia 2014). Another record was returned as part of the DBCA Threatened Fauna database from 11 km north of the Survey Area which is likely a duplicate. The distribution of the species appears to be widespread across the Pilbara region.

5.6. Survey Adequacy

The total species count recorded during the current two-phase Detailed survey is higher than some previous counts (e.g. Pilgangoora survey: 64 species) though lower than the total recorded during the North Star Detailed survey (186 species) (Table 4.1). Relative survey intensity and diversity of habitats sampled may explain this wide range of survey results. The Pilgangoora survey was single phase (six sites) with a low diversity of habitats sampled, whereas the North Star survey included three phases (16 sites) and sampled both rocky range habitats like those within the current Survey Area, as well as sandy flats and granite outcrops. The current survey falls between these previous results in both sampling intensity and diversity of habitats sampled, and the resulting total species count matches this.

Interpretation of the species accumulation curves indicates that the majority of both trappable vertebrates and bird species were recorded by systematic survey efforts over both phases. However, the corresponding estimates of total species richness (Michaelis-Menten curves) give a combined theoretical maximum of approximately 72 species, considerably lower than the 87 species recorded during this survey. This demonstrates the significance and efficacy of non-systematic survey methods in better representing the vertebrate fauna present. When considering the determination of survey adequacy, the likelihood of certain species being recorded by systematic survey methods must also be considered. Many species are unlikely to be recorded this way, which is why non-systematic survey methods such as opportunistic searches, motion cameras and bat recording devices were used to supplement this. These methods mostly target such habitats as Gorges and Gullies, which are typically unable to be surveyed systematically. This explains the discrepancy between the total number of species recorded versus those only recorded systematically. Nineteen species (one amphibian, 12 birds, four mammals and two reptiles) were recorded only during opportunistic surveys completed at specific locations targeting suitable habitat, or were recorded while traversing the Survey Area. When these species are taken into account, the overall species richness actually exceeds that predicted by the Michaelis-Menten curves. The results of the current survey are therefore considered to be an adequate representation of the fauna present.

6. CONCLUSION

A total of 90 vertebrate fauna species were recorded during the two phases of the Detailed (Level 2) survey and Targeted surveys completed within the Glacier Valley Survey Area. This total was comprised of one amphibian, 39 birds, 12 native non-volant mammals, three introduced mammals, three* bats (*estimated number of species, awaiting confirmation from GHD) and 32 reptiles. This result sits within the range of totals recorded during previous surveys in the region, and is comparable or higher than the results of surveys utilising similar sampling intensity within similarly diverse habitats. Amphibian diversity and abundance was predictably low as few species occur within the rocky habitats found in the Survey Area, and no significant rainfall was experienced during the field surveys.

The Detailed surveys were completed in autumn (May) and spring (October) during periods of peak vertebrate fauna activity in the Pilbara region. The Targeted Northern Quoll survey was completed in winter (July) during a period of high activity and thus detectability.

Four species listed by the EPBC Act were recorded during the current field surveys: the Northern Quoll (*Dasyurus hallucatus*; VU), Ghost Bat (*Macroderma gigas*; VU), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*; VU) and Pilbara Olive Python (*Liasis olivaceus barroni*; VU). An additional conservation significant species (Peregrine Falcon – *Falco peregrinus*; WC Act OS) was recorded within the Survey Area during a previous assessment. A further five species were determined to have a medium or high likelihood of occurrence in the Survey Area.

Four broad fauna habitat types were identified within the Glacier Valley Survey Area. The Gorges and Gullies and Rocky Escarpment habitat types were confirmed to be inhibited by Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python. The combined total area of these habitat types within the Survey Area is 140.6 ha. All habitat types recorded during the survey area present in the Pilbara region and are not limited to the Survey Area. The most common habitat type (Hills, Ranges and Plateaux) is not critical for the survival of any of the EPBC-Act or BC-Act listed species.

Threatened fauna distribution modelling was completed, ground-truthed, and refined for the Northern Quoll, Pilbara Olive Python, Pilbara Leaf-nosed Bat and Ghost Bat. The model suggests that the Survey Area contains approximately 482 ha of critical/ breeding habitat for Northern Quoll, 533 ha of the equivalent habitat for the Pilbara Olive Python and 1,982 ha of the potential refuge/roosting habitat for Pilbara Leaf-nosed Bat and Ghost Bat. The entirety of the Survey Area is assumed to be foraging habitat for both bat species.

The desired objectives and outcomes were successfully reached during the current assessment. There were no significant limitations to the survey work, and the level of survey effort and number of species recorded is considered adequate for the Survey Area. All field work was completed in accordance with relevant government legislation, guidance and standard operating procedures.

7. REFERENCES

360 Environmental (2016) *Pilgangoora Baseline Vertebrate Fauna Survey. Unpublished Report for Pilbara Minerals*.

360 Environmental (2018) *Wodgina Gas Pipeline Targeted Fauna Survey. Unpublished Report for Mineral Resources Limited.*

Anstee, S. D., Roberts, J. D. and Shea, J. E. (1997) 'Social Structure and patterns of Movement of the Western Pebble-mound Mouse, Pseudomys chapmani, at Marandoo, Western Australia', *Wildlife Research*, 24, pp. 295–305.

Aplin, K. P. (1998) 'Three new blindsnakes (Squamata: Typhlopidae) from northwestern Australia', *Records of the Western Australian Museum*.

Archer, M. *et al.* (2002) 'The Evolution of Australia: 110 million years of change', *Sydney: Australian Museum*.

Armstrong, K. N. (2001) 'The distribution and roost habitat of the orange leaf-nosed bat, Rhinonicteris aurantius, in the Pilbara region of Western Australia.', *Wildlife Research*, 28, pp. 95–104.

Armstrong, K. N. (2003) *The bats that time forgot: the Orange Leaf-nosed Bat Rhinonicteris aurantius (Gray, 1845) (Microchiroptera: Hipposideridae) in the Pilbara region of Western Australia.* The University of Western Australia, Department of Animal Biology.

Armstrong, K. N. (2006) 'Resolving the correct nomenclature of the orange leaf-nosed bat Rhinonicteris aurantia (Gray, 1845) (Hipposideridae).', *Australian Mammalogy*, 28, pp. 125–130.

Armstrong, K. N. and Anstee, S. D. (2000) 'The ghost bat in the pilbara: 100 years on.', *Australian Mammalogy*, 22, pp. 93–101.

Armstrong, K. N. and Coles, R. B. (2007) 'Echolocation call frequency differences between geographic isolates of Rhinonicteris aurantia (Chiroptera: Hipposideridae): implications of nasal chamber size.', *Journal of Mammalogy*, 88, pp. 94–104.

Augusteyn, J. *et al.* (2018) 'Tracking and tracing central Queensland's Macroderma - determining the size of the Mount Etna ghost bat population and potential threats', *Australian Mammalogy*, 40(2), pp. 243–253.

Australian Government & Department of Agriculture Water and the Environment (2020) *Species Profile and Threats Database. Apus pacificus - Fork-tailed Swift*. Available at: http://secure.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=678.

Beard, J. S. (1980) 'A new phytogeographic map of Western Australia'.

Birdlife Australia (2012) 'Peregrine Falcon'.

Birdlife International (2020) *BirdLife International (2020) Species factsheet: Motacilla flava.* Available at: http://datazone.birdlife.org/species/factsheet/western-yellow-wagtail-motacilla-flava/text.

Boles, W. E. (1999) 'Avian prey of the Australian Ghost bat Macroderma gigas (Microchiptera: Megadermatidae): prey characteristics and damage from predation', *Australian Zoologist*, 31(1), pp. 82–91.

Bullen, R. D. (2013) *Fortescue Metals Group North Star Project, Pilbara Leaf-nosed Bat Colony Survey*.

Bunge, J. and Fitzpatrick, M. (1993) 'Estimating the Number of Species: A Review', *Journal of the American Statistical Association*, 88(421), pp. 364–373. doi: 10.2307/2290733.

Bureau of Meteorology (2020) *Climate Data Online*. Available at: http://www.bom.gov.au/climate/data/

(Accessed: 1 October 2020).

Churchill, S. (2009) *Australian Bats*. 2nd Editio. Allen & Unwin.

Cogger, H. G. (2014) *Reptiles and Amphibians of Australia*. 7th Editio. Collingwood, Victoria: CSIRO Publishing.

Colwell, R. (2016) 'EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples'.

Colwell, R. and Coddington, J. (1994) 'Estimating Terrestrial Biodiversity Through Extrapolation', *Phil. Trans. R. Soc. Lond. B Biol Sci.*, (345), pp. 101–118.

Cramer, V. A. *et al.* (2016) 'Research priorities for the Pilbara leaf-nosed bat (Rhinonicteris aurantia Pilbara form)', *Australian Mammalogy*, 38(2), pp. 149–157.

Department of Agriculture Water and the Environment (2020) *Species Profile and Threats Database. Dasyurus hallucatus — Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu]*. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=331 (Accessed: 17 September 2018).

Department of Biodiversity Conservation and Attractions (2019a) *2018 Statewide Vegetation Statistics - Simplified Report*. Available at: https://data.gov.au/dataset/ds-wa-3d8c36a4-1863-4eee-9b7b-bcc33973987f/distribution/dist-wa-df50abed-297d-4e12-bb47-7e14c862dca3/details?q=.

Department of Biodiversity Conservation and Attractions (2019b) *DBCA Standard Operating Procedures (SOPs)*. Available at: https://www.dpaw.wa.gov.au/plants-and-animals/96-monitoring/standards/99-standard-operating-procedures (Accessed: 26 April 2020).

Department of Biodiversity Conservation and Attractions (2021) *NatureMap: Mapping Western Australia's Biodiversity. Department of Parks and Wildlife*. Available at: https://naturemap.dpaw.wa.gov.au/.

Department of Mines and Petroleum (2013) *Clearing Permit Decision Report. BHP Billiton Iron ore Pty Ltd. Bing Siding to Walla Siding*.

Department of Mines, I. R. and S. (2020) *1:500 000 State interpreted bedrock geology of Western Australia, 2020*.

Department of Parks and Wildlife (2017) *Interim guideline for preliminary surveys of night parrot (Pezoporus occidentalis) in Western Australia*.

Department of Primary Industry and Regional Development (2019) 'Pre-European Vegetation - Western Australia (NVIS Compliant Version 20110715)'.

Department of Sustainability Environment Water Population and Communities (2011a) *Survey guidelines for Australia's threatened fish. Guidelines for detecting fish listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*.

Department of Sustainability Environment Water Population and Communities (2011b) 'Survey guidelines for Australia's threatened mammals. Guidelines for detecting mammals listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999'.

Department of Sustainability Environment Water Population and Communities (2011c) 'Survey guidelines for Australia's threatened reptiles. Guidelines for detecting reptiles listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999'.

Department of the Environment (2016) *EPBC Act referral guideline for endangered northern quoll Dasyurus hallucatus. EPBC Act Policy Statement*.

Department of the Environment (2018) *Species Profile and Threats Database. Rhinonicteris aurantia (Pilbara form) - Pilbara Leaf-nosed Bat*. Available at: http://www.environment.gov.au/biodiversity/threatened/species/bats.html. (Accessed: 17 September 2018).

Department of the Environment (2020) *Species Profile and Threats Database - Barn Swallow Hirundo rustica*.

Department of the Environment and Energy (2019) 'Australian Wetlands Database'. Australian Government. Available at: https://www.environment.gov.au/water/wetlands/australian-wetlands-database.

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

Department of the Environment Water Heritage and the Arts (2010b) 'Survey guidelines for Australia's threatened birds. Guidelines for detecting birds listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999'.

Department of the Environment Water Heritage and the Arts (2010c) *Survey guidelines for Australia's threatened frogs. Guidelines for detecting frogs listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*.

Department of Water and Environmental Regulation (2019) 'Clearing Regulations - Environmentally Sensitive Areas'. Government of Western Australia.

Duffy, A. M. . *et al.* (2000) 'The efficacy of Anabat ultrasonic detectors and harp traps for surveying microchiropterans in southeastern Australia.', *Acta Chiropterologica*, 2, pp. 127–144.

Dunlop, J. N. and Pound, I. R. (1981) 'Observations on the Pebble-mound Mouse Pseudomys chapmani Kitchener, 1980', *Records of the Western Australian Museum*.

Dunlop, J. N. and Sawle, M. (1982) 'The Habitat and Life History of the Pilbara Ningaui Ningaui timealeyi', *Records of the Australian Museum*, 10(1), pp. 47–52.

Dunlop, J., Rayner, K. and Doherty, T. S. (2017) 'Dietary flexibility in small carnivores: a case study on the endangered northern quoll, Dasyurus hallucatus', *Journal of Mammalogy*, 98(3), pp. 858–866.

Van Dyck, S. and Strahan, R. (2008) *The Mammals of Australia (Third Edition)*. Sydney: Reed New Holland.

Dziminski, M. A. and Carpenter, F. (2016) *The conservation and management of the bilby (*Macrotis lagotis*) in the Pilbara. Progress report 2016.*

Dziminski, M. A. and Carpenter, F. (2018) *The conservation and management of the bilby (*Macrotis lagotis*) in the Pilbara. Annual report 2017-2018.*

ecologia Environment (2011) *North Star Project. Targeted Conservation Significant Fauna Survey. Fortescue Metals Group.*

ecologia Environment (2012a) *North Star Access Corridor flora, vegetation, vertebrate fauna and fauna habitat assessment*. Unpublished Report for FMG Iron Bridge.

ecologia Environment (2012b) *North Star Project. Level 2 Terrestrial Vertebrate Fauna Assessment. Fortescue Metals Group Ltd*.

ecologia Environment (2012c) *North Star Project Short-range Endemic Invertebrate Survey*.

ecologia Environment (2014a) *North Star Hematite Project. EPBC Listed Threatened Fauna Monitoring Report*

2014. Unpublished Report for Fortescue Metals Group/Ironbridge.

ecologia Environment (2014b) 'Stingray Vegetation and Flora Assessment. Fortescue metals Group Ltd.'

ecologia Environment (2015a) *Additional Rail Infrastructure Project. Conservation Significant Fauna Monitoring 2013/2014. Unpublished report for Fortescue Metals Group.*

ecologia Environment (2015b) *Additional Rail Infrastructure Project Conservation Significant Fauna Monitoring Annual Report 2014/2015. Unpublished report for Fortescue Metals Group.*

ecologia Environment (2015c) *North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment*.

Ecoscape (Australia) (2015) *North Star Pilbara Olive Python monitoring 2015. Unpublished report for Fortescue Metals Group.*

Ecoscape (Australia) (2016a) *Cape Preston Northern Quoll Reconnaissance Survey. CITIC Pacific Mining Management.*

Ecoscape (Australia) (2016b) *Cape Preston Northern Quoll Targeted Survey. CITIC Pacific Mining Management*.

Ecoscape (Australia) (2016c) *Conservation Significant Fauna Monitoring 2015/2016 - Operations. Unpublished report for Fortescue Metals Group.*

Ecoscape (Australia) (2016d) *North Star Conservation Significant Fauna monitoring 2015/2016. Unpublished report for Fortescue Metals Group.*

Ecoscape (Australia) (2017a) *Conservation Significant Fauna Monitoring 2016/2017. Unpublished report for Fortescue Metals Group.*

Ecoscape (Australia) (2017b) *Eliwana Project: Consolidated Vertebrate Fauna. Fortescue Metals Group.*

Ecoscape (Australia) (2018) *Conservation Significant Fauna Monitoring 2017/2018. Unpublished report for Fortescue Metals Group*.

Ellis, R. (2010) 'Pilbara Olive Python Liasis olivaceus barroni. A (sub)species overview. Presentation at the Pilbara Olive Python workshop', in.

Environmental Protection Authority (2016a) 'Technical Guidance: Sampling of short range endemic invertebrate fauna'. Environmental Protection Authority.

Environmental Protection Authority (2016b) 'Technical Guidance - Sampling methods for terrestrial vertebrate fauna'. Perth, Western Australia: EPA.

Environmental Protection Authority (2016c) 'Technical Guidance - Terrestrial Fauna Surveys'. Western Australia.

Environmental Protection Authority (2020) 'Technical Guidance: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment'. Western Australia: EPA.

Fielding, A. H. and Bell, J. F. (1997) 'A review of methods for the assessment of prediction errors in conservation presence/absence models', *Environmental Conservation*. doi: 10.1017/S0376892997000088.

Fortescue Metals Group (2010) *Environmental Document Standard Terminology (100-GU-EN-0002)*.

Fortescue Metals Group (2011) *Geographic Information Systems and Raw Data Guidelines (100-GU-EN-0009)*.

Fortescue Metals Group (2012) *Environmental Datasets - Data Governance (100-GU-EN-0020)*.

Fortescue Metals Group (2014) *Terrestrial Vertebrate Fauna Assessment Guidelines (100-GU-EN-0006)*.

Gaston, K. (1996) 'Species richness: measure and measurement. Biodiversity, a biology of number and difference.', *Blackwell Science, Cambridge*.

GHD (2015) *North Star Mine. Pilbara Leaf-nosed Bat roost habitat survey. Unpublished report for Fortescue Metals Group/Ironbridge*.

GHD (2020) *Glacier Valley and South Star Fauna Surveys Fauna Survey Report*.

Government of Western Australia (2018) *Long-tailed Dunnart Sminthopsis longicaudata. WA Museum Collections & Research*.

Guppy, A. ., Coles, R. B. . and Pettigrew, J. D. (1985) 'Echolocation and acoustic communication in the Australian Ghost Bat, Macroderma gigas (Microchiroptera: Megadermatidae).', *Australian Mammology*, 8, pp. 299–308.

Hall, L. *et al.* (1997) 'The importance of abandoned mines as habitat for bats', in Hale, P. and Lamb, D. (eds) *Conervation Outside Nature Reserves,*. Centre for Conservation Biology, University of Queensland, Brisbane., pp. 326–334.

Hammer and Harper, D. A. . and Ryan, P. . (2001) 'PAST: Paleontological Statistics Software Package for Education and Data Analysis. Version 3.14', *Palaeontologia Electronica*, 4(1), p. 9pp.

Hanrahan, N. (2020) *The acoustic ecology of the ghost bat (Macroderma gigas): form, function and applied uses of vocalisations*. PhD Thesis. Western Sydney University, Sydney.

Hanrahan, N. . *et al.* (2021) 'Ghost bats exhibit informative daily and seasonal temporal patterns in the production of social vocalisations.', *Australian Journal of Zoology*, 67, pp. 305–315.

How, R. A. and Cooper, N. . (2002) 'Terrestrial small mammals of the Abydos Plain in the north-eastern Pilbara, Western Australia', *Journal of the Royal Society of Western Australia*, 85, pp. 71–82.

Hoyle, S. D., Pople, A. . and Toop, G. J. (2001) 'Mark-recapture may reveal more about ecology than about population trends: Demography of a threatened ghost bat (Macroderma gigas) population.', *Australian Ecology*, 26, pp. 80–92.

Jackett, N. A. *et al.* (2017) 'A nesting record and vocalisations of the Night Parrot Pezoporus occidentalis from the East Murchison, Western Australia.', *Australian Field Ornithology*, 34, pp. 144–150.

Kendrick, P. (2001) 'Pilbara 1 (PIL1 - Fortescue Plains Subregion)', in *A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions in 2002*. Department of Conservation and Land Management, pp. 559–567.

Kulzer, E. . *et al.* (1984) 'Prey-catching behaviour and echolocation in the Australian ghost bat, Macroderma gigas (Microchiroptera: Megadermatidae).', *Australian mammalogy*, 7, pp. 37–50.

Kutt, A. S. and Kemp, J. E. (2005) 'Distribution, habitat and conservation status of Leggadina lakedownensis (Rodentia: Muridae) in Queensland.', *Australian Zoologist*, 33(2), pp. 258–264.

Leighton, K. A. (2004) 'Climate', in *Technical Bulletin 92 - An inventory and condition survey of the Pilbara region, Western Australia,*. Perth, WA: Western Australian Department of Agriculture, pp. 19–38.

Mckenzie, N. L., Van Leeuwen, S. and Pinder, A. M. (2009) 'Introduction to the Pilbara Biodiversity Survey, 2002-2007', *Records of the Western Australian Museum, Supplement*, 78, pp. 3–89. doi: 10.18195/issn.0313-122x.78(1).2009.003-089.

McKenzie, N. L., May, J. E. and McKenna, S. (2003) 'Bioregional Summary of the 2002 Biodiversity Audit for Western Australia'.

Menkhorst, P. *et al.* (2019) *The Australian Bird Guide*. Revised. Csiro Publishing.

Mills, D. J. *et al.* (1996) 'Designing surveys for microchiropteran bats in complex forest landscapes – a pilot study from south-east Australia.', *Forest Ecology and Management*, 85(1–3), pp. 149–161.

Molhar (2007) *Field survey for conservation significant bats near Sulphur Springs, Pilbara*.

MWH (2016) *Corunna Downs Project: Terrestrial Vertebrate Fauna Survey*.

Oakwood, M. (2008) 'Northern Quoll Dasyurus hallucatus', in Van Dyck, S. & R. S. (ed.) *The Mammals of Australia*. 3rd Editio. Sydney, NSW: Reed New Holland, pp. 57–59.

Olsen, J. *et al.* (2006) 'Male Peregrine Falcon Falco peregrinus fledged from a cliff-nest found breeding in a stick-nest', *Australian Field Ornithology*, 23(1), pp. 8–14.

Olson, P. D. and Olson, J. (1986) 'Distribution, status, movements and breeding of the Grey Falcon Falco hypoleucos', *Emu*, 86, pp. 47–51.

Outback Ecology (2011a) *Abydos DSO Project. Terrestrial Vertebrate Fauna Baseline Survey. Report for Atlas Iron Limited.*

Outback Ecology (2011b) *Atlas Iron Limited Mt Dove DSO Project Vertebrate Fauna Assessment*.

Pavey, C. (2006) *Threatened Species of the Northern Territory - Long-tailed Dunnart Sminthopsis longicaudata*.

Pavey, C. R. *et al.* (2011) 'Habitat use, population dynamics and species identification of mulgara, Dasycercus blythi and D. cristicauda, in a zone of sympatry in central Australia', *Australian Journal of Zoology*.

Pearson, D. (2003) 'Giant Pythons of the Pilbara', *Landscope*, 19(1), pp. 32–39.

Peel, M. C., Finlayson, B. L. and McMahon, T. A. (2007) 'Updated world map of the Köppen-Geiger climate classification', *Hydrology and Earth System Sciences Discussions*, 4(2), pp. 439–473.

Pettigrew, J. D. *et al.* (1986) 'The Australian Ghost Bat, Macroderma gigas, at Pine Creek, Northern Territory', *Macroderma*, 2(1), pp. 8–19.

Pettigrew, J. D. *et al.* (1988) 'Peak density and distribution of ganglion cells in the retinae of microchiropteran bats: Implications for visual acuity', *Brain, Behaviour and Evolution*, 32, pp. 39–56.

Phillips, S. (2008) 'A Brief Tutorial on Maxent', *AT&T Research*. doi: 10.4016/33172.01.

Phillips, S. J., Dudík, M. and Schapire, R. E. (2004) 'A maximum entropy approach to species distribution modeling', in *Twenty-first international conference on Machine learning - ICML '04*. doi: 10.1145/1015330.1015412.

Pizzey, G. and Knight, F. (2012) *The Field Guide to the Birds of Australia. Ninth Edition.* Edited by S. Pizzey.

van Proosdij, A. S. J. *et al.* (2016) 'Minimum required number of specimen records to develop accurate species distribution models', *Ecography*, 39(6), pp. 542–552. doi: 10.1111/ecog.01509.

Schoenjahn, J. (2011) 'How scarce is the Grey Falcon?', *Boobook*, 29(1), pp. 24–25.

Schoenjahn, J. (2013) 'A hot environment and one type of prey: investigating why the Grey Falcon (Falco hypoleucos) is Australia's rarest falcon.', *Emu*, 113(1), pp. 19–25.

Schoenjahn, J., Pavey, C. R. and Walter, G. H. (2020) 'Ecology of the Grey Falcon Falco hypoleucos–current and required knowledge', *Emu-Austral Ornithology*, 120(1), pp. 74–82.

Schulz, M. and Menkhorst, K. (1986) 'Roost Preferences of Cave-Dwelling Bats at Pine Creek, Northern Territory.', *Macroderma*, 2(1), pp. 2–7.

Shepherd, D. P., Beeston, G. R. and Hopkins, A. J. M. (2001) *Native vegetation in Western Australia: Extent, type and status. Technical Report 249.*

Simpson, K. and Day, N. (2017) *Field Guide to the Birds of Australia*. 7th Editio. Camberwell, Victoria: Penguin Group.

Spectrum Ecology (2019a) *Mt Mulgine Fauna Clearance Survey. Unpublished letter report for Tungsten Mining Ltd.*

Spectrum Ecology (2019b) *Operational Areas, Nullagine and North Star. Fauna Monitoring 2018. Prepared for Fortescue Metals Group.*

Spectrum Ecology (2020a) *Annual Fauna Monitoring Program 2019. Prepared for Fortescue Metals Group*.

Spectrum Ecology (2020b) *Fortescue Metals Group Annual Fauna Monitoring Program 2019. Prepared for Fortescue Metals Group*. Perth, WA.

Spectrum Ecology (2020c) *Fortescue Metals Group Annual Fauna Monitoring Program 2020*.

Spectrum Ecology (2020d) 'Operational Areas, Nullagine and North Star. Fauna Monitoring 2019. Prepared for Fortescue Metals Group.'

Thackway, R. and Cresswell, I. D. (1995) 'An Interim Biogeographic Regionalisation for Australia (IBRA)'.

Tidemann, C. R. R. *et al.* (1985) 'Foraging Behaviour of the Australian Ghost Bat, Macroderma gigas (Microchiroptera: Megadermatidae)', *Australian Journal of Zoology*, 33(5), pp. 705–713.

Toop, G. J. (1985) 'Habitat requirements, survival strategies and ecology of the ghost bat, Macroderma gigas Dobson, (Microchiptera Megadermatidae) in central coastal Queensland.', *Macroderma*, 1, pp. 37–41.

Tyler, M. J. and Doughty, P. (2009) *Field Guide to Frogs of Western Australia*. Western Australian Museum, Perth.

Van Vreeswyk, A. M. E. *et al.* (2004) 'An inventory and condition survey of the Pilbara region, Western Australia'. Department of Agriculture and Food.

Wilson, S., Swan, G. (2021) *A Complete Guide to Reptiles of Australia*. 6th Editio. Sydney, NSW: New Holland Publishers.

Wilson, S. and Swan, G. (2017) *A Complete Guide to Reptiles of Australia*. 5th Editio. Sydney, NSW: New Holland Publishers.

Worthington Wilmer, J. *et al.* (2008) 'Extreme population structuring in the threatened ghost bat, Macroderma gigas: evidence from mitochondrial DNA.', *Biological Sciences*, 257, pp. 193–198.

Appendix A: Conservation Codes

EPBC Act 1999 Categories for Flora and Fauna

Code	Definition (EPBC Act)
Extinct	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
Extinct in the wild	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
Critically Endangered (CE)	A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered (EN)	A native species is eligible to be included in the endangered category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Vulnerable (VU)	A native species is eligible to be included in the vulnerable category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
Conservation Dependent (CD)	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

Conservation Codes for Western Australian Flora and Fauna (DBCA 2019)

Code	Definition (BC Act)
Threatened Species (T) Listed by order of the Minister as Threatened in the category of critically endangered, endangered or vulnerable under section 19(1), or is a rediscovered species to be regarded as threatened species under section 26(2) of the Biodiversity Conservation Act 2016 (BC Act). **Threatened fauna** is that subset of 'Specially Protected Fauna' listed under schedules 1 to 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for Threatened Fauna. **Threatened flora** is that subset of 'Rare Flora' listed under schedules 1 to 3 of the Wildlife Conservation (Rare Flora) Notice 2018 for Threatened Flora. The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.	
Critically Endangered (CR)	Threatened species considered to be "facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines". Listed as critically endangered under section 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines. Published under **schedule 1** of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for critically endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for critically endangered flora.
Endangered (EN)	Threatened species considered to be "facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines". Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines. Published under **schedule 2** of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for endangered flora.
Vulnerable (VU)	Threatened species considered to be "facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines". Listed as vulnerable under section 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines. Published under **schedule 3** of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for vulnerable fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for vulnerable flora.
Extinct species Listed by order of the Minister as extinct under section 23(1) of the BC Act as extinct or extinct in the wild.	
Extinct species (EX)	Species where "there is no reasonable doubt that the last member of the species has died", and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act). Published as presumed extinct under **schedule 4** of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for extinct fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for extinct flora.

Code	Definition (BC Act)
Extinct in the wild species (EW)	Species that "is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; and it has not been recorded in its known habitat or expected habitat, at appropriate seasons, anywhere in its past range, despite surveys over a time frame appropriate to its life cycle and form", and listing is otherwise in accordance with the ministerial guidelines (section 25 of the BC Act). Currently there are no threatened fauna or threatened flora species listed as extinct in the wild. If listing of a species as extinct in the wild occurs, then a schedule will be added to the applicable notice.
Specially protected species Listed by order of the Minister as specially protected under section 13(1) of the BC Act. Meeting one or more of the following categories: species of special conservation interest; migratory species; cetaceans; species subject to international agreement; or species otherwise in need of special protection. Species that are listed as threatened species (critically endangered, endangered or vulnerable) or extinct species under the BC Act cannot also be listed as Specially Protected species.	
Migratory species (MI)	Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15 of the BC Act). Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals, that are known to visit Western Australia, protected under the international agreements or treaties, excluding species that are listed as Threatened species. Published as migratory birds protected under an international agreement under schedule 5 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.
Conservation Dependent (CD)	Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act). Published as conservation dependent fauna under schedule 6 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018
Other specially protected fauna (OS)	Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18 of the BC Act). Published as other specially protected fauna under schedule 7 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018

Code	Definition (BC Act)
Priority species (P) Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened fauna or flora. Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring. Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.	
Priority 1: Poorly-known species (P1)	Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.
Priority 2: Poorly-known species (P2)	Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
Priority 3: Poorly-known species (P3)	Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.
Priority 4: Rare, Near Threatened and other species in need of monitoring (P4)	(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

[1] The definition of flora includes algae, fungi and lichens; [2] Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).

Definitions of Threatened Ecological Communities (DEC 2013)

Code	Definition
Presumed Totally Destroyed (PD	An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future. An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B): A) Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats or B) All occurrences recorded within the last 50 years have since been destroyed
Critically Endangered (CR)	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated. An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C): A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii): i) geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years); ii) modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the community is unlikely to be capable of being substantially rehabilitated. B) Current distribution is limited, and one or more of the following apply (i, ii or iii): i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years); ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes; iii) there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes. C) The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within approximately 10 years).

Code	Definition
Endangered (EN)	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future. An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C): A) The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii): i) the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years); ii) modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated. B) Current distribution is limited, and one or more of the following apply (i, ii or iii): i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years); ii) there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes; iii) there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.
Vulnerable (VU)	An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range. An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium (within approximately 50 years) to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C): A) The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated. B) The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations. C) The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long-term future because of existing or impending threatening processes.

Definitions of Priority Ecological Communities (DEC 2013)

Code	Definition
Priority One	Poorly-known ecological communities. Ecological communities that are known from very few occurrences with a very restricted distribution (generally ≤5 occurrences or a total area of ≤ 100ha). Occurrences are believed to be under threat either due to limited extent, or being on lands under immediate threat (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) or for which current threats exist. May include communities with occurrences on protected lands. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.
Priority Two	Poorly-known ecological communities. Communities that are known from few occurrences with a restricted distribution (generally ≤10 occurrences or a total area of ≤200ha). At least some occurrences are not believed to be under immediate threat (within approximately 10 years) of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under threat from known threatening processes.
Priority Three	Poorly known ecological communities. (i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or: (ii) communities known from a few widespread occurrences, which are either large or with significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat (within approximately 10 years), or; (iii) communities made up of large, and/or widespread occurrences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, inappropriate fire regimes, clearing, hydrological change etc. Communities may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and/or are not well defined, and known threatening processes exist that could affect them.
Priority Four	Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring. (i) Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These communities are usually represented on conservation lands. (ii) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for a higher threat category. (iii) Ecological communities that have been removed from the list of threatened communities during the past five years.
Priority Five	Conservation Dependent ecological communities Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

Appendix B: Previous Survey Details

Previous Fauna Surveys Completed in the Region

Report	Report Date	Type	Survey Dates	Reference Code (Appendix C)
Field Survey for Conservation Significant Bats near Sulphur Springs, Pilbara (Molhar, 2007)	July 2007	Targeted	11-16 June 2007	1
Atlas Iron Limited Mt Dove DSO Project Vertebrate Fauna Assessment (Outback Ecology, 2011b)	August 2011	Level 2 (2 Phase)	19-30 May 2010 3-12 September 2010	2
North Star Project Targeted Conservation Significant Fauna Survey (ecologia Environment, 2011)	November 2011	Targeted	29 March – 9 April 2011 5-7 July 2011 22-30 July 2011	3
Atlas Iron Limited Abydos DSO Project Terrestrial Vertebrate Fauna Baseline Survey (Outback Ecology, 2011a)	November 2011	Level 2	29 April – 10 May 2010 3 – 12 September 2010	4
North Star Project Short-range Endemic Invertebrate Survey (ecologia 2012c)	March 2012	SRE (2 phase)	February – March 2011 July – August 2011	-
North Star Project Level 2 Terrestrial Vertebrate Fauna Assessment (ecologia Environment, 2012b)	July 2012	Level 2 (3 Phase)	29 March – 9 April 2011 25 October – 5 November 2011 10-21 October 2011	5
North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment (ecologia Environment, 2012a)	September 2012	Level 1	15-18 May 2012	6
FMG North Star Project Pilbara Leaf-nosed Bat Colony Survey (Bullen, 2013)	July 2013	Targeted	7-13 April 2013	7
FMG North Star Hematite Project EPBC Listed Threatened Fauna Monitoring Report 2014 (ecologia Environment, 2014a)	November 2014	Targeted	5-11 April 2014 23-31 August 2014 13-16 October 2014	8

North Star Pilbara Olive Python Monitoring (Ecoscape (Australia), 2015)	March 2015	Targeted	19-25 February 2015	9
North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment (ecologia Environment, 2015c)	October 2015	Level 1	22-26 August 2015	10
Conservation Significant Fauna Monitoring 2015-2016 (Ecoscape (Australia), 2016d)	March 2016	Targeted	19-28 August 2015 26-29 September 2015 4-12 December 2015	11
Pilgangoora Baseline Vertebrate Fauna Survey (360 Environmental, 2016)	May 2016	Level 2 (1 Phase)	8-18 March 2016	12
Corunna Downs Project: Terrestrial Vertebrate Fauna Survey (MWH, 2016)	Nov 2016	Level 2 (2 Phase)	24 February - 7 March 2014 22 September – 5 October 2016	13
Conservation Significant Fauna Monitoring 2014-2020 (ecologia Environment, 2014a; Ecoscape (Australia), 2016d, 2017a, 2018; Spectrum Ecology, 2019b, 2020d, 2020c)	2014-2020	Targeted	21-29 August 2017 7-13 December 2017	14
Wodgina Gas Pipeline Targeted Fauna Survey (360 Environmental, 2018)	July 2018	Targeted	June 2018	15
Glacier Valley and South Star Fauna Surveys Fauna Survey Report (GHD, 2020)	February 2020	Targeted	9-13 May 2018 5-7 June 2018 3-6 July 2018 8-10 August 2018 21-24 January 2019 26-28 February 2019	16

Appendix C: Regional Vertebrate Fauna List

Amphibian Species Recorded during Previous Surveys and Database Searches

Family and Species	Common name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
PELODRYADIDAE																								
Cyclorana australis	Giant Frog								X	X											X	X		
Cyclorana maini	Main's Frog						X			X								X				X		
Litoria rubella	Little Red Tree Frog				X				X	X								X			X	X		
LIMNODYNASTIDAE																								
Neobatrachus sutor	Shoemaker Frog																					X		
Notaden nichollsi	Desert Spadefoot									X												X		
Platyplectrum spenceri	Centralian Burrowing Frog									X								X						
MYOBATRACHIDAE																								
Uperoleia glandulosa	Glandular Toadlet							X														X		
Uperoleia russelli	Northwest Toadlet								X													X		
Uperoleia saxatilis	Pilbara Toadlet							X										X			X	X		

Bird Species Recorded during Previous Surveys and Database Searches

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
DROMAIIDAE																								
Dromaius novaehollandiae	Emu						X																	
ANATIDAE																								
Dendrocygna eytoni	Plumed Whistling-duck																					X		
Cygnus atratus	Black Swan									X												X		
Chenonetta jubata	Australian Wood Duck																					X		
Malacorhynchus membranaceus	Pink-eared Duck																					X		
Anas gracilis	Grey Teal									X												X		
Anas superciliosa	Pacific Black Duck									X												X		
Aythya australis	Hardhead																					X		
PHASMINIDAE																								
Coturnix ypsilophora	Brown Quail				X		X			X	X						X					X		
PODICIPEDIDAE																								
Tachybaptus novaehollandiae	Australasian Grebe																				X	X		
Poliocephalus poliocephalus	Hoary-headed Grebe																					X		
PHALACROCORACIDAE																								

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Phalacrocorax melanoleucos	Little Pied Cormorant							X														X		
Phalacrocorax sulcirostris	Little Black Cormorant							X														X		
Phalacrocorax varius	Pied Cormorant																					X		
THRESKIORNITHIDAE																								
Threskiornis spinicollis	Straw-necked Ibis																					X		
Platalea regia	Royal Spoonbill																					X		
CICONIIDAE																								
Ephippiorhynchus asiaticus	Black-necked Stork																					X		
ARDEIDAE																								
Ardea pacifica	White-necked Heron							X							X						X	X		
Ardea modesta	Great Egret																					X		X
Ardea garzetta	Little Egret																					X		
Ardea novaehollandiae	White-faced Heron							X		X												X		
Nycticorax caledonicus	Nankeen Night Heron							X														X		
PELECANIDAE																								
Pelecanus conspicillatus	Australian Pelican																					X		
ANHINGIDAE																								
Anhinga novaehollandiae	Australasian Darter									X												X		
PANDIONIDAE																								
Pandion haliaetus	Eastern Osprey	MI	MI																					X
ACCIPITRIDAE																								
Elanus caeruleus axillaris	Black-shouldered Kite																	X			X	X		
Hamirostra isura	Square-tailed Kite									X												X		
Haliaeetus leucogaster	White-bellied Sea-Eagle																							X
Haliastur sphenurus	Whistling Kite						X			X	X							X			X	X		
Hamirostra melanosternon	Black-breasted Buzzard																				X			
Milvus migrans	Black Kite				X					X								X			X	X		
Accipiter fasciatus	Brown Goshawk								X		X							X			X	X		
Accipiter cirrocephalus	Collared Sparrowhawk									X								X			X	X		
Circus assimilis	Spotted Harrier				X						X							X			X	X		
Aquila audax	Wedge-tailed Eagle				X		X		X	X								X			X	X		
Hieraaetus morphnoides	Little Eagle																				X	X		
OTIDIDAE																								
Ardeotis australis	Australian Bustard						X			X	X				X			X				X		
RALLIDAE																								
Gallirallus philippensis	Buff-banded Rail									X												X		
Fulica atra	Eurasian Coot																					X		
BURHINIDAE																								

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Burhinus grallarius	Bush Stone-curlew									X			X	X				X				X		
RECURVIROSTRIDAE																								
Himantopus himantopus	Black-winged Stilt																					X		
CHARADRIIDAE																								
Charadrius veredus	Oriental Plover	MI	MI																			X		X
Elseyornis melanops	Black-fronted Dotterel									X								X				X		
Erythrogonys cinctus	Red-kneed Dotterel																					X		
Vanellus tricolor	Banded Lapwing																					X		
ROSTRATULIDAE																								
Rostratula australis	Australian Painted Snipe	EN	EN																					X
SCOLOPACIDAE																								
Actitis hypoleucos	Common Sandpiper	MI	MI																					X
Calidris acuminata	Sharp-tailed Sandpiper	MI	MI																					X
Calidris ferruginea	Curlew Sandpiper	CR & MI	CR																					X
Calidris melanotos	Pectoral Sandpiper	MI	MI																					X
Numenius madagascariensis	Eastern Curlew	CR & MI	CR																					X
Tringa glareola	Wood Sandpiper	MI	MI																			X	X	
Tringa nebularia	Common Greenshank	MI	MI																			X		
GLAREOLIDAE																								
Glareola maldivarum	Oriental Pratincole	MI	MI																			X		X
TURNICIDAE																								
Turnix velox	Little Button-quail									X	X				X						X	X		
LARIDAE																								
Chlidonias hybrida	Whiskered Tern									X												X		
COLUMBIDAE																								
Phaps chalcoptera	Common Bronzewing				X		X		X	X	X					X	X	X			X	X		
Phaps histrionica	Flock Bronzewing																					X		
Ocyphaps lophotes	Crested Pigeon				X		X			X	X						X	X			X	X		
Geophaps plumifera	Spinifex Pigeon				X		X		X	X	X				X	X	X	X			X	X		
Geopelia cuneata	Diamond Dove				X					X	X				X		X	X			X	X		
Geopelia striata	Peaceful Dove								X	X								X			X	X		
*Columba livia**	Rock Pigeon																							X
CENTRATOPOGONIDAE																								
Centropus phasianinus	Pheasant Coucal									X												X		
CUCULIDAE																								
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo						X			X								X				X		
Chrysococcyx osculans	Black-eared Cuckoo																							X

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Cacomantis pallidus	Pallid Cuckoo									X								X			X	X		
TYTONIDAE																								
Tyto javanica delicatula	Eastern Barn Owl																	X						
STRIGIDAE																								
Ninox connivens	Barking Owl																					X		
Ninox boobook	Southern Boobook						X			X	X							X			X			
PODARGIDAE																								
Podargus strigoides	Tawny Frogmouth								X	X												X		
CAPRIMULGIDAE																								
Eurostopodus argus	Spotted Nightjar				X		X		X	X					X		X	X			X	X		
AEGOTHELIDAE																								
Aegotheles cristatus	Australian Owlet-nightjar									X								X			X	X		
APODIDAE																								
Apus pacificus	Fork-tailed Swift	MI	MI							X												X	X	X
ALCEDINIDAE																								
Dacelo leachii	Blue-winged Kookaburra								X	X								X			X	X		
Todiramphus pyrrhopygius	Red-backed Kingfisher				X		X		X	X	X							X			X	X		
Todiramphus sanctus	Sacred Kingfisher								X	X					X						X	X		
FALCONIDAE																								
Falco cenchroides	Australian Kestrel				X		X		X	X	X							X			X	X		
Falco berigora	Brown Falcon				X		X		X	X	X				X		X	X			X	X		
Falco longipennis	Australian Hobby																				X	X		
Falco hypoleucos	Grey Falcon		VU							X												X		X
Falco subniger	Black Falcon																					X		
Falco peregrinus	Peregrine Falcon		OS															X			X	X		
MEROPIDAE																								
Merops ornatus	Rainbow Bee-eater				X		X		X	X	X		X	X	X	X	X	X			X	X		X
CACATUIDAE																								
Eolophus roseicapillus	Galah				X		X		X	X	X				X		X	X			X	X		
Cacatua sanguinea	Little Corella								X	X								X			X	X		
Nymphicus hollandicus	Cockatiel				X		X		X	X	X						X	X			X	X		
PSITTACIDAE																								
Barnardius zonarius	Australian Ringneck						X		X	X								X			X	X		
Platycercus spurius	Red-capped Parrot																					X		
Neophema elegans	Elegant Parrot																					X		
Melopsittacus undulatus	Budgerigar				X					X	X				X			X			X	X		
Pezoporus occidentalis	Night Parrot	EN	CR																					X
PTILONORHYNCHIDAE																								

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Ptilonorhynchus guttatus	Western Bowerbird				X		X		X	X						X		X			X	X		
CLIMACTERIDAE																								
Climacteris melanura	Black-tailed Treecreeper																	X						
MALURIDAE																								
Malurus leucopterus	White-winged Fairy-wren						X			X	X											X		
Malurus lamberti	Variegated Fairy-wren				X		X		X	X	X						X	X			X	X		
Stipiturus ruficeps	Rufous-crowned Emu-wren																					X		
Amytornis striatus whitei	Rufous Grasswren				X				X	X						X	X	X			X	X		
MELIPHAGIDAE																								
Certhionyx variegatus	Pied Honeyeater								X												X	X		
Gavicalis virescens	Singing Honeyeater						X		X	X	X							X			X	X		
Ptilotula keartlandi	Grey-headed Honeyeater				X		X		X	X						X	X	X			X	X		
Ptilotula plumulus	Grey-fronted Honeyeater																	X			X			
Ptilotula penicillatus	White-plumed Honeyeater						X		X	X	X							X			X			
Manorina flavigula	Yellow-throated Miner				X		X		X	X	X				X			X			X	X		
Acanthagenys rufogularis	Spiny-cheeked Honeyeater									X								X				X		
Lacustroica whitei	Grey Honeyeater								X									X				X		
Epthianura tricolor	Crimson Chat						X			X	X				X				X		X	X		
Sugomel niger	Black Honeyeater										X										X			
Lichmera indistincta	Brown Honeyeater				X				X	X	X							X	X		X	X		
Melithreptus gularis	Black-chinned Honeyeater				X					X								X	X			X		
PARDALOTIDAE																								
Pardalotus rubricatus	Red-browed Pardalote				X					X									X		X	X		
Pardalotus striatus	Striated Pardalote																					X		
ACANTHIZIDAE																								
Smicrornis brevirostris	Weebill								X	X								X			X	X		
Gerygone fusca	Western Gerygone																					X		
POMATOSTOMIDAE																								
Pomatostomus temporalis	Grey-crowned Babbler									X	X							X			X	X		
ARTAMIDAE																								
Artamus leucorhynchus	White-breasted Woodswallow																				X			
Artamus personatus	Masked Woodswallow									X	X										X	X		
Artamus cinereus	Black-faced Woodswallow						X		X	X	X							X	X		X	X		
Artamus minor	Little Woodswallow				X					X									X		X	X		
CRACTICIDAE																								
Cracticus torquatus	Grey Butcherbird						X			X								X			X	X		
Cracticus nigrogularis	Pied Butcherbird				X		X		X	X	X						X		X		X	X		
Cracticus tibicen	Australian Magpie									X					X			X			X	X		

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
CAMPEPHAGIDAE																								
Coracina maxima	Ground Cuckoo-shrike				X																	X		
Coracina novaehollandiae	Black-faced Cuckoo-shrike				X		X		X	X	X						X	X			X	X		
Lalage tricolor	White-winged Triller				X					X								X			X	X		
OREOICIDAE																								
Oreoica gutturalis	Crested Bellbird				X		X		X	X								X			X	X		
PACHYCEPHALIDAE																								
Pachycephala rufiventris	Rufous Whistler				X		X			X							X	X			X	X		
Colluricincla harmonica	Grey Shrike-thrush				X				X	X						X		X			X	X		
RHIPIDURIDAE																								
Rhipidura albiscapa	Grey Fantail																	X						
Rhipidura leucophrys	Willie Wagtail				X		X		X	X	X				X		X	X			X	X		
Rhipidura rufiventris	Northern Fantail																					X		
MONARCHIDAE																								
Grallina cyanoleuca	Magpie-lark				X		X		X	X	X				X		X	X			X	X		
CORVIDAE																								
Corvus bennetti	Little Crow										X							X				X		
Corvus coronoides	Australian Raven																					X		
Corvus orru	Torresian Crow				X		X		X	X					X	X	X	X			X	X		
PETROICIDAE																								
Petroica goodenovii	Red-capped Robin																					X		
Melanodryas cucullata	Hooded Robin				X													X				X		
ALAUDIDAE																								
Mirafra javanica	Horsfield's Bushlark									X												X		
HIRUNDINIDAE																								
Hirundo rustica	Barn Swallow	MI	MI																					X
Petrochelidon ariel	Fairy Martin				X					X								X				X		
Petrochelidon nigricans	Tree Martin									X								X			X	X		
ACROCEPHALIDAE																								
Acrocephalus australis	Australian Reed-Warbler																					X		
LOCUSTELLIDAE																								
Cincloramphus mathewsi	Rufous Songlark									X								X			X			
Cincloramphus cruralis	Brown Songlark						X			X											X			
Poodytes carteri	Spinifexbird				X		X		X	X	X						X	X			X			
DICAEIDAE																								
Dicaeum hirundinaceum	Mistletoebird																	X				X		
ESTRILIDAE																								
Taeniopygia guttata	Zebra Finch						X		X	X	X				X		X	X			X	X		

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Neochmia ruficauda subclarescens	Star Finch									X												X		
Emblema pictum	Painted Finch				X		X		X	X	X						X	X			X	X		
MOTACILLIDAE																								
Motacilla flava	Yellow Wagtail	MI	MI																					X
Motacilla cinerea	Grey Wagtail	MI	MI																					X
Anthus australia	Australasian Pipit						X			X	X							X			X	X		

Mammal Species Recorded during Previous Surveys and Database Searches

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
TACHYGLOSSIDAE																								
Tachyglossus aculeatus	Short-beaked Echidna						X		X							X		X			X	X		
DASYURIDAE																								
Dasycercus blythi	Brush-tailed Mulgara			P4																X		X	X	
Dasykaluta rosamondae	Kaluta				X		X			X								X		X		X		
Dasyurus hallucatus	Northern Quoll	EN	EN		X		X	X	X	X			X	X	X	X		X			X	X	X	X
Ningaui timealeyi	Pilbara Ningaui				X					X								X				X		
Planigale ingrami	Long-tailed Planigale				X				X									X						
Planigale sp. (prev. maculata)	Pilbara Planigale species 1'				X		X			X							X				X	X		
Pseudantechinus roryi	Rory's Pseudantechinus																					X		
Pseudantechinus woolleyae	Woolley's Pseudantechinus				X			X	X							X						X		
Sminthopsis longicaudata	Long-tailed Dunnart			P4				X		X											X	X	X	
Sminthopsis macroura	Stripe-faced Dunnart						X															X		
Sminthopsis ooldea	Ooldea Dunnart																					X		
Sminthopsis youngsoni	Lesser Hairy-footed Dunnart									X												X		
THYLACOMYIDAE																								
Macrotis lagotis	Bilby	VU	VU																	X		X	X	X
PHALANGERIDAE																								
Trichosurus vulpecula	Common Brushtail Possum																	X				X		
MACROPODIDAE																								
Lagorchestes conspicillatus leichardti	Spectacled Hare-wallaby			P4														X				X	X	
Macropus agilis	Agile Wallaby																					X		
Osphranter robustus	Euro				X		X		X	X	X				X	X	X	X			X	X		
Osphranter rufus	Red Kangaroo						X											X				X		

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Petrogale rothschildi	Rothschild's Rock Wallaby				X				X	X						X		X			X	X		
MURIDAE																								
Leggadina lakedownensis	Short-tailed Mouse			P4																		X	X	
Notomys alexis	Spinifex Hopping-mouse						X													X		X		
Pseudomys chapmani	Western Pebble-mound Mouse			P4			X	X		X	X				X			X				X	X	
Pseudomys delicatulus	Delicate Mouse				X					X								X				X		
Pseudomys desertor	Desert Mouse				X					X								X				X		
Pseudomys hermannsburgensis	Sandy Inland Mouse				X		X		X	X							X	X				X		
Pseudomys nanus	Western Chestnut Mouse																					X		
Zyzomys argurus	Common Rock-rat				X			X	X	X					X	X		X			X	X		
RHINONYCTERIDAE																								
Rhinonicteris aurantia	Pilbara Leaf-nosed Bat	VU	VU			X	X	X	X	X		X	X	X		X		X		X	X	X	X	X
MEGADERMATIDAE																								
Macroderma gigas	Ghost Bat	VU	VU				X	X	X			X						X			X	X	X	X
EMBALLONURIDAE																								
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat						X		X									X				X		
Taphozous georgianus	Common Sheathtail Bat						X		X	X		X						X			X	X		
MOLOSSIDAE																								
Chaerophon jobensis	Greater Northern Free-tailed Bat																	X			X	X		
Ozimops lumsdenae	Northern Free-tailed Bat																					X		
Austronomus australis	White-striped Freetail Bat																				X			
VESPERTILIONIDAE																								
Nyctophilus geoffroyi	Lesser Long-eared Bat									X								X				X		
Chalinolobus gouldii	Gould's Wattled Bat						X		X	X								X				X		
Nyctophilus bifax daedalus	Northwestern Long- eared Bat																							
Scotorepens greyii	Little Broad-nosed Bat						X		X	X								X				X		
Vespadelus finlaysoni	Finlayson's Cave Bat						X		X	X		X						X			X	X		
INTRODUCED MAMMALS																								
**Mus musculus*	House Mouse																	X				X		X
**Canis familiaris dingo*	Dingo				X		X		X		X			X				X			X	X		X
**Vulpes vulpes*	Red Fox						X																	X
**Felis catus*	Cat				X		X		X	X	X					X		X		X	X	X		X
**Equus caballus*	Horse																					X		X
**Equus asinus*	Donkey						X				X											X		X
**Camelus dromedarius*	Camel						X			X								X			X	X		X
**Oryctolagus cuniculus*	Rabbit																							X
**Sus Scrofa*	Pig																							X
**Bos taurus*	European Cattle				X		X		X	X	X				X	X		X			X	X		

Reptiles Species Recorded during Previous Surveys and Database Searches

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
CHELUIDAE																								
Chelodina steindachneri	Flat-shelled Turtle									X								X				X		
DIPLODACTYLIDAE																								
Crenadactylus ocellatus	Clawless Gecko									X							X					X		
Diplodactylus conspicillatus	Fat-tailed Gecko						X			X							X	X			X	X		
Diplodactylus galaxias	Northern Pilbara Beak-faced Gecko									X												X		
Diplodactylus savagei	Yellow-spotted Pilbara Gecko				X				X	X							X	X				X		
Lucasium stenodactylum	Sand-plain Gecko				X		X		X	X							X	X				X		
Lucasium wombeyi	Pilbara Ground Gecko				X				X	X								X				X		
Oedura fimbria	Marbled Velvet Gecko						X		X	X				X				X			X	X		
Rhynchoedura ornata	Beaked Gecko						X											X				X		
Strophurus ciliaris	Northern Spiny-tailed Gecko																							
Strophurus elderi	Jewelled Gecko				X					X							X	X				X		
Strophurus jeanae	Southern Phasmid Gecko																					X		
CARPHODACTYLIDAE																								
Nephrurus wheeleri	Banded Knob-tailed Gecko																					X		
Nephrurus levis	Smooth Knob-tailed Gecko									X												X		
GEKKONIDAE																								
*Gehyra media**	Medium Pilbara Spotted Rock Gehyra				X																			
Gehyra pilbara	Pilbara Dtella						X		X													X		
Gehyra punctata	Spotted Dtella								X	X				X	X		X	X			X	X		
Gehyra purpurascens	Purplish Dtella						X																	
Gehyra variegata	Tree Dtella						X		X	X				X			X	X			X	X		
Heteronotia binoei	Bynoe's Gecko				X		X		X	X				X			X	X			X	X		
Heteronotia planiceps	Bynoe's Prickly Dtella													X										
Heteronotia spelea	Desert Cave Gecko								X	X							X	X			X	X		
PYGOPODIDAE																								
Delma butleri	Unbanded Delma																	X				X		
Delma elegans	Pilbara Delma				X				X	X								X			X	X		
Delma fraseri	Fraser's Delma									X												X		
Delma nasuta	Sharp-snouted Delma								X	X								X				X		
Delma pax	Peace Delma				X				X	X							X	X				X		
Delma tincta	Excitable Delma								X	X								X				X		
Lialis burtonis	Burton's Snake-lizard						X			X							X	X				X		
Pygopus nigriceps	Western Hooded Scaly-foot				X					X								X				X		
AGAMIDAE																								
Gowidon longirostris	Long-nosed Dragon				X				X	X				X	X		X	X			X	X		

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Ctenophorus caudicinctus	Ring-tailed Dragon				X		X		X	X	X			X	X	X		X			X	X		
Ctenophorus isolepis	Central Military Dragon						X			X	X						X	X				X		
Ctenophorus nuchalis	Central Netted Dragon						X			X								X				X		
Ctenophorus reticulatus	Western Netted Dragon										X											X		
Ctenophorus scutulatus	Lozenge-marked Dragon																					X		
Ctenophorus rubens	Red Dragon																					X		
Diporiphora vescus	Southern Pilbara Tree Dragon									X												X		
Diporiphora winneckei	Canegrass Dragon						X																	
Pogona minor	Dwarf Bearded Dragon						X			X												X		
SCINCIDAE																								
Carlia munda	Shaded-litter Rainbow-skink				X		X		X	X				X	X		X	X			X	X		
Carlia triacantha	Desert Rainbow-skink						X			X							X	X				X		
Cryptoblepharus buchananii	Buchanan's Snake-eyed Skink									X												X		
Cryptoblepharus ustulatus	Russet Snake-eyed Skink				X				X	X								X			X	X		
Cryptoblepharus plagiocephalus	Peron's Snake-eyed Skink																							
Ctenotus fallens	West-coast Laterite Ctenotus																X					X		
Ctenotus duricola	Eastern Pilbara Lined Ctenotus				X		X		X	X							X	X				X		
Ctenotus grandis	Grand Ctenotus						X		X	X							X	X				X		
Ctenotus hanloni	Nimble Ctenotus																					X		
Ctenotus helenae	Clay-soil Ctenotus						X			X					X			X				X		
Ctenotus leonhardii	Leonhard's Ctenotus																	X				X		
Ctenotus nigrilineatus	Pin-striped Finesnout Ctenotus																					X	X	
Ctenotus pantherinus	Leopard Ctenotus				X		X		X	X	X				X		X	X				X		
Ctenotus piankai	Coaruse Sands Ctenotus									X												X		
Ctenotus robustus	Eastern Striped Skink																					X		
Ctenotus rubicundus	Ruddy Ctenotus								X	X								X			X	X		
Ctenotus rutilans	Rusty-shouldered Ctenotus																	X						
Ctenotus saxatilis	Rock Ctenotus				X		X		X	X							X				X	X		
Ctenotus schomburgkii	Barred Wedgesnout Ctenotus									X												X		
Ctenotus serventyi	North-western Sandy-loam Ctenotus																					X		
Ctenotus superciliaris	Sharp-browed Ctenotus																					X		
Ctenotus uber	Spotted Ctenotus																					X		
Cyclodomorphus melanops	Spinifex Slender Blue-tongue								X	X					X		X	X				X		
Egernia depressa	Southern Pygmy Spiny-tailed Skink																					X		
Egernia epsisolus	Eastern Pilbara Spiny-tailed Skink									X	X							X				X		
Egernia formosa	Goldfields Crevice-skink								X	X						X		X			X	X		
Eremiascincus richardsonii	Broad-banded Sand-swimmer														X						X	X		
Lerista bipes	North-westrn Sandslider						X		X	X							X	X				X		
Lerista clara	Sharp-blazed Three-toed Slider								X								X					X		

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Lerista jacksoni	Jackson's Three-toed Slider				X				X	X								X				X		
Lerista muelleri	Wood Mulch-slider				X					X							X	X				X		
Lerista verhmens	Powerful Three-toed Slider				X					X												X		
Liopholis striata	Night Skink						X															X		
Menetia greyii	Common Dwarf Skink								X	X								X			X	X		
Menetia surda	Western Dwarf Skink																					X		
Morethia ruficauda exquisita	Lined Fire-tailed Skink				X		X		X	X					X		X	X			X	X		
Notoscincus ornatus	Ornate Soil-crevice Skink				X				X	X								X				X		
Proablepharus reginae	Western Soil-crevice Skink								X	X												X		
Tiliqua multifasciata	Centralian Blue-tongue									X							X	X				X		
VARANIDAE																								
Varanus acanthurus	Spiny-tailed Monitor				X				X	X					X		X	X			X	X		
Varanus brevicauda	Short-tailed Pygmy Monitor				X					X								X				X		
Varanus eremius	Pygmy Desert Monitor						X			X				X				X				X		
Varanus giganteus	Perentie				X				X	X				X		X		X			X	X		
Varanus gouldii	Gould's Monitor						X			X							X					X		
Varanus panoptes	Yellow-spotted Monitor									X	X			X				X			X	X		
Varanus pilbarensis	Pilbara Rock Monitor				X				X	X						X		X			X	X		
Varanus tristis	Black-headed Monitor				X				X	X					X			X			X	X		
TYPHLOPIDAE																								
Anilios ammodytes	Sand-diving Blind Snake						X			X								X						
Anilios ganei	Gane's Blind Snake			P1									X									X	X	
Anilios grypus	Beaked Blind Snake				X					X							X	X			X			
Anilios hamatus	Pale-headed Blind Snake																	X						
Anilios pilbarensis	Pilbara Blind Snake						X																	
BOIDAE																								
Antaresia perthensis	Pygmy Python				X					X				X			X	X			X	X		
Antaresia stimsoni	Stimson's Python								X	X				X							X	X		
Aspidites melanocephalus	Black-headed Python																					X		
Liasis olivaceus barroni	Pilbara Olive Python	VU	VU		X			X	X	X			X	X		X		X			X	X	X	X
ELAPIDAE																								
Acanthophis wellsi	Pilbara Death Adder									X				X				X				X		
Acanthophis pyrrhus	Desert Death Adder																	X						
Brachyurophis approximans	North-west Shovel-nosed Snake				X					X							X	X				X		
Demansia psammophis	Yellow-faced Whipsnake									X								X				X		
Demansia rufescens	Rufous Whipsnake				X				X	X								X				X		
Furina ornata	Moon Snake						X			X				X			X	X				X		
Parasuta monachus	Monk Snake									X								X				X		
Pseudechis australis	Mulga Snake				X					X	X			X				X			X	X		

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
Pseudonaja mengdeni	Gwardar									X					X							X		
Pseudonaja modesta	Ringed Brown Snake						X			X								X				X		
Suta fasciata	Rosen's Snake									X								X				X		
Suta punctata	Little Spotted Snake																					X		
Vermicella snelli	Pilbara Bandy Bandy								X									X				X		

Fish Species Recorded during Previous Surveys and Database Searches

Family and Species	Common Name	Conservation Status			Current Surveys	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NatureMap	DBCA Database	DAWE Protected Matters Search
		EPBC Act	BC Act	DBCA																				
CLUPEIDAE																								
Nematolosa erebi	Bony Bream									X														
MELANOTAENIIDAE																								
Melanotaenia australis	Western Rainbowfish								X	X											X			
PLOTOSIDAE																								
Neosilurus hyrtli	Hyrtl's Tandan								X	X														
TERAPONTIDAE																								
Leiopotherapon unicolor	Spangled Perch								X	X														

Appendix D: Survey Site Locations

All Survey Site Locations

Site Name	Survey	Survey Site Type	Coordinates (GDA94 Z50)	
			Easting	Northing
GV BAT1 6282	Ph 1	Bat Recorder	713542.3031	7638408.036
GV BAT2 6270	Ph 1	Bat Recorder	713661.2354	7640326.914
GV BAT3 6174	Ph 1	Bat Recorder	714098.7899	7642641.642
GV BAT4 6272	Ph 1	Bat Recorder	713885.0278	7641532.011
GV BAT5 6269	Ph 1	Bat Recorder	713424.691	7644690.428
GV BAT6 6256	Ph 1	Bat Recorder	713231	7643867
GV BS22 BAT 6174	Ph 1	Bat Recorder	713147.0276	7646589.182
GV BS23 BAT 6272	Ph 1	Bat Recorder	713101.9605	7646340.742
GV SSPOOL L28	Ph 1	Bat Recorder	712543.9265	7645698.519
GV SSPOOL L29	Ph 1	Bat Recorder	712564.0603	7645663.051
GV SSPOOL L30	Ph 1	Bat Recorder	712549.599	7645661.323
GV MC21	Ph 1	Motion Camera	713501.1274	7638198.923
GV MC22	Ph 1	Motion Camera	713527.7685	7638440.425
GV MC23	Ph 1	Motion Camera	713394.9065	7638059.279
GV MC24	Ph 1	Motion Camera	713402.4281	7638168.916
GV MC25	Ph 1	Motion Camera	713516.4181	7638317.383
GV MC26	Ph 1	Motion Camera	709284.2356	7643620.882
GV MC27	Ph 1	Motion Camera	709282.8526	7643689.57
GV MC28	Ph 1	Motion Camera	709400.82	7643641.012
GV MC29	Ph 1	Motion Camera	709248.2984	7643659.604
GV MC30	Ph 1	Motion Camera	709162.0254	7643582.558
GV MC31	Ph 1	Motion Camera	714169.489	7641945.257
GV MC32	Ph 1	Motion Camera	714247.3899	7642221.012
GV MC33	Ph 1	Motion Camera	714209.4409	7642317.574
GV MC34	Ph 1	Motion Camera	714197.155	7642043.829
GV MC35	Ph 1	Motion Camera	713308.1029	7643878.365
GV MC36	Ph 1	Motion Camera	714212.2138	7642122.918
GV MC37	Ph 1	Motion Camera	713214.4793	7643855.818
GV MC38	Ph 1	Motion Camera	713266.4418	7643856.455
GV MC39	Ph 1	Motion Camera	713295.0277	7643873.727
GV MC40	Ph 1	Motion Camera	713208.3157	7643850.155
GV PH1 OP1	Ph 1	Opportunistic Site	713904.2602	7640274.444
GV PH1 OP2	Ph 1	Opportunistic Site	713760.3884	7639601.203
GV PH1 OP3	Ph 1	Opportunistic Site	710437.7256	7644037.246
GV PH1 OP4	Ph 1	Opportunistic Site	708640.125	7644132.434
GV PH1 OP5	Ph 1	Opportunistic Site	713515.6478	7638867.401
GV S1	Ph 1/ 2	Fauna Trapping Site	708753.8606	7644962.96
GV S2	Ph 1/ 2	Fauna Trapping Site	710896.9645	7644661.405
GV S3	Ph 1/ 2	Fauna Trapping Site	714004.2002	7644201.783
GV S4	Ph 1/ 2	Fauna Trapping Site	713476.1874	7638898.491

GV S1 BIRD	Ph 1/ 2	Birding Site	708734.6685	7644994.342
GV S2 BIRD	Ph 1/ 2	Birding Site	710904.9109	7644665.04
GV S3 BIRD	Ph 1/ 2	Birding Site	714021.2795	7644464.637
GV S4 BIRD	Ph 1/ 2	Birding Site	713503.7624	7638849.71
GV PH2 OP1	Ph 2	Opportunistic Site	711893.1016	7645152.804
GV PH2 OP2	Ph 2	Opportunistic Site	712164.3886	7645731.213
GV PH2 OP3	Ph 2	Opportunistic Site	711694.7793	7645366.041
GV PH2 OP4	Ph 2	Opportunistic Site	709597.4872	7645659.368
GV PH2 OP5	Ph 2	Opportunistic Site	709471.4115	7644895.911
GV PH2 OP6	Ph 2	Opportunistic Site	709620.3739	7645076.749
GV PH2 OP7	Ph 2	Opportunistic Site	711088.5356	7643671.386
GV PH2 OP8	Ph 2	Opportunistic Site	711472.3106	7644333.025
GV PH2 OP9	Ph 2	Opportunistic Site	713411.8552	7644890.165
GV PH2 OP10	Ph 2	Opportunistic Site	713334.4103	7643795.614
GV POP1	Targeted	Targeted POP Site	710480.2464	7644022.054
GV POP2	Targeted	Targeted POP Site	713287.3753	7644667.465
GV POP3	Targeted	Targeted POP Site	713160.7961	7643826.875
GV NQ S1C1	Targeted	Northern Quoll Trap Location	713539.8049	7638440.76
GV NQ S1C10	Targeted	Northern Quoll Trap Location	713471.0521	7638015.387
GV NQ S1C11	Targeted	Northern Quoll Trap Location	713464.3058	7637967.631
GV NQ S1C12	Targeted	Northern Quoll Trap Location	713450.3163	7637913.437
GV NQ S1C13	Targeted	Northern Quoll Trap Location	713401.4112	7637918.506
GV NQ S1C14	Targeted	Northern Quoll Trap Location	713395.3902	7637981.712
GV NQ S1C15	Targeted	Northern Quoll Trap Location	713408.1197	7638026.842
GV NQ S1C16	Targeted	Northern Quoll Trap Location	713399.4236	7638075.907
GV NQ S1C17	Targeted	Northern Quoll Trap Location	713401.4253	7638125.828
GV NQ S1C18	Targeted	Northern Quoll Trap Location	713409.6359	7638182.425
GV NQ S1C19	Targeted	Northern Quoll Trap Location	713420.9644	7638239.423
GV NQ S1C2	Targeted	Northern Quoll Trap Location	713537.6664	7638396.267
GV NQ S1C20	Targeted	Northern Quoll Trap Location	713456.5969	7638282.481
GV NQ S1C3	Targeted	Northern Quoll Trap Location	713526.2516	7638348.573
GV NQ S1C4	Targeted	Northern Quoll Trap Location	713510.0636	7638300.831
GV NQ S1C5	Targeted	Northern Quoll Trap Location	713505.6414	7638256.257
GV NQ S1C6	Targeted	Northern Quoll Trap Location	713501.1531	7638214.563
GV NQ S1C7	Targeted	Northern Quoll Trap Location	713490.3349	7638164.867
GV NQ S1C8	Targeted	Northern Quoll Trap Location	713480.6877	7638109.508
GV NQ S1C9	Targeted	Northern Quoll Trap Location	713462.0893	7638059.914
GV NQ S2C1	Targeted	Northern Quoll Trap Location	714233.0726	7642259.281
GV NQ S2C10	Targeted	Northern Quoll Trap Location	714130.8981	7641811.533
GV NQ S2C11	Targeted	Northern Quoll Trap Location	714121.2523	7641756.506
GV NQ S2C12	Targeted	Northern Quoll Trap Location	714109.228	7641710.038
GV NQ S2C13	Targeted	Northern Quoll Trap Location	714101.2511	7641655.654
GV NQ S2C14	Targeted	Northern Quoll Trap Location	714079.5156	7641612.525

GV NQ S2C15	Targeted	Northern Quoll Trap Location	714056.3269	7641561.441
GV NQ S2C16	Targeted	Northern Quoll Trap Location	714039.44	7641508.171
GV NQ S2C17	Targeted	Northern Quoll Trap Location	714028.9906	7641455.148
GV NQ S2C18	Targeted	Northern Quoll Trap Location	714068.6119	7641421.847
GV NQ S2C19	Targeted	Northern Quoll Trap Location	714053.2328	7641372.766
GV NQ S2C2	Targeted	Northern Quoll Trap Location	714239.5619	7642208.03
GV NQ S2C20	Targeted	Northern Quoll Trap Location	714065.1615	7641332.74
GV NQ S2C3	Targeted	Northern Quoll Trap Location	714231.9038	7642162.17
GV NQ S2C4	Targeted	Northern Quoll Trap Location	714210.4968	7642112.503
GV NQ S2C5	Targeted	Northern Quoll Trap Location	714208.4949	7642062.692
GV NQ S2C6	Targeted	Northern Quoll Trap Location	714197.7226	7642016.761
GV NQ S2C7	Targeted	Northern Quoll Trap Location	714168.8283	7641973.837
GV NQ S2C8	Targeted	Northern Quoll Trap Location	714160.4536	7641920.787
GV NQ S2C9	Targeted	Northern Quoll Trap Location	714148.2825	7641863.136
GV NQ S3C1	Targeted	Northern Quoll Trap Location	713551.7608	7643913.254
GV NQ S3C10	Targeted	Northern Quoll Trap Location	713338.7954	7643890.45
GV NQ S3C11	Targeted	Northern Quoll Trap Location	713309.7531	7643883.962
GV NQ S3C12	Targeted	Northern Quoll Trap Location	713296.5564	7643874.831
GV NQ S3C13	Targeted	Northern Quoll Trap Location	713276.2889	7643872.659
GV NQ S3C14	Targeted	Northern Quoll Trap Location	713263.7205	7643855.989
GV NQ S3C15	Targeted	Northern Quoll Trap Location	713242.2684	7643858.484
GV NQ S3C16	Targeted	Northern Quoll Trap Location	713221.9823	7643862.846
GV NQ S3C17	Targeted	Northern Quoll Trap Location	713205.4375	7643851.654
GV NQ S3C18	Targeted	Northern Quoll Trap Location	713187.538	7643848.012
GV NQ S3C19	Targeted	Northern Quoll Trap Location	713178.6221	7643840.818
GV NQ S3C2	Targeted	Northern Quoll Trap Location	713528.6841	7643910.565
GV NQ S3C20	Targeted	Northern Quoll Trap Location	713169.0317	7643837.621
GV NQ S3C3	Targeted	Northern Quoll Trap Location	713508.5667	7643919.909
GV NQ S3C4	Targeted	Northern Quoll Trap Location	713479.6298	7643921.505
GV NQ S3C5	Targeted	Northern Quoll Trap Location	713452.8447	7643920.969
GV NQ S3C6	Targeted	Northern Quoll Trap Location	713429.0488	7643918.842
GV NQ S3C7	Targeted	Northern Quoll Trap Location	713410.3532	7643901.92
GV NQ S3C8	Targeted	Northern Quoll Trap Location	713389.3908	7643894.22
GV NQ S3C9	Targeted	Northern Quoll Trap Location	713363.0222	7643893.789

Appendix E: Recorded Vertebrate Fauna Species

Scientific Name	Common Name	Conservation Status			Fauna Trapping Sites								Bird Surveys								Opportunistic Sites											Opportunistic Observations		Targeted Survey	Motion Camera Captures	SRE Bycatch
					GV S1		GV S2		GV S3		GV S4		GV S1 BIRD		GV S2 BIRD		GV S3 BIRD		GV S4 BIRD		Ph 1			Ph 2										Ph 1	Ph 2			
		EPBC Act	BC Act	DBCA	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	GV PH1 OP1	GV PH1 OP3	GV PH1 OP5	GV PH2 OP1	GV PH2 OP2	GV PH2 OP3	GV PH2 OP4	GV PH2 OP6	GV PH2 OP7	GV PH2 OP9	GV PH2 OP10						
Amphibians																																					
Pelodryadidae																																					
Litoria rubella	Little Red Tree Frog																													1							
Birds																																					
Phasianidae																																					
Coturnix ypsilophora	Brown Quail																																	1			
Accipitridae																																					
Aquila audax	Wedge-tailed Eagle																																			2	
Circus assimilis	Spotted Harrier																																	1		1	
Milvus migrans	Black Kite																																1				
Columbidae																																					
Phaps chalcoptera	Common Bronzewing													1	1																			5		1	
Ocyphaps lophotes	Crested Pigeon												1																								
Geophaps plumifera	Spinifex Pigeon													5	1	1		1		2										2			1				
Geopelia cuneata	Diamond Dove																	1							1										1		
Caprimulgidae																																					
Eurostopodus argus	Spotted Nightjar																																1				
Alcedinidae																																					
Todiramphus pyrrhopygius	Red-backed Kingfisher															1																					
Meropidae																																					
Merops ornatus	Rainbow Bee-eater														1	2														2	1	2	1				
Falconidae																																					
Falco cenchroides	Australian Kestrel																																1			2	
Falco berigora	Brown Falcon																																1				
Cacatuidae																																					
Cacatua roseicapilla	Galah													2	1	8										3											
Nymphicus hollandicus	Cockatiel																																1				
Melopsittacus undulatus	Budgerigar														1																						
Ptilonorhynchidae																																					
Ptilonorhynchus maculatus guttatus	Western Bowerbird																																			1	
Maluridae																																					
Malurus lamberti	Variegated Fairy-wren																									3	1			2							
Amytornis striatus whitei	Rufous Grasswren																													2			1				

Scientific Name	Common Name	Conservation Status			Fauna Trapping Sites								Bird Surveys								Opportunistic Sites											Opportunistic Observations		Targeted Survey	Motion Camera Captures	SRE Bycatch
					GV S1		GV S2		GV S3		GV S4		GV S1 BIRD		GV S2 BIRD		GV S3 BIRD		GV S4 BIRD		Ph 1			Ph 2										Ph 1	Ph 2			
		EPBC Act	BC Act	DBCA	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	GV PH1 OP1	GV PH1 OP3	GV PH1 OP5	GV PH2 OP1	GV PH2 OP2	GV PH2 OP3	GV PH2 OP4	GV PH2 OP6	GV PH2 OP7	GV PH2 OP9	GV PH2 OP10					
Meliphagidae																																					
Lichmera indistincta	Brown Honeyeater														5														1			1				
Melithreptus gularis	Black-chinned Honeyeater																												6	4						
Manorina flavigula	Yellow-throated Miner												3																			1				
Ptilotula keartlandi	Grey-headed Honeyeater												1	6	2	23		13		7					2					10					1	
Pardalotidae																																					
Pardalotus rubricatus	Red-browed Pardalote														3	4										1						1				
Artamidae																																					
Artamus minor	Little Woodswallow												1	1		3				3				1					1			1	2		2	
Cracticidae																																					
Cracticus nigrogularis	Pied Butcherbird													4	2	4	1	6							3										
Campephagidae																																					
Coracina maxima	Ground Cuckoo-shrike																							1									3			
Coracina novaehollandiae	Black-faced Cuckoo-shrike												1												2						1	2			
Lalage tricolor	White-winged Triller															2																				
Oreoicidae																																					
Oreoica gutturalis	Crested Bellbird												3	1		1		1														1				
Pachycephalidae																																					
Pachycephala rufiventris	Rufous Whistler															2		1																		
Colluricincla harmonica	Grey Shrike-thrush												1					4		1				1	1			1		2		1			3	
Rhipiduridae																																					
Rhipidura leucophrys	Willie Wagtail														1	3			1						2							1				
Monarchidae																																					
Grallina cyanoleuca	Magpie-lark																															1				
Corvidae																																					
Corvus orru	Torresian Crow												1							1									1			1			1	
Petroicidae																																					
Melanodryas cucullata	Hooded Robin																															1				
Hirundinidae																																					
Petrochelidon ariel	Fairy Martin																			3																
Locustellidae																																					
Poodytes carteri	Spinifexbird												3	3				1																		
Estrildidae																																					
Emblema pictum	Painted Finch												1	4		2	1	10		1										6	2	1			1	

Scientific Name	Common Name	Conservation Status			Fauna Trapping Sites								Bird Surveys								Opportunistic Sites										Opportunistic Observations		Targeted Survey	Motion Camera Captures	SRE Bycatch
					GV S1		GV S2		GV S3		GV S4		GV S1 BIRD		GV S2 BIRD		GV S3 BIRD		GV S4 BIRD		Ph 1			Ph 2									Ph 1	Ph 2			
		EPBC Act	BC Act	DBCA	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	GV PH1 OP1	GV PH1 OP3	GV PH1 OP5	GV PH2 OP1	GV PH2 OP2	GV PH2 OP3	GV PH2 OP4	GV PH2 OP6	GV PH2 OP7	GV PH2 OP9	GV PH2 OP10					
Mammals																																				
Dasyuridae																																				
Dasykaluta rosamondae	Kaluta				1					1																										
Dasyurus hallucatus	Northern Quoll	EN	EN																															8	14	
Ningaui timealeyi	Pilbara Ningaui				2	10			1	9		2																								
Planigale ingrami	Long-tailed Planigale						1																												1	
Planigale 'species 1'	Pilbara Planigale							1		2																										
Pseudantechinus woolleyae	Woolley's Pseudantechinus																																			
Macropodidae																																				
Osphranter robustus	Euro						1															1		1											6	
Petrogale rothschildi	Rothschild's Rock-wallaby																																		8	
Emballonuridae																																				
Taphozous georgianus	Common Sheathtail Bat																																	R*		
Vespertilionidae																																				
Scotorepens greyii	Little Broad-nosed Bat																																	R*		
Vespadelus finlaysoni	Finlayson's Cave Bat																																	R*		
Muridae																																				
Pseudomys delicatulus	Delicate Mouse							2																												
Pseudomys desertor	Desert Mouse					1																														
Pseudomys hermannsburgensis	Sandy Inland Mouse						1																													
Zyzomys argurus	Common Rock-rat									1		1																							7	
Introduced Mammals																																				
Canidae																																				
Canis familiaris dingo	Dingo						1	1																										1		
Felidae																																				
Felis catus	Cat						1	1																											2	
Bovidae																																				
Bos taurus	European Cattle																																3		2	
Reptiles																																				
Diplodactylidae																																				
Diplodactylus savagei	Southern Pilbara Beak-faced Gecko						2	2			2																									
Lucasium stenodactylum	Sand-plain Gecko							2																												
Lucasium wombeyi	Pilbara Ground Gecko				1	2	1	1	1		2	1																								

Scientific Name	Common Name	Conservation Status			Fauna Trapping Sites								Bird Surveys								Opportunistic Sites										Opportunistic Observations		Targeted Survey	Motion Camera Captures	SRE Bycatch
					GV S1		GV S2		GV S3		GV S4		GV S1 BIRD		GV S2 BIRD		GV S3 BIRD		GV S4 BIRD		Ph 1			Ph 2									Ph 1	Ph 2			
		EPBC Act	BC Act	DBCA	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	GV PH1 OP1	GV PH1 OP3	GV PH1 OP5	GV PH2 OP1	GV PH2 OP2	GV PH2 OP3	GV PH2 OP4	GV PH2 OP6	GV PH2 OP7	GV PH2 OP9	GV PH2 OP10					
Strophurus elderi	Jewelled Gecko									1																									
Gekkonidae																																			
Gehyra media	Medium Pilbara Spotted Rock Gehyra											1																							
Heteronotia binoei	Bynoe's Gecko					1	1														1														
Pygopodidae																																			
Delma elegans	Pilbara Delma									1																									
Delma pax	Peace Delma																																		1
Pygopus nigriceps	Hooded Scaly-foot						1																												
Agamidae																																			
Ctenophorus caudicinctus	Western Ring-tailed Dragon				3	5	12	6	2	9	4	7									1						1								6
Gowidon longirostris	Long-nosed Dragon						5																						1						1
Scincidae																																			
Carlia munda	Shaded-litter Rainbow-skink						2															1	1			1				1					3
Cryptoblepharus ustulatus	Russet Snake-eyed Skink																						1												
Ctenotus duricola	Eastern Pilbara Lined Ctenotus						1	1		1																									
Ctenotus pantherinus ocellifer	Leopard Ctenotus									1																									
Ctenotus saxatilis	Rock Ctenotus				3	3	12	9	3	1	2																									8
Lerista jacksoni	Jackson's Three-toed Slider																																		2
Lerista muelleri	Wood Mulch-slider					2																													
Lerista verhmens	Powerful Three-toed Slider																																		1
Morethia ruficauda exquisita	Lined Firetail Skink				1		1	2	1			1																							2
Notoscincus ornatus	Ornate Soil-crevice Skink							1		1																									
Varanidae																																			
Varanus acanthurus	Spiny-tailed Goanna								2			1																							
Varanus brevicauda	Short-tailed Pygmy Goanna									1																									
Varanus giganteus	Perentie																																2		1	
Varanus pilbarensis	Nothern Pilbara Rock Goanna																																		4	
Varanus tristis	Black-headed Monitor																																		1	
Typhlopidae																																			
Anilios grypus	Beaked Blind Snake					1				1																									
Boidae																																			

Scientific Name	Common Name	Conservation Status			Fauna Trapping Sites								Bird Surveys								Opportunistic Sites												Opportunistic Observations		Targeted Survey	Motion Camera Captures	SRE Bycatch
					GV S1		GV S2		GV S3		GV S4		GV S1 BIRD		GV S2 BIRD		GV S3 BIRD		GV S4 BIRD		Ph 1			Ph 2											Ph 1	Ph 2			
		EPBC Act	BC Act	DBCA	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	Ph 1	Ph 2	GV PH1 OP1	GV PH1 OP3	GV PH1 OP5	GV PH2 OP1	GV PH2 OP2	GV PH2 OP3	GV PH2 OP4	GV PH2 OP6	GV PH2 OP7	GV PH2 OP9	GV PH2 OP10						
Antaresia perthensis	Pygmy Python					1																														
Liasis olivaceus barroni	Pilbara Olive Python	VU	VU																																1		
Elapidae																																						
Brachyurophis approximans	North-western Shovel-nosed Snake							1																														
Demansia rufescens	Rufous Whipsnake				2																																
Pseudechis australis	Mulga Snake							1																														

R*= to be confirmed by GHD

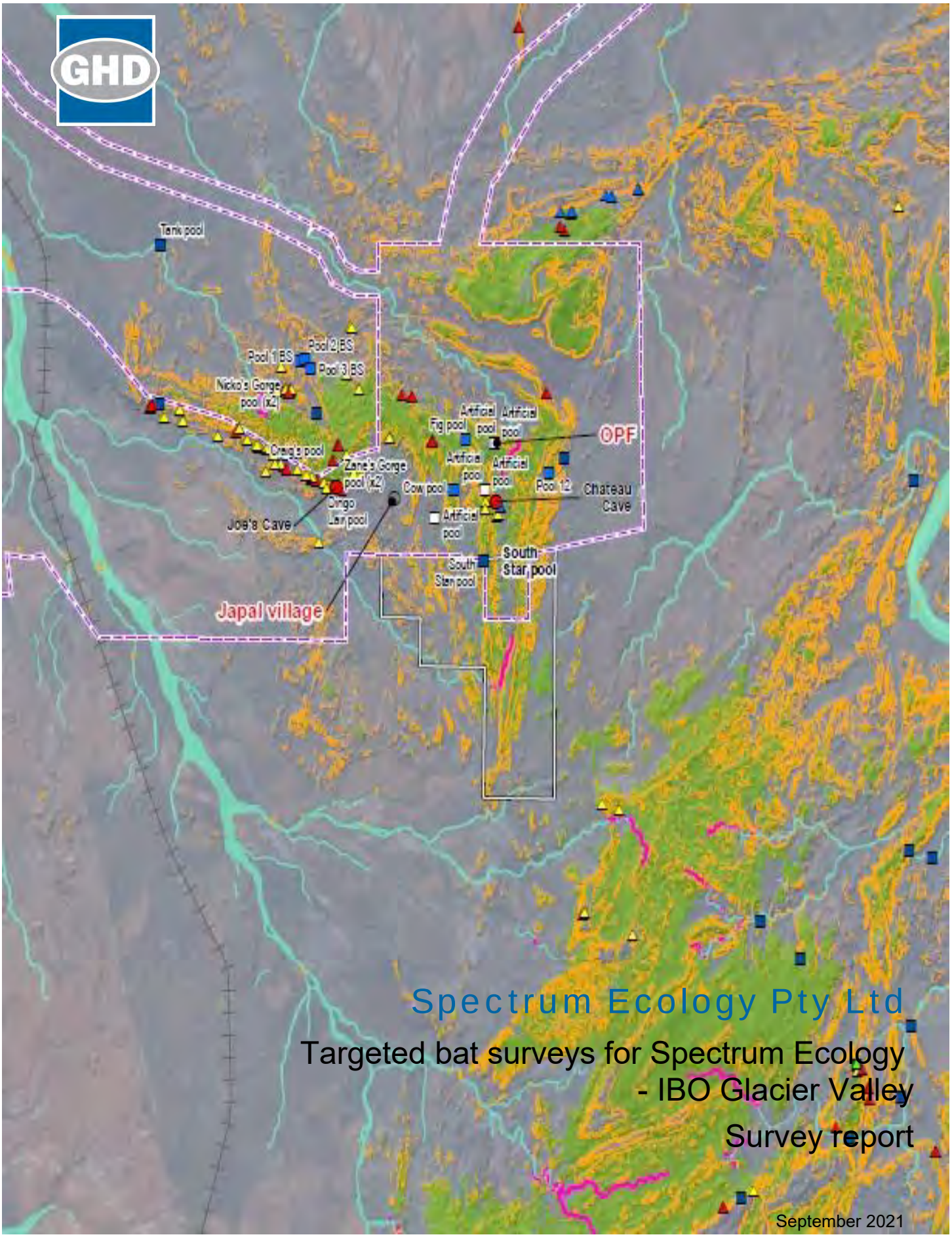
Appendix F: Northern Quoll Trapping Survey Site Descriptions

Northern Quoll Site 1 (GV NQ S1)
Northern Quoll Site 1 (trap locations GV NQ S1C1-20) was located at the southern end of the north-south oriented ridgeline that hosts the North Star Mine further to the north (Map 3.2). Cage traps were deployed along the edges of the ridge where Banded Iron Formation (BIF) outcropping provides suitable crevice habitat for Northern Quolls. Vegetation was comprised of scattered *Eucalyptus leucophloia* and *Acacia pruinocarpa* over *Eremophila* sp., *Acacia orthocarpa* and *Grevillea wickhamii*. Hummock grasses such as *Triodia wiseana* were also present with *Eriachne* and *Cymbopogon* sp. tussock grasses occupying steeper areas. Fire age was estimated to be greater than 5 years.

Northern Quoll Site 2 (GV NQ S2)
Northern Quoll Site 2 (trap locations GV NQ S2C1-20) was located in steep BIF ridge habitat similar to that found at Northern Quoll Site 1. Vegetation was limited to shrubs and grasses with *Acacia* sp., *Eremophila* sp. and *Grevillea wickhamii* growing over *Triodia wiseana*. Fire age was estimated to be greater than 5 years.


Northern Quoll Site 3 (GV NQ S3)
Northern Quoll Site 3 (trap locations GV NQ S3C1-20) was located within the proposed Glacier Valley disturbance footprint. Twenty cage traps were deployed within a deep, steep sided, BIF gorge that offered abundant crevice habitat as well as a source of permanent water. The edges of the gorge were vegetated with sparse *Eucalyptus leucophloia* and *Acacia pruinocarpa* over *Triodia wiseana*. Deeper into the gorge, large *Ficus brachypoda* and *Terminalia circumalata* were present over scattered *Acacia tumida* and tussock grasses creating a cool, moist microclimate with significant leaf litter beds. Fire age was estimated at greater than 5 years, likely much longer to have allowed the leaf litter accumulation that was present.


Appendix G: Targeted Bat Survey Report (GHD)



Spectrum Ecology Pty Ltd

Targeted bat surveys for Spectrum Ecology - IBO Glacier Valley

Survey report

September 2021

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Appendices

1. Introduction

1.1 Project overview

IB Operations Pty Ltd (IBO) proposes to continue to develop the iron ore mining operations located at North Star in the Pilbara region of Western Australia. The North Star Project is located approximately 110 km south of Port Hedland in the Njamal Native Title area. IBO is a majority owned subsidiary of Fortescue Metals Group Ltd (Fortescue), which owns and operates several mining and infrastructure projects in Western Australia.

The Glacier Valley ore body extension lies south of the North Star deposit. IBO are proposing to extend the North Star mining project into the Glacier Valley Mining Development Area (GVMDE) (Figure 1) which will likely involve mine pits, waste rock dumps and supporting infrastructure. The host to the magnetite mineralisation at Glacier Valley is the main banded iron formation (BIF) member of the Pincunah formation. The Picunah formation is one of several prominent banded BIF units within the greenstone belts of the Pilbara Craton which host primary magnetite mineralisation.

1.2 Project purpose and scope of works

IBO is undertaking environmental investigations of the Glacier Valley area to support the environmental approvals process. Spectrum Ecology was engaged by IBO to undertake a Level 2 terrestrial fauna assessment including targeted conservation significant fauna surveys and a short-range endemic assessment of the Glacier Valley survey area. GHD Pty Ltd are responsible for assisting Spectrum Ecology with undertaking targeted surveys for two threatened bats species (Pilbara Leaf-nosed Bat, *Rhinonicteris aurantia* and Ghost Bat, *Macroderma gigas*).

This report will be issued as an Appendix to the Spectrum Ecology report for the Glacier valley Terrestrial Fauna and Short-Range Endemic Fauna Assessment.

The GHD scope of works will be limited to the assessment of threatened bat fauna within the proposed survey areas and include following items:

- Task 1 - Desktop assessment and regional habitat modelling
- Task 2 - Survey plan
- Task 3 - Field survey of area defined in the survey plan using targeted bat survey techniques.
- Task 4 - Reporting according to relevant FMG and other guidelines, including analysis of data collected during the field surveys.

This report is Task 4 and includes the outcomes of Tasks 1 and 3. Task 2 was provided as a separate memorandum to Spectrum Ecology, 13 May 2020.

In addition to the information collected for this scope of works GHD has also included methods, effort and results from surveys undertaken within the survey area for FMG during 2020. The purpose of including this additional information is to provide a consolidated report with all recent relevant information for the Pilbara Leaf-nosed Bat (PLNB) and Ghost Bat rather than two survey reports.

1.3 Survey area description

For the purpose of this report the **survey area** consists of two components

1. **GVSS survey area** (GVSS) incorporating the GVMDE and the Glacier Valley and South Star survey extension area (approximately 5,467 ha). The GVMDE includes a small portion of the North Star Mining Development Area.
2. **Regional survey area** includes the GVSS and the regional area within a 30-40 km buffer of the GVSS, encompassing approximately 391,605 ha (Figure 1) including the North Star mine development area.

1.4 GHD Disclaimer

This report has been prepared by GHD for Spectrum Ecology and may only be used and relied on by Spectrum Ecology for the purpose agreed between GHD and Spectrum Ecology as set out in Section 1.2 of this report, and detailed in the GHD memo - *12528008-PRP-Memo_GHD (dated 8/04/2020)* and GHD Proposal – *12528008-PRP-Glacier_Valley_SpectrumEcology_proposal (dated 4/03/2020)*. GHD otherwise disclaims responsibility to any person other than Spectrum Ecology 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.

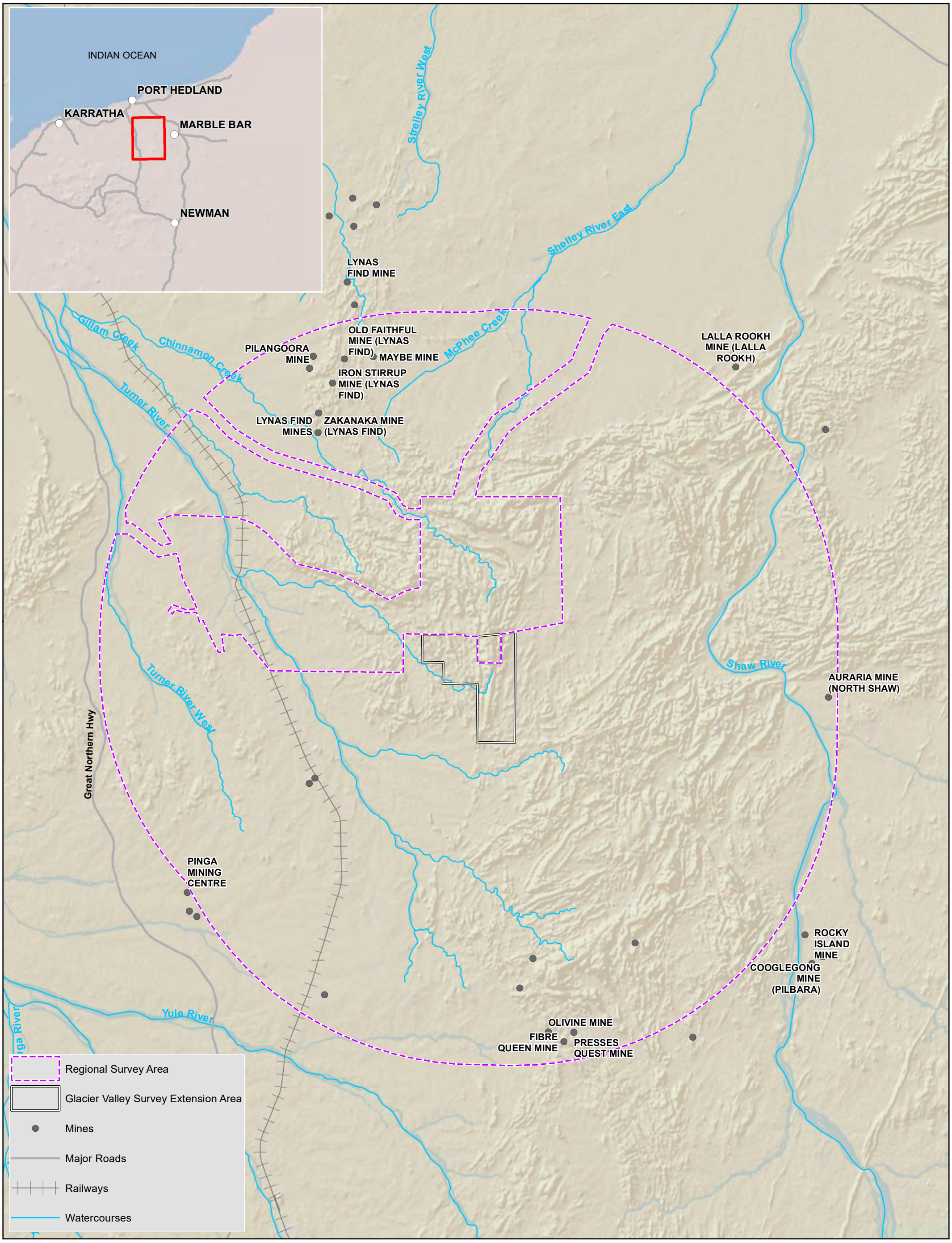
GHD has prepared this report on the basis of information provided by and others who provided information to GHD including FMG and IBO, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including 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 and regional survey area described in section 1.3 and displayed on Figure 1.



Paper Size A3

0 5 10

Kilometres

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

N

Fortescue Metals Group Ltd

Job Number 12528008
Revision 0
Date 16 Dec 2020

Study Area

Figure 1

\\ghdnet\ghd\AU\Geelong\Projects\31\12528008\GIS\Maps\Working\12528008__001_StudyArea_A4PRev0.mxd
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS

2. Methods

2.1 Desktop assessment and habitat modelling

The desktop review aims to identify all records and categorise the type of records for the Pilbara Leaf-nosed Bat and Ghost Bat within the survey area. GHD completed a detailed literature review for the Pilbara Leaf-nosed Bat and Ghost Bat as part of the targeted fauna survey report undertaken of the Glacier Valley survey area. The review for this report was expanded to account for a slight change to the regional survey area boundary using the following sources:

- Department of Biodiversity, Conservation and Attractions (DBCA) – records for the Pilbara Leaf-nosed Bat and Ghost Bat within the survey area from NatureMap dating from 2002 - 2018
- Existing spatial data from FMG containing records for surveys undertaken by a variety of consultants for the survey area dating to end of 2019
- Specialised Zoological (2017). A review of past surveys for Pilbara bats of conservation significance including spatial information. SZ409 Unpublished report for FMG
- Specialised Zoological (2018). Long term trends in nightly activity of the Pilbara Leaf-nosed Bat at North Star, Western Australia. SZ461 Unpublished report for GHD.
- Various consultant reports produced between 2012 and 2019 from the survey area. A summary of the key survey findings for the Pilbara Leaf-nosed Bat and Ghost Bat to the end of 2019 is provided in:
    - GHD (2020a) Glacier Valley and South Star Fauna Surveys: Conservation Significant Fauna Survey report results, March 2020. Unpublished report for Fortescue Metals Group Iron Bridge
    - GHD (2020b), Pilbara Leaf-nosed Bat radio tracking survey 2019-2020 Survey report, May 2020. Unpublished report for Fortescue Metals Group Iron Bridge

Information gained from the review was used to inform the habitat modelling and the survey plan, identify gaps in data where little or no survey has been undertaken and potential locations for targeted survey effort.

The data mapped for each species (see Figures 2a, 2b, 3a and 3b) is based on DBCA NatureMap records, and other information sources listed above, including additional records from FMG that were not present in NatureMap. Mapping these records of occurrence provides an indication of:

1. How often the species are encountered within the survey area
2. Whether each of the target bat species associates predictably with particular habitat in the survey area
3. Areas that have not received attention in surveys, and also conversely, areas that have received relatively intense survey effort
4. The locations of confirmed roost sites.

A key objective of this 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. In summary the step by step process involves:

1. Evaluation of survey data (e.g. previous studies and records) and guidelines

2. Evaluation of spatial data layers including contour, elevation modelling, aerial imagery and geological information
3. Mapping of potential roosting and foraging habitat.

2.1.1 Categorisation of records and habitat

Pilbara Leaf-nosed Bat and Ghost Bat – non-roost/habitat records

There is no standard nomenclature for PLNB and Ghost Bat records taken from the DBCA and FMG databases. Given the lack of consistent record labelling we attempted to categorise records according to the following descriptions:

- Specimen - trap or voucher
- Observation - in cave or flying at night
- Emergence period detector record – record from an ultrasonic recording device within 20 minutes of civil twilight (sunset or sunrise) for two or more nights
- Detector record – record from ultrasonic recording device (e.g. SongMeter) – time unknown or outside the emergence period
- Survey – unknown record (source of record unknown/cannot be confirmed).

Pilbara Leaf-nosed Bat and Ghost Bat – roost habitat.

While Pilbara Leaf-Nosed Bat and Ghost Bat are both cave roosting, there are differences with respect to the roost habitat selected by both species which is reflected in the terminology used to describe them. The Threatened Species Scientific Committee (TSSC 2016a) and Department of the Environment (DotE 2020a) provide standardised nomenclature for the different types of PLNB roosts (here in referred to as categories) with consideration to both breeding and daily survival requirements for the species. Known roost records for the PLNB obtained from the desktop review and field surveys were described according to these categories. Potential roost records also follow a similar nomenclature, however, cannot be definitively categorised due to the absence of some information (e.g. the roost structure and microclimate appear to be suitable, however evidence of PLNB is yet to be recorded in the roost). The use of this categorisation method is consistent with all PLNB surveys undertaken by GHD in the North Star mine area since 2016.

Roost categories include:

- ***Permanent diurnal roost*** (map symbol GREEN TRIANGLE) —occupied year-round and likely the focus for some part of the 9-month breeding cycle; considered as critical habitat that is essential for the daily survival of the PLNB.
- ***Non-permanent breeding roost*** (map symbol GREEN TRIANGLE) —evidence of usage during some part of the 9-month breeding cycle (July–March), but not occupied year-round; considered as critical habitat that is essential for both the daily and long-term survival of the PLNB.
- ***Transitory diurnal roost*** (map symbol BLUE TRIANGLE) —occupied for part of the year only, outside the breeding season (i.e. April–June), and which could facilitate long distance dispersal in the region; considered as critical habitat that is essential for both the daily and long-term survival of the PLNB.
- ***Nocturnal refuge*** (map symbol YELLOW TRIANGLE) —occupied or entered at night for resting, feeding or other purposes, with perching not a requirement. Excludes overhangs. Not considered critical habitat but are important for persistence in a local area.

Unlike the Pilbara Leaf-nosed Bat, the roost habitats of the Ghost Bat are not yet formally categorised in current published guidance. The categorisation approach used here for Ghost Bat roost habitat is consistent with surveys undertaken to date by GHD for Ghost Bat and other mining projects in the Pilbara and considers the roosting requirements of the species as documented in TSSC (2016b). Potential roost records also follow a similar nomenclature, however, cannot be definitively categorised due to the absence of some information (e.g. the roost structure appears to be suitable, however evidence of Ghost Bat is yet to be recorded in the roost). In addition to the structural aspect of the roost, an assessment of usage including evidence for feeding, scat deposits and/or presence of Ghost Bat should be used to categorise the roost type. Information including acoustic and visual data may also be required to understand ongoing usage. Roost categories include:

- ***Breeding roost*** (map symbol GREEN TRIANGLE) — evidence of occupation from early September through to mid-February by more than a few individuals. The roost may or may not be occupied all year round. Pregnancy in the Pilbara has been recorded in August and births occurred after late October (Douglas 1967 cited in Armstrong 2000). A study of the Ghost Bat in the Pilbara noted pregnant bats in September 1998 and young attached to the teat in November and December 1998 (Armstrong and Anstee 2000). Parturition occurs over a month commencing in mid-October and juvenile bats commence flying at seven weeks with young capable of flight by the end of January (Toop 1985). Considered as critical habitat for both the daily and long-term survival of the Ghost Bat.
- ***Diurnal roost with ongoing use*** (map symbol ORANGE TRIANGLE) — evidence of occupation during different times of the year by one or more individuals however structure of roost unlikely to support breeding habitat requirements. Considered as critical habitat for both the daily and long-term survival of the Ghost Bat.
- ***Diurnal roost with occasional use*** (map symbol BLUE TRIANGLE) — roost occasionally used at different times of the year for a few individuals. Structure of roost small and does not support breeding or large colony habitat requirements. Roost could facilitate dispersal in the region. Considered as important habitat for both the daily and long-term survival of the Ghost Bat.
- ***Nocturnal/feeding refuge*** (map symbol YELLOW TRIANGLE) — occupied or entered at night for resting, feeding or other purposes. Not considered critical habitat but are important for persistence in a local area. Nocturnal refuge sites may also be shallow caves, or deeper overhangs that do not offer diurnal roosting opportunities.

Pilbara Leaf-nosed Bat and Ghost Bat – foraging habitat types

The type and quality of foraging habitat surrounding known and potential roost sites can be critical to the survival of the PLNB (TSSC 2016a) and the Ghost Bat (TSSC 2016b). Unlike the Pilbara Leaf-nosed Bat, there is no consensus on categories used to describe the foraging habitats of the Ghost Bat. PLNB habitat categories (described below) were used as a surrogate for mapping foraging habitat for the Ghost Bat in GHD 2020a. Colonies of both species require access to suitable foraging habitat within a nightly flight range (TSSC 2016a,b). Larger colonies of the PLNB might require access to greater proportion of the landscape and maternity colonies for the PLNB 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 PLNB it is difficult to define critical foraging habitat for the species (TSSC 2016a). However, based on the observations of where PLNB 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 including:

- ***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
- ***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
- ***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
- ***Major Watercourses (Priority 4)*** – 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.
- ***Open Grassland and woodland (Priority 5)*** – dominated by Triodia, on lowland plains colluvial slopes and hilltops.

Given the overlapping habitat requirements with the PLNB and precedent for consistency, the above categories will be adopted to map habitats for the Ghost Bat for the regional survey area with key differences discussed in the results section.

2.1.2 Habitat modelling

GHD completed a preliminary regional habitat model for suitable roosting areas within a 30 km radius of Cave 13 (see *North Star Magnetite Project – Survey Plan for Pilbara Leaf-nosed Bat,* Step 1, Unpublished report to Iron Bridge Pty Ltd, GHD 2017). The desktop review process evaluated available survey data and spatial information for the study area to identify prospective roost habitat for the PLNB.

This report is an update to the existing model using the guidelines (e.g. TSSC 2016a and 2016b) for both species and site-specific information collected since 2016 including the surveys undertaken during 2020. The aim is to map and calculate the area of foraging and roosting habitat according to the five priority foraging habitat categories discussed in section 2.1.1. Although the approach presented in this report is similar to that reported in GHD 2020a, there are a number of minor differences, particularly regarding the scale of the modelling (e.g. local versus regional). As a result the outputs for the GVSS survey area are not the same as reported for GHD 2020a, although habitat type descriptions remain consistent.

The foraging and roosting habitat mapping included the following steps:

- Step 1 - Review the 2017 model to inform the field survey plan using desktop review information
- Step 2 – Identify additional data to model roost and foraging habitat types according to the descriptions (section 2.1.1)
- Step 3 – Review modelled habitat types using field data and refine where necessary

Step 1 - Review the 2017 model to inform the field survey plan using desktop review information.

Multiple spatial datasets were used to model prospective roost and habitat types for targeted field assessments within the larger regional survey area. The following data were used:

- 10 m Contours (source: Landgate)
- Hillshade, Slope Analysis and Digital Elevation Model (source: GHD)
- Known roost sites, including elevation, aspect and geology

- Aerial image (source: Landgate)
- FMG tenement boundaries and other mine tenement boundaries

The outputs of this process are displayed as prospective survey areas on Figure 4.

Step 2- Identify data to model roost and foraging habitat types according to habitat type descriptions

Additional data was sourced to best model the extent of the priority forging habitat types described in section 2.1.1. Table 1 provides a description of each habitat and summary of data used to determine outputs.

Table 1 Description of habitat types and data inputs

Habitat type	Description	Data inputs and explanation
1	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. 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. This habitat type includes the greatest potential for diurnal roost habitat and nocturnal refuge and nocturnal refuge/feeding habitats.	This habitat type also incorporates secondary unnamed water courses buffered by 50 m but above 250 m elevation, and slopes at 20% or greater buffered by 50 m at 200 m or greater elevation. Data inputs/amendments in addition to data from step 1: • Geology 250k and 500k DMIRS • Broad vegetation types • Slope type (> 20 degree) and sub categories • RL 310-400 m (relief) and sub categories • Water features – pools, waterfalls, springs watercourses buffered by 100 m Priority 1 and 3 habitat types were combined because of their occurrence in elevated areas (typically above 250 m). Furthermore both were determined to be areas that have greatest potential for roosting habitat.
2	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. Includes potential diurnal roost habitat particularly when adjacent to habitat type 1.	Includes primary named and unnamed watercourses above 200 m elevation, associated with upland areas. Likely to support roosting habitat when intersecting with habitat type 1. Data inputs/amendments in addition to data from step 1: • Water Line (Lgate-167) - watercourses above 200 m – major rivers buffered by 50 m • Water Polygon (Lgate-169) - above layers with water polygon • Additional drainage lines with intersection of water features data – GHD
3	Major Watercourses (Priority 4) – 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.	Includes primary named and unnamed watercourses below 200 m elevation, associated with lowland areas. Unlikely to support roosting habitat of any types. Data inputs/amendments in addition to data from step 1: • Water Line (Lgate-167) - watercourses at or below 200 m – major rivers buffered by 50 m • Water Polygon (Lgate-169) - above layer with water polygon
4	Open Grassland and woodland (Priority 5) – dominated by Triodia, on lowland plains colluvial slopes and hilltops.	Includes all lowland areas at 140 m or below excluding habitat type 3, and all other areas above 400 m elevation with a slope of 20% or less (e.g. flat hill top areas). Unlikely to support roosting habitat. Data inputs/amendments in addition to data from step 1:

Habitat type	Description	Data inputs and explanation
		• Geology 250k and 500k DMIRS • Broad vegetation types • Slope type (< 20 degree) and sub categories The difference between highest and lowest elevations (relief) was categorised as 140-310 and 400-510-400 m.

Step 3 – Review modelled habitat types using field data and refine where necessary.

The modelled output from step 2 was further refined with additional data from the 2020 field surveys. The key refinement was the reduction of the extent of habitat type 1 (priority 1). The preliminary results overestimated the area of this habitat, particularly areas between 280 and 300 elevation. A combination of elevation, relief and slope data in combination with qualitative analysis of high-resolution satellite imagery was used to refine the extent of habitat type 1 (priority 1) and was ground-truthed using field survey data.

2.2 Field survey

The field survey consisted of four site visits conducted by Spectrum Ecology and GHD within the survey area during 2020. The GHD survey was conducted with GHD Animal Ethics Committee, Animal Research Authority approval (ARA 12517457) and the Department of Biodiversity, Conservation and Attractions, Authorisation to take of disturb threatened species (Authorisation number TFA 2020-0023).

The following methods were used for the targeted bat surveys:

- Bat trapping
- Roost habitat assessment
- Bat call survey
- Emergence survey.

Table 2 summarises the date, purpose and personnel for each field survey. The methods, timing and survey effort for each trip are described in sections 2.2.1-2.2.5. Figure 4 displays the prospective roost search areas and methods used during the survey. A helicopter was utilised over four days to extend survey effort and access locations that would otherwise be inaccessible during the October 2020 survey.

Table 2 Summary of survey dates, purpose and personnel experience

Survey	Date and Purpose	Personnel and Experience
1	May 19th – 23rd 2020 Deployment of ultrasonic and acoustic bat detectors for Ghost Bat and Pilbara Leaf-nosed Bat within the GVSS survey area	Jordan Vos – 10 years, Astrid Heidrich – 12 years, Dr Floyd Holmes – 7 years Melinda Henderson – 2 years
2	August 19th – 25th 2020 Targeted Ghost Bat survey – trap, cave emergence and habitat assessment within survey area	GHD - Glen Gaikhorst – 21 + years, Robert Browne-Cooper – 21 + years, Madison Roberts – 3 years, Brad Maryan – 21 + years, Lynette Greer – 2 years
3	September 7th – 11th 2020 Targeted Ghost Bat survey – cave emergence, bat call surveys and habitat assessment within survey area	GHD - Robert Browne-Cooper – 21 + years, Brad Maryan – 21 + years
4	October 22nd to 29th 2020 Targeted Ghost Bat and Pilbara Leaf-nosed Bat survey – habitat and roost assessment via helicopter, roost habitat assessment, cave emergence and bat call surveys within survey area	GHD - Robert Browne-Cooper – 21 + years, Madison Roberts – 3 years

2.2.1 Guiding documents, identification and nomenclature

Guiding documents

The survey methodology and data collection that GHD employed was consistent with:

- Environmental Protection Authority (EPA) Technical Guidance –Terrestrial Fauna Surveys (EPA 2016a)
- EPA Technical Guidance – Sampling methods for terrestrial vertebrate fauna (EPA 2016b)[1]
- Survey Guidelines for Australia's Threatened Bats (DEWHA 2010b).

Bat identification and nomenclature

Bats were identified in the field or office (in situ camera) using reference books and field guides (e.g. Churchill 2008; Van Dyck et al. 2013). Bat call identification was assisted by consulting distribution information for potential species (e.g. Armstrong 2011 and McKenzie et al various dates; Churchill 2008; Van Dyck et al. 2013; Atlas of Living Australia 2020 and NatureMap 2020) and published call descriptions (e.g. Armstrong and Cole 2007; McKenzie and Bullen 2009; Guppy et al. 1985; Hourigan 2011).

Nomenclature used in this report follows that used by the Western Australian Museum (WAM) as reported on NatureMap. This nomenclature is deemed the most up-to-date species information for Western Australian fauna.

2.2.2 Bat trapping

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

[1] Note: the recently revised EPA guidance was released June 2020, following the commencement of this survey, however ultrasonic surveys were undertaken for at least 3 nights for all sites with the exception of two sites as recommended by the EPA 2020 guidelines.

Harp traps were erected approximately 15 minutes before sunset at various locations over the course of five nights. Sheets and other objects (e.g. large leafy branches) were used to funnel bats into the harp traps where possible. Table 3 and Figure 4 provide location details for each trap site.

Trap(s) were continuously monitored by two Senior Ecologists for the duration of the survey with monitors positioned within 10 metres from the trap to ensure captured bats were retrieved as soon as possible. All bats were assessed and released at the point of capture.

Table 3 Harp trap locations

Date - Location	Latitude	Longitude	Figure 4 reference
19/8/20 - Dry creek above Python Cave	119.056531	-21.294272	H1
20/8/20 - Wallaby Cave gully	119.024412	-21.230236	H2
21/8/20 - Dingo Pool (below Joe's Cave)	118.973940	-21.251326	H3
23/8/20 - Pool 12 wet creek	119.079042	-21.245135	H4
24/8/20 - Pool 12 wet creek	119.079036	-21.245135	H5

2.2.3 Habitat assessment

Reconnaissance surveys in combination with roost habitat assessments and ultrasonic surveys were undertaken for both bat species for the purpose of identifying roosting sites and areas that may provide roosting habitat.

A helicopter was used to determine opportunities for access to survey areas, refine the prospective search area or eliminate potential roost locations. When it was deemed safe to land and investigate an area on foot a team of three consisting of a GHD senior ecologist, FMG geotechnical advisor and FMG occupational health and safety officer completed the roost habitat assessment. Two types of assessment were undertaken based on the ability to safely access sites deemed as potential habitat. Figure 4 provides a point for each location searched for roost habitat.

- Helicopter/foot assessment (ha) – map symbol black triangle Figure 4. For each habitat assessment the area was either searched on foot and/or by observation from the helicopter for potential roost sites, however a detailed habitat assessment was not undertaken due to the lack of suitable roosting habitat or the ability to access the site (e.g. for safety or time constraints). The observer noted if there was any potential for suitable roosting habitat.
- Roost habitat assessment (rha) – map symbol red cross Figure 4. For each site that was deemed safe to access a field sheet was completed to document the roost structure and evidence of use or occupation by bat species in accordance with methods detailed in GHD 2017 (*North Star Magnetite Project – Survey Plan for Pilbara Leaf-nosed Bat,* Step 1 and Step 2). The information documented was used to assist with determining the category of roost and habitat mapping as described in Section 2.1.1 and 2.1.2.

When a potential diurnal roost location was identified, GHD placed a full spectrum ultrasonic recorder for three consecutive nights to interpret patterns of activity in the context of the nightly usage of the potential roost.

2.2.4 Roost emergence surveys

Roost emergence surveys for the Ghost Bat were undertaken at Chateau Cave, Joes Cave, Cave 13 and South Star Pool Caves. This technique enables a non-invasive assessment of roost occupancy and emergence at dusk without entering the cave. (DotEE 2016). The

approach includes a combination of a widely used methods for bats-referred to as visual emergence counts or exit counts (e.g. Brown etc at 2008) including:

- At least one observer positioned at each entry/exit point counting bats as they emerge and re-enter until light is insufficient. For most surveys at least two observers were able to view the roost, allowing for a comparison of counts at the end of the survey
- Use of an IR video camera coupled with an IR lamp to record bats exiting and re-entering the roost. Infrared video cameras (Sionyx Sport HD Camera and Bushnell Equinox Monocular) were sometimes used to capture video samples of bats emerging from the roost. The camera was coupled with an IR spotlight was placed on the floor of the passage approximately 5-10 m in front of the entrance of the roost entrance/exit. Video footage was recorded to a micro SD card and analysed post survey.
- At least one ultrasonic detector was placed at the entrance/inside the roost being monitored. Additionally, in some circumstances another was placed nearby the roost or alongside the video camera to record the species of bat exiting and entering the roost from call identification and synchronisation with observations and video counts. The full spectrum ultrasonic recorder was used to determine the timing and presence/absence of PLNB, Ghost Bat and other echolocating bat species and analyse the pattern of activity for the emergence period.

An attempt was also made to categorise the size/shape of the bats when flying out of the roost during the survey and recorded on the video using the following categories:

- Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB
- Medium bat = Common Sheathtail Bat
- Large Bat = Ghost Bat

Plate 1 Video camera, IR lamp and detector set at South Star Pool cave complex

2.2.5 Bat call survey and analysis

Insitu bat detector surveys

Bat calls were recorded during field surveys using in situ (stationary) full spectrum ultrasonic detectors (Song Meter SM2 bat plus and SM4 FS, Wildlife Acoustics or Anabat Swift detectors, Titley Scientific) at 31 locations in the study area. In situ detectors were set for a minimum of two nights at each location and programmed to record from 30 minutes pre-sunset to 30 minutes post-sunrise. Three locations were also surveyed during May 2020 within the GVSS survey area using acoustic recorders (Songmeter SM4 acoustic, Wildlife Acoustics) for the purpose of targeting social calls of the Ghost Bat. Bat detectors were positioned in areas where bat species were likely to be present i.e. water bodies, flyways such as rocky gullies, and potential roost caves.

Of the 31 sites, four were subject to technical issues (e.g. not set correctly, firmware issue or faulty microphone) and did not record any or very few files. A total of 377,837 files (.wav, .wav4, or .wac) were recorded for the survey. Appendix B provides a list of all in-situ sites and results for each site.

Bat call analysis

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

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

1. Data files were downloaded for each site and saved to an external hard drive following the survey for processing and analysis
2. For full spectrum compressed .wav and .wac files collected using the Song Meter units, files were converted to standard .wav using the conversion function in Kaleidoscope Pro
3. For each night data was manually reviewed for bat calls using Kaleidoscope Pro and Anabat Insight from sunset onwards for approximately 45 mins for PLNB and Ghost Bat calls 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 (see species descriptions below and McKenzie and Bullen 2009 and 2012).
4. Data for each night and site was then processed using the Wildlife Acoustic Kaleidoscope Pro cluster analysis function and species-specific classifiers for the Pilbara Leaf-nosed Bat and Ghost Bat. Species-specific and/or species-group filters in Anabat Insight were also used to check the results. Further manual data review was also completed for validation purposes which was repeated several times to accurately identify species.

Steps 3 and 4 were completed for all nights for PLNB however due to the constraints associated with automating the analysis of Ghost Bat calls (due to complexity of vocalisations) additional validation was necessary. A sample of 14109 files from 15 sites was sent to an expert on Ghost Bat vocalisations (N. Hanrahan) for review, including files with possible Ghost Bat social calls derived from the above review process and a random number of files from a random selection of sites. Validation of these calls was was aligned with the process detailed in Hanrahan 2020.

Section 3.2.3 provides a summary of the key results from the bat call analysis process. Appendix B provides additional results for each site and review of Ghost Bat calls undertaken by N. Hanrahan.

Call description

A call (pass) was defined as a sequence of three or more consecutive pulses of similar frequency and shape over a period of one second with the exception of the Pilbara Leaf-nosed Bat where at least one clear pulse 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 Table 3.

Table 4 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. *Macroderma gigas/ Taphozous georgianus* (particularly social calls and in roost calls) *Taphozous georgianus/ Taphozous hilli* Nyctophilus sp. The calls of Nyctophilus *geoffroyi / daedalus/ arnhemensis.*

Species call description

Pilbara Leaf-nosed Bat

Echolocation calls are distinctive, having a CF-FM (constant frequency - frequency modulated) structure, and with a characteristic frequency between 117 and 125 kHz (DAWE 2020a). The mean characteristic frequency of the loudest (second) emitted harmonic is 121 kHz in the Pilbara, which is around 6 kHz higher than in the northern distribution of the species. Each pulse consists of a constant frequency tone of c. 8 milliseconds duration, followed by a very brief broadband downwards sweep through c. 20 kHz (Armstrong and Coles 2007). It is possible to identify the species unambiguously from good quality echolocation calls.

Ghost Bat

Ghost Bats make several social calls that are audible to humans (‘chirps’, ‘squabbles’ and ‘twitters’; Kulzer et al 1984; Guppy et al. 1985; Pettigrew et al. 1986). When free flying, echolocation calls are characterised by steep linear frequency modulated pulses at 45-56 kHz, of low intensity and short duration (0.8-2.3 ms) (Guppy et al. 1985; McKenzie et al. 1996). Echolocation calls have up to four harmonics but most of the strength is in the 2nd or 3rd harmonic (Guppy et al.1985). More recently Hanrahan (2020; 2021) reviewed and revised the social vocalisations of the species as ‘chirp and trill’, ‘squabble’ and ‘ultrasonic social’ (see examples Appendix B).

Activity description

A maximum file length of one second was chosen as the basic unit for the summation of activity for the Pilbara Leaf-nosed Bat and Ghost Bat as consistent with previous analysis undertaken by Specialised Zoological and GHD for both species within the survey area. Activity was based on the presence of one call in a .wav file of a duration one second. Information on sunset,

sunrise and civil twilight end and begin times was obtained from timeanddate.com for Marble Bar (https://www.timeanddate.com/sun/@2067029).

Summaries of the activity patterns of the PLNB can give an indication of how the species uses each cave (e.g. diurnal roost or nocturnal usage) and assist with determining the category of diurnal roost as defined in the categories described in section 2.1.1.

Limitations

Both the PLNB and Ghost Bat need to be in close proximity to the bat detector to be recorded. For example, the detection range of echolocation calls for the PLNB depends on the type and sensitivity settings of bat detectors but is typically a few metres (Specialised Zoological 2017). The calls of the Ghost Bat are of low intensity, the bat must be close to the microphone (< 5-7 m) in order to detect the call and obtain reasonable recordings (Pettigrew et al. 1986).

The semi-automated analysis process does not always capture all 'softer' (those calls with a lower amplitude) PLNB and Ghost Bat calls and sometimes calls with few pulses. Noting these limitations, the manual review of all spectrogram files for the first 45 mins of the analysis process each night ensured no emergence calls were missed for the PLNB. Furthermore, random manual checking of data revealed that very few if any PLNB calls were missed by the semi-automated process used to detect PLNB files throughout the night.

There is potential for automated and semi-automated processes to identify overload signals, parts of echolocation call from other cave roosting bats and ultra-high frequency calls of the Finlayson's Cave Bat as PLNB calls (see Specialised Zoological (2018). The manual review of files and use of filters removed the majority of these false positives. However, a very small portion of files from sites with high activity may contain a small portion of false positives, as manual review of all possible PLNB calls was not feasible for all sites.

The Common Sheathtail Bat produces some echolocation and social calls very similar to the frequency and structure of Ghost Bat social and echolocation calls, particularly when in the roost (Specialised Zoological 2018). The manual review process and validation of a sample of files by an independent reviewer with expertise in Ghost Bat call identification aimed to reduce the number of false positives from the semi-automated process.

The PLNB is known to visit caves while out foraging at night and linger around cave entrances soon after dusk and prior to dawn, but it will not use all the caves it visits as diurnal roosts (see Specialised Zoological 2018). It is therefore important to consider the timing of activity data (e.g. before, during and after the emergence period at dusk and re-emergence period at dawn), and review data from multiple nights of survey effort in order to understand patterns of activity to support any outcomes regarding roost categorisation.

The Ghost Bat may hang within the entrance of a roost cave before moving out to forage, and visit caves to rest and feed while out foraging at night, therefore activity based on the detection of echolocation and social calls may not always be useful for predictions about diurnal usage (see Specialised Zoological 2018). However, continuous presence over many nights can indicate the importance of a particular structure for a local group of Ghost Bat.

It is for these reasons that ultrasonic surveys should not be the primary means of survey for the Ghost Bat, or the only survey technique for the PLNB.

2.3 Survey limitations

Terrain and access

Surveys conducted 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 access

in combination with the distances required to travel to the site to conduct return visits hindered survey efforts in some areas. It is possible that suitable roosting habitat occurs in these inaccessible areas.

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 caves contained one or more individuals at the time of the surveys.

Weather

Weather experienced during the survey was generally suitable. No adverse weather events were recorded for the survey.

Site conditions

Blasting operations for the development of the North Star Mines site were undertaken each evening for the duration of the August survey and for some evenings during the September and October surveys. The blasting was undertaken in the area to the north-west and west of Chateau Cave. The potential impacts of the blasting operations to the colony of PLNB within Chateau Cave, and Ghost Bat at South Star Pool Cave complex was not included as part of this assessment. If the results presented in this report are used for the assessment of potential impacts to either species for the purpose of a development application, the interpretation of the results should consider the potential impacts (e.g. vibrations and noise) of blasting operations particularly when considering the presence and absence of either species from potential and known roost sites within the proximity of the blast area (i.e. the area affected by noise and vibrations) .

3. Results

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 *Environment Protection and Biodiversity Conservation Act 1999* (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.

3.1 Desktop assessment

This section provides both the broad context of the occurrence of the two bat species across the survey area including a comparison of the records within the GVSS survey area and the larger regional survey area until the end of 2019. A detailed analysis of survey methods and effort for both species to the end of 2019 can be found in GHD (2020a and 2020b) and Specialised Zoological (2017). The results reported below exclude the findings from surveys conducted during 2020 within the survey area by GHD and Spectrum Ecology which are presented from Section 3.3.

3.1.1 Historical review of effort

Prior to 2014 the assessment of bats within the survey area focused on results gained from the use of ultrasonic detectors and habitat surveys targeted at the PLNB. The habitat assessments were most likely undertaken from outside of caves in order to reduce disturbance to bats. The Ghost Bat was not listed under the EPBC Act until May 2016 and therefore was not afforded the same level of consideration as the PLNB, hence targeted survey effort was not completed for this species. Furthermore, the majority of the detector effort prior to late 2015 early 2016 employed a band filter to ignore signals below c. 50 kHz, thus eliminating the majority of the frequency band in which the Ghost Bat calls.

Due to the need to meet the EPA condition 10 requirements there has been a concerted effort since early 2015 to demonstrate ongoing occurrence, categorise known roost sites and locate additional roost sites for the PLNB within the North Star mine study area. The North Star mine study area encompassed a 30 km radius from Cave 13, thus overlapped with much of the survey area for this project. The approach to locate and categorise roost sites has included a combination of desktop and field survey techniques (e.g. roost habitat assessments including detailed structural and microclimate assessments, targeted sheeting surveys to confirm occupancy of PLNB within roost sites, roost emergence surveys, radio-tracking of PLNB and long-term monitoring of roost sites using detectors). The results from these efforts are summarised below and displayed in Figures 2a, 2b, 3a and 3b. More detail regarding known and potential roosting habitat is provided in Section 3.2.

The listing of the Ghost Bat in 2016 under the EPBC Act prompted FMG and IBO to take into consideration this species for future mining developments outside the North Star mine development envelope (MDE). Since 2018 additional surveys have been undertaken in the South Star and Glacier Valley area located south and south-west of the North Star MDE for both species (see GHD 2020a and GHD 2020b).

3.1.2 Collation and mapping of records

The following information is summarised and displayed for each species:

- Roost records (e.g. breeding roost) and non-roost records (e.g. observations, trap record) for the Ghost Bat within the survey area – Table 5 and Figure 2a and 2b.
- Roost records (e.g. permanent roost) and non-roost records (e.g. observations, trap record) for the PLNB within the survey area – Table 6 and Figure 3a and 3b.

Table 5 Summary of roost and non-roost type records for Ghost Bat

Record type	GVSS survey area	Regional survey area (excluding GVSS records)
Roost		
Breeding roost	1 (Cave 3 of South Star Pool cave complex). (Note: Caves 1, 2 and top Cave of South Star Pool complex determined likely ongoing or occasional use diurnal roosts*)	0
Diurnal roost ongoing use	1 (Python Cave)	8
Diurnal roost occasional use	0	0
Potential diurnal roost – unknown type	0	11
Potential habitat*	19	6
Non-roost		
Observation (in cave, flying or scat)	5 (including South Star Pool cave complex roost records)	8
Specimen (trap or voucher)	0	4
Detector record	0	0
Survey – unknown record	0	18

Note: *not included on Figure 2a (see GHD 2020a and section 3.2 for greater detail)

Table 6 Summary of roost and non-roost type records for PLNB

Record type	GVSS survey area	Regional survey area (excluding GVSS records)
Roost		
Permanent diurnal or Non-permanent breeding roost	0	1 (Chateau Cave)
Transitory diurnal roost	0	8 (Joe's Cave, Cave 13, and Caves C, D, E, F, G and H at Abydos mine)
Potential diurnal roost unknown category	0	17 (includes cluster of records southern section of survey area)
Potential transitory diurnal roost	1 (Python Cave)	0
Nocturnal refuge	0 (excludes potential habitat locations from the GHD 2020 survey that may be nocturnal refuge records)	52
Potential habitat*	22 (includes South Star Pool Cave complex)	8
Non-roost		
Observation (in cave, flying or scat)	0	5
Specimen (trap or voucher)	0	4
Detector record (not within 20 min of civil twilight)	7	68
Detector record (+/- 20 min civil twilight)**	5	6

Note: *not included on Figure 3a (see GHD 2020a/b and section 3.2 for greater detail).

3.1.3 Known diurnal roost sites Ghost Bat

Targeted survey results from 2018 and 2019 (see GHD 2020b) and a review of studies undertaken to 2019 have categorised five sites according to the categories devised in Section 2.1.1. All roosts are displayed on Figure 2a.

South Star Pool cave complex – Category: *Breeding roost (cave3) and potential ongoing use diurnal roost (other caves).* GHD completed roost emergence surveys during January 2019 and confirmed that a large number of Ghost Bats (26-30 Ghost Bats) were roosting within cave 3 of this natural cave complex. This cave is most likely a maternity roost considering the number of Ghost Bats recorded and the timing of the surveys (January).

Python Cave – Category: *Diurnal roost ongoing use*. The presence of a small scat pile containing historical and fresh scat during February 2016 and again in May 2018 in combination with scattered Ghost Bat scat in other parts of the cave provide evidence of regular and ongoing use by a small number of Ghost Bat.

Bone Cave – Category: *Diurnal roost ongoing use*. A single Ghost Bat was observed roosting in March 2015, and two were observed roosting in November of 2016. Scattered fresh and historical scat were also recorded during each visit, but no obvious large scat piles. The information reviewed to date suggests this natural cave is regularly occupied by a few Ghost Bat. The depth, structure and microclimate of the cave may provide potential breeding habitat for a small colony of Ghost Bat, however further survey work is required to determine occupation and use during the breeding period.

Cave 13 – Category: *Diurnal roost occasional use*. A single Ghost Bat has also been observed roosting within Cave 13 on three occasions, including June 2017 (GHD 2017) and most recently November 2019 (pers obs C. Grabham 2017 and 2019). This species was also observed exiting the cave during roost emergence surveys in April 2013 (Bat Call WA, 2013). The information reviewed to date suggests Cave 13 is a natural cave occupied regularly by a small number (1 or 2) of Ghost Bat. However, it was not occupied during the period of the cave occupancy surveys (February and September 2016) suggesting the Ghost Bat was not using Cave 13 during the 2015-2016 breeding season. Furthermore, the small size and structure of the roost and lack of other evidence (e.g. scat piles) supports only occasional use of the roost.

Wallaby Cave Category: *Diurnal roost occasional use*. Four Ghost Bat observed roosting in March 2015. No other information collected since initial observation. The information reviewed to date suggests this natural cave is occasionally occupied by a few Ghost Bat. The depth, structure and microclimate of the cave has not been investigated. Further survey work required to determine occupation and use.

3.1.4 Known diurnal roost sites Pilbara Leaf-nosed Bat

Cave occupancy surveys for the PLNB within Cave 13, Joe's Cave and Chateau Cave during February and September 2016 (see GHD 2016a and 2016b) and December 2019 (see GHD 2020b) and a review of studies undertaken to 2019 have categorised the three sites according to the Threatened Species Scientific Committee (TSSC), Approved Conservation Advice for the Pilbara Leaf-nosed Bat (TSSC 2016) and the DoTE (2019). One other location within the study area is known to support diurnal roosts (Abydos mine). All roosts are displayed on Figure 3a.

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

ultrasonic data by Specialised Zoological (2018) also suggests that this cave most likely functions as a 'permanent diurnal roost' that has an important role in the breeding cycle for the PLNB. Bat call analysis and roost occupancy surveys during 2019 further confirmed this finding (see GHD 2020b).

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

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

Abydos Mine Project, Atlas Iron – Category: *Transitory diurnal roost*. Located approximately 15 km north-east of Cave 13 (see Figure 1 and 2). Four caves were suspected to be used as some type of diurnal roost (not categorised) by the PLNBs. The caves were retained and excluded from the development area and buffers were established preventing any works within 50 m of the caves. Atlas Iron established a significant species management plan which included actions to monitor PLNBs within the caves. The roost requires further investigation to understand its current status. A visit to the site during May 2021 by a GHD ecologist revealed PLNB occupying at least one of the known roost sites.

3.1.5 Other roost locations

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

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

- GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report
- GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat
- GHD 2020 (February 2020a), Unpublished report for Fortescue Metals Group Iron Bridge – Glacier Valley and South Star Fauna Surveys: Fauna Survey report results

Table 7 identifies locations that could provide potential diurnal roosting of some type (including possible permanent diurnal roost, non-permanent breeding roost, or transitory diurnal roosts) for the PLNB and Ghost Bat.

Blue Square/ Nicko's Gorge area

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

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

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

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

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

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

- The preliminary habitat assessments recorded five sites that require further investigation for PLNB and/or Ghost Bat. Three of the sites could not be appropriately accessed but appeared to contain some potential habitat (e.g. a large opening with a deep passage) for supporting roosting (e.g. temporary diurnal or maternity) opportunities

- Two sites – unknown cave 1 (UC1) and Bone Cave were given a preliminary categorisation of 'transitory diurnal roost' (TSSC 2016) for the PLNB, given the architecture and potential microclimate habitat of the cave. Further survey is required to confirm this categorisation
- Ultrasonic call analysis revealed the three sites with water recorded PLNB activity within 15 minutes of civil twilight ending (18:48 +/- 5 minutes)
- No PLNB were recorded in roosts during the survey, although the Ghost Bat was recorded at three locations via direct observation or scats during the survey
- The field assessment and review of geological information suggests the area searched has the capacity to provide roosting habitat for the PLNB and Ghost Bat.

The main purpose of the 2019 radio-tracking survey was to locate and/or narrow the potential location of an alternative natural maternity roost site(s) for the PLNB. The 2019 study findings (GHD 2020b), coupled with information from the 2017 radio-tracking study (GHD 2017f) provides sufficient evidence that at least one or two diurnal roosts occur within the range of reception of the receivers in addition to the known diurnal roost of Chateau Cave and Cave 13. There is evidence to suggest that Joe's Cave may have been used as a diurnal roost during the survey by up to two PLNB (Tag 11 and/or 20) however as indicated by the data, it is unlikely that either bat consistently used Joe's Cave for every night of the survey period.

- Potential roost location, north-east through south-west of Joe's Cave - base station receiver 2 and base station receiver (bs)4 were the only base station to record valid first and last tag detections. As previously discussed, the data indicates the presence of a diurnal roost within the reception range of bs2, including the area, south-east, through south-west of the base station. This broad area incorporates:
  - Potential roosting habitat surveyed during manual tracking searches (within 1 km north-east of Joes cave). The area east-north-east of Joe's Cave has several locations identified as potential roosting habitat.
  - Zane's Gorge and the southern facing cliff face for within 4 kms west of Joe's Cave. The area west of Zane's Gorge has several locations identified as potential roosting habitat.
- Potential roost location, north-east of Joe's Cave - the timing of the last tag detection recorded by base stations (4:29 am) for the morning of the 1/12/19 and first tag detection (7:18 pm) for the night of the 1/12/19 by bs2 – Antenna 3 (orientated east-north-east) for three and four consecutive detections then by Antenna 4 (orientated south-south-west) indicates Tag 19 was roosting in the area north-east of Joe's Cave. Potential roosting habitat surveyed during manual tracking searches (within 1 km north-east of Joes cave). The area east-north-east of Joe's Cave has several locations identified as potential roosting habitat.
- Potential roost location, South Star Pool area - The timing of the data from bs4 for the night of the 30/11/19 indicates Tag 22 was detected in close proximity to or leaving a diurnal roost. Following the first tag detection by bs4, Antenna 1 (orientated south-west, south of South Star pool) at 7:01 pm, 74 consecutive tag detections were recorded by Antenna 1 for an 11 minute period from 7:01 – 7:12 pm, with 7:12 pm being the last valid detection recorded. No other tag detections were recorded by bs4 or other base stations within 20 minutes of civil twilight.
- Other diurnal roosts may also exist in areas outside the reception range of the base stations, as indicated by the 2017 study however, particular the Abydos Mine area however insufficient data was collected during the 2019 study to add to the 2017 findings.

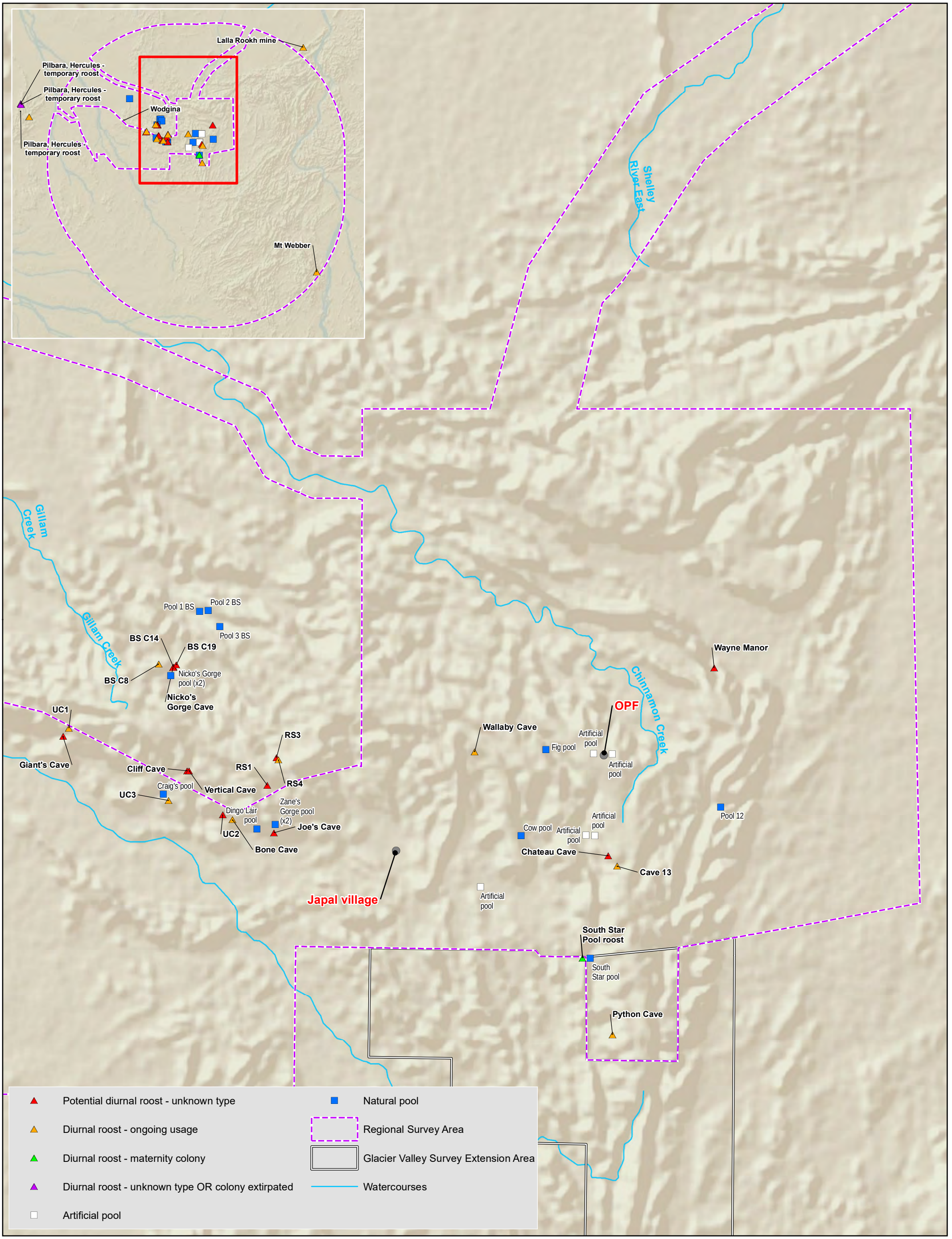
- The manual tracking and roost search survey results undertaken in the area north east of Joe's Cave during the 2017 study recorded temporary diurnal refuge roosts and potential transitory diurnal roosts, although no sites that could support breeding or a large aggregation of PLNB were recorded. However, sites (e.g. openings along cliff faces, at height) that were not safe to access, which could provide potential roost opportunities were recorded. The information reviewed from the survey suggests that other roost(s) could be in the vicinity of Joe's Cave/Zane's Gorge, probably within 3-4 km of Joe's Cave/Zane's Gorge in an area spanning from the north through to north-east. The findings from the 2019 radio-tracking study support the discussions regarding the location of potential diurnal roost habitat in the Joe's Cave and Zane's Gorge areas, and the area north-east of Joe's Cave.

Table 7 Summary of potential diurnal roosting locations recorded to date (note: nocturnal refuge sites not included)

Location	Site name	Altitude (m)	Type of roost	Date
North Star MDE – Regional survey area	Chateau Cave	368	Potential occasional use diurnal roost (passage and second chamber) for Ghost Bat. Species observed hunting out front of cave and inside passage. No confirmed roosting to date.	Observations from 2016, June 2017, November 2019
Nicko's Gorge - Regional survey area	Nicko's Gorge	Approx 250 (floor)	Multiple potential roost locations for both species	9/1/2015
	C14BS	261	Potential nocturnal refuge and temporary diurnal roost for PLNB	9/1/2015
	C19BS	292	Potential nocturnal refuge and temporary diurnal roost for PLNB	9/1/2015
Blue Square – Regional survey area	C8BS	331	Potential roost location unknown type – most likely transitory diurnal or nocturnal refuge roost for PLNB, unknown for Ghost Bat	9/1/2015
Joe's Cave/ Zane's Gorge area – Regional survey area	Unknown cave 1 (UC1)	-	Potential roost location unknown type – most likely transitory diurnal or nocturnal refuge roost for PLNB	Nov 2016
	UC2	-	Potential roost location unknown type both species	Nov 2016
	UC3	-	Potential roost location unknown type both species	Nov 2016
	Giant's Cave	-	Potential roost location unknown type both species	Nov 2016
	Bone Cave	-	Potential PLNB roost unknown type. Known Ghost Bat diurnal roost occasional use – 1 and 2 Ghost Bat recorded in back chamber, each visit	March 2015 and Nov 2016
	Vertical cave	-	Potential roost location unknown type both species	March 2015
	Cliff cave	-	Potential roost location unknown type both species	March 2015
	RS1	352	Potential diurnal roost location unknown type PLNB	22/06/17
	RS3	352	Potential diurnal roost location unknown type PLNB	22/06/17
	RS4	367	Potential diurnal roost location unknown type PLNB	22/06/17

Location	Site name	Altitude (m)	Type of roost	Date
North Star MDE or adjacent – regional survey area	Wallaby Cave	Approx 340	Potential PLNB diurnal roost location unknown type, most likely transitory or nocturnal refuge. Known Ghost Bat diurnal roost – 4 Ghost Bat recorded, occasional use diurnal roost	March 2015
	Wayne Manor	313	Potential roost location unknown type both species	21/2/15
South of North Star MDE – GVSS survey area	Python Cave	364	Known Ghost bat diurnal roost – scat pile displaying historical evidence recorded, most likely diurnal roost ongoing use	February 2016 May 2018
	Glacier Valley 12*	327	Potential nocturnal refuge and temporary diurnal roost for PLNB	May 2018
	Cave 32*	380	Known Ghost Bat diurnal roost – 1 Ghost Bat recorded	January 2019
	Glacier Valley 16*	379	Potential nocturnal refuge and temporary diurnal roost for PLNB	May 2018
	Cave 33*	380	Potential roost location for Ghost Bat - unknown type, feeding evidence and scat present	January 2019
	South Star Pool Cave complex	Approx 320	Potential nocturnal refuge and temporary diurnal roost for PLNB Know breeding / diurnal roost, due to large numbers of bats (up to 30) and time of year present (January) during cave occupancy surveys	May 2018 January 2019

Note: *not included on Figures 2a or 3a (see GHD 2020a/b).



Paper Size A3

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Kilometres

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

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Job Number	12528008
Revision	0
Date	16 Dec 2020

Roost records Ghost Bat

Figure 2a

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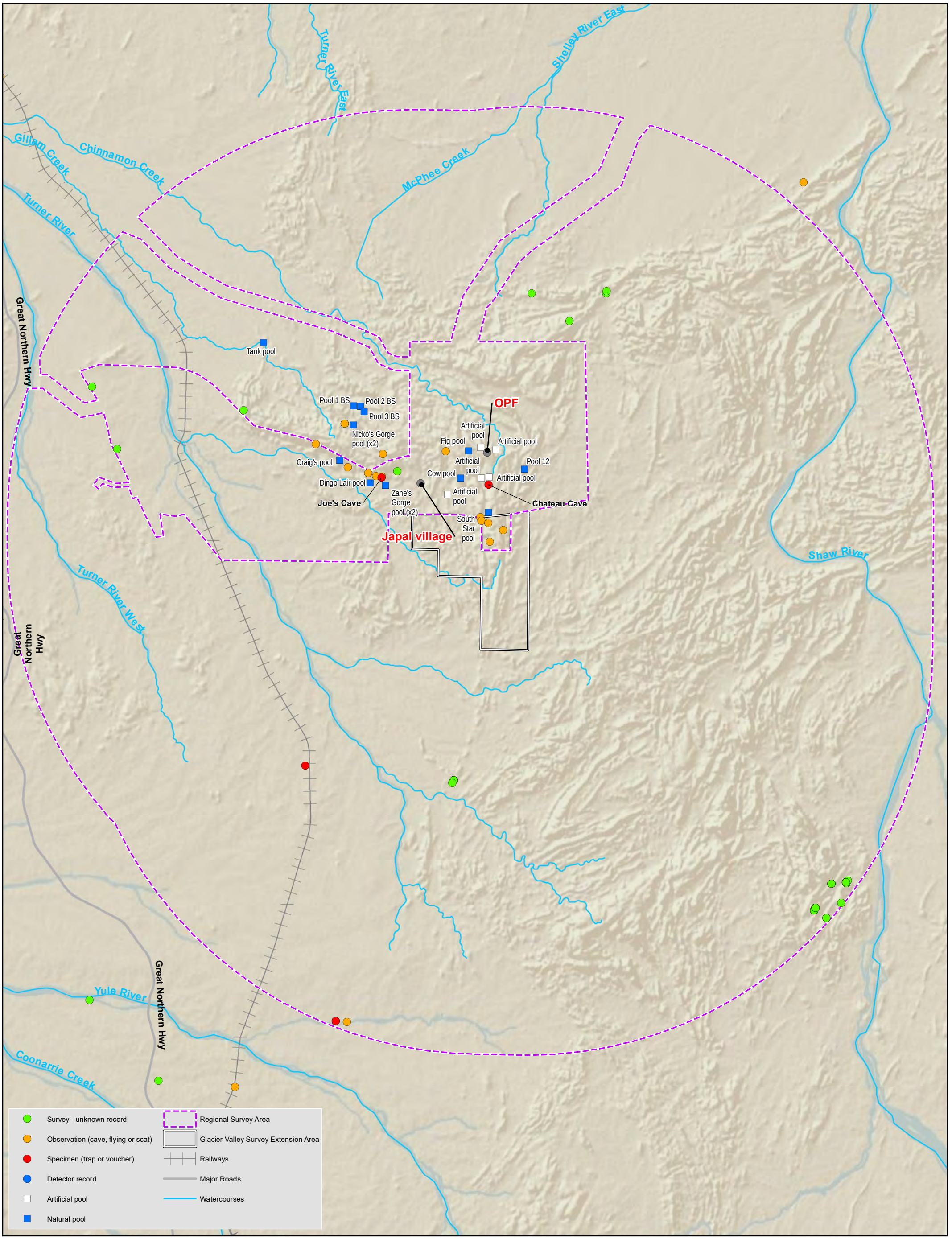
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS



Paper Size A3

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Kilometres

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

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Fortescue Metals Group Ltd

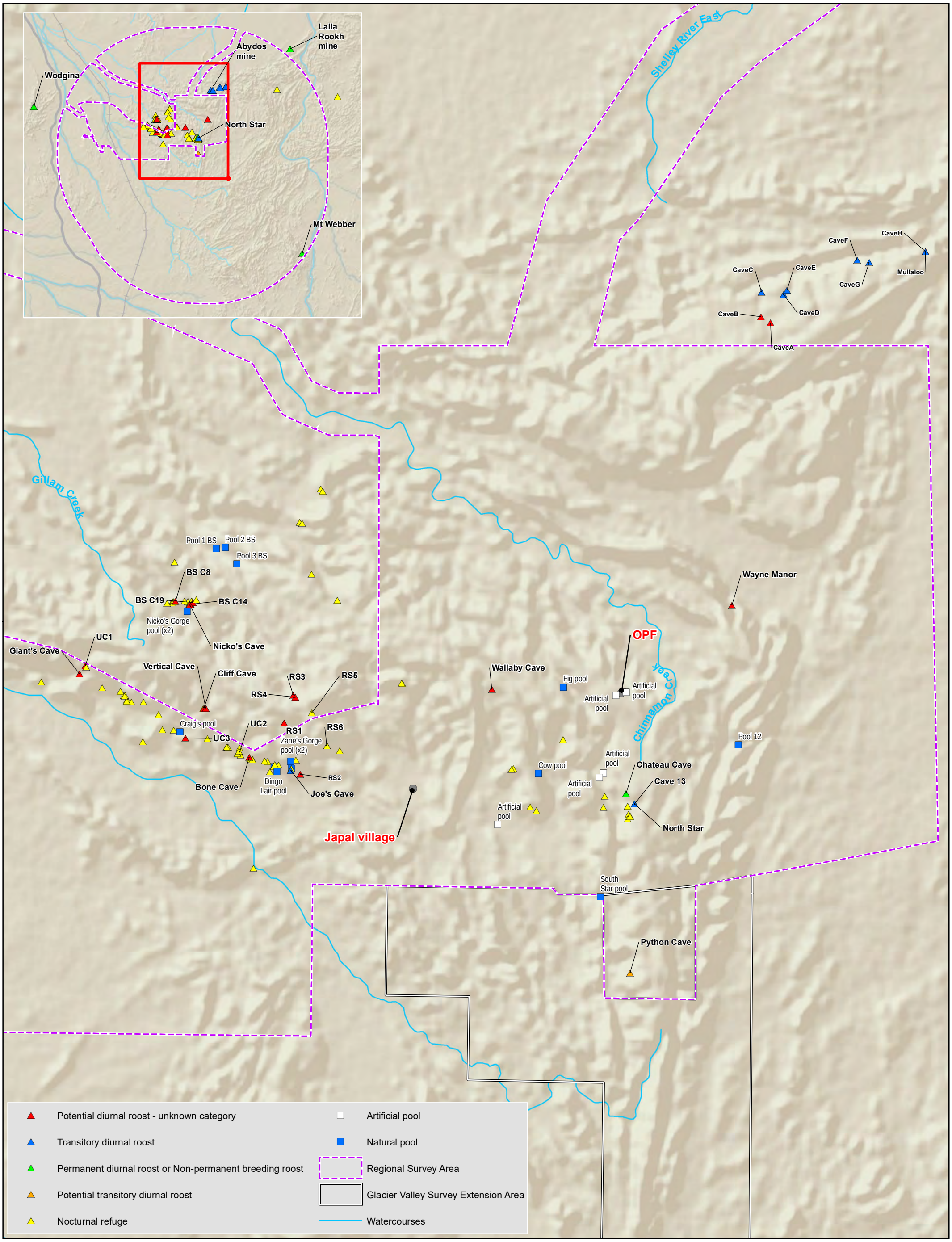
Job Number	12528008
Revision	0
Date	16 Dec 2020

Non-roost records Ghost Bat

Figure 2b

\\ghdnet\ghd\AU\Geelong\Projects\31\12528008\GIS\Maps\Working\12528008__02b_NonRoostRecordsGhostBat_A4PRev0.mxd 999 Hay Street Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS



Paper Size A3

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Kilometres

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

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Job Number	12528008
Revision	0
Date	16 Dec 2020

Roost records Pilbara Leaf-nosed Bat

Figure 3a

\\ghdnet\ghd\AU\Geelong\Projects\31\12528008\GIS\Maps\Working\12528008__03a_RoostRecordsPLNB_A4PRev0.mxd
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS

Turner River East
Shelley River East
Gillam Creek
Chinnamon Creek
McPhee Creek
Turner River
Great Northern Hwy
Tank pool
Pool 1 BS
Pool 2 BS
Pool 3 BS
Nicko's Gorge pool (x2)
Joe's Cave
Fig pool
Artificial pool
OPF
Craig's pool
Zane's Gorge pool (x2)
Artificial pool
Artificial pool
Dingo Lair pool
Cow pool
Chateau Cave
Artificial pool
South Star pool
Japal village
Shaw River
Turner River West
Great Northern Hwy
Great Northern Hwy
Yule River
Coonarrie Creek

Specimen (trap or voucher)
Observation (cave or flying at night)
Detector record
Detector record (+/- 20 min civil twilight)
Artificial pool
Natural pool
Regional Survey Area
Glacier Valley Survey Extension Area
Railways
Major Roads
Watercourses

Paper Size A3
0 2.5 5
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Job Number 12528008
Revision 0
Date 16 Dec 2020

Non-roost records Pilbara Leaf-nosed Bat

Figure 3b

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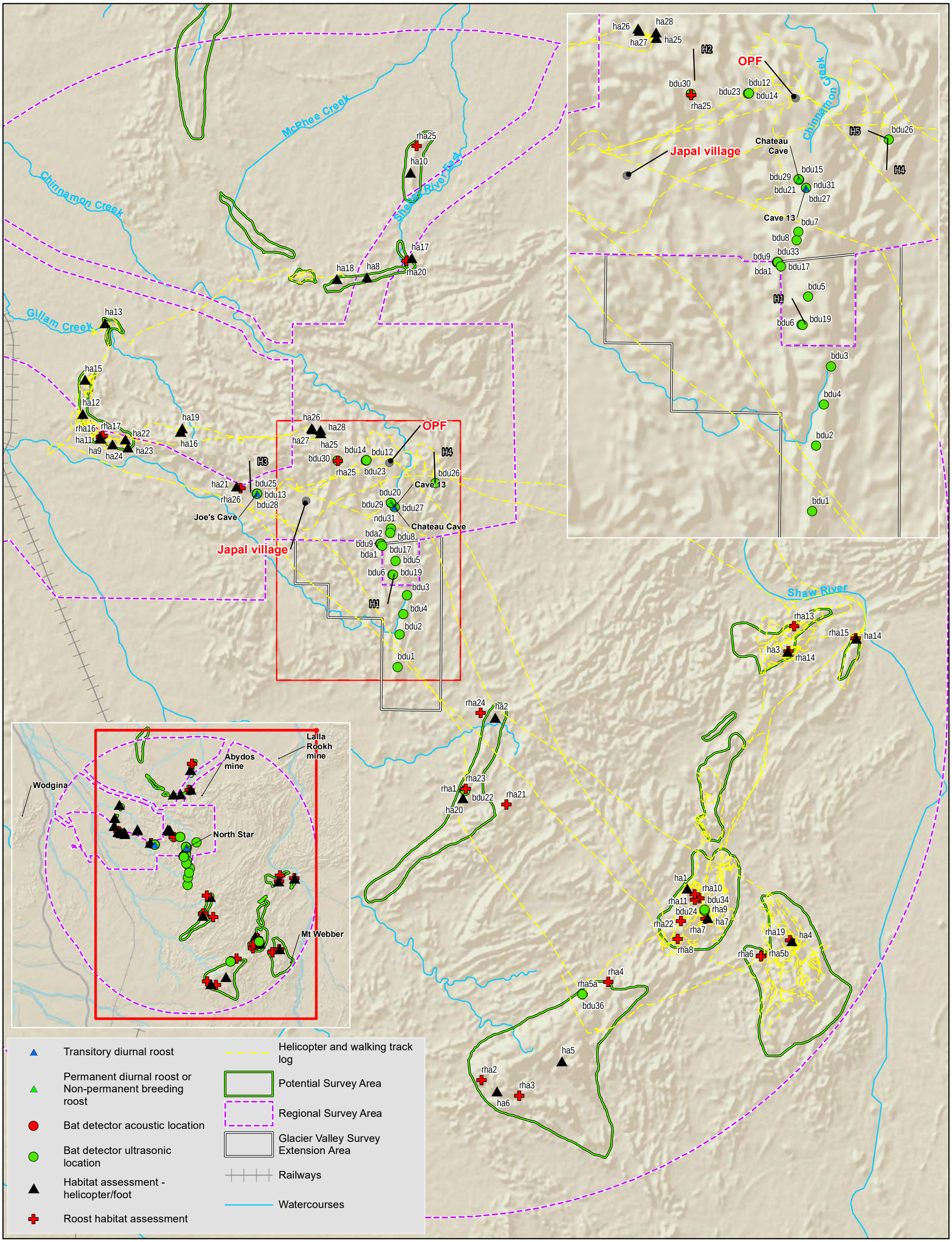
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS



Paper Size A3

0 2.5 5

Kilometres

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

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Fortescue Metals Group Ltd

Job Number 12528008
Revision 0
Date 24 Dec 2020

Survey methods

Figure 4

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

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS

3.2 Field surveys 2020

3.2.1 Bat trapping

Nine bats consisting of four species were captured from 5 nights of harp trapping at four locations. No Ghost Bat were captured, however five Pilbara Leaf-nosed Bat were captured and released. Table 8 provides a summary of the number of species and individuals trapped at each location during each trap night.

Table 8 Summary of trap results and observations August 2020

Trap night /location	Effort	Trap results	Observations/ comments
Harp trap site 1 - 19/08/2020 dry gully above Python Cave	Start c. 5:50 pm End C 10:30 pm 4 banks (each with 2 traps) x c. 5 hours	No bats captured	Sunset at c. 5:48 pm Ghost bat social call lure played at c. 6:30 pm (2 mins on then 2 mins off for c. 30 mins) No observations of Ghost Bats Overall bat activity low – few observed or heard Temp - 27 dc, 20% cloud cover, no wind Vibrations and noise from blasting obvious at start of trapping.
Harp trap site 2 - 20/08/2020 Gully and dry creek with Wallaby Cave	Start c. 5:50 pm End C 10:15 pm 4 banks (each with 2 traps) x c. 5 hours	No bats captured	Sunset at c. 5:48 pm Ghost bat social call lure played at c. 6:30 pm (2 mins on then 2 mins off for c. 30 mins) 1 x Spotted Nightjar and 1 x Owlet Nightjar heard calling 1 x possible 'chatter' Ghost Bat call No observations of Ghost Bats Overall bat activity low – few observed Temp - 27 dc, 20% cloud cover, no wind
Harp trap site 3 - 21/08/20 Dingo Pool and dry creek, near Joes Cave	Start c. 5:50 pm End C 10:30 pm 3 banks (each with 2 traps) x c. 5 hours	First bat captured 6:27 pm 2 x Finalysons Cave Bat (*Vespadelus finlaysoni*) 1 x Common Sheathtail (*Taphozous georgianus*) 1 x PLNB (female) 1 x PLNB (male) 1 x Little Broad-nosed Bat (*Scotorepens greyii*) Total bats captured = 6	Sunset at c. 5:48 pm Ghost bat social call lure played at c. 6:30 pm (2 mins on then 2 mins off for c. 30 mins) 2 x bat flew through harps All bats trapped during 'off' period' – when lure was not broadcast Overall bat activity moderate Temp - 28 dc, 20% cloud cover, no wind
22/8/2020	-	-	No trapping. Emergence survey South Star Pool Cave complex Vibrations and noise from blasting obvious at start of emergence survey.
Harp trap site 4 - 23/08/20 Pool 12, wet creek	Start c. 5:30 pm End C 10:25 pm 4 banks (each with 2 traps) x c. 5 hours	1 x PLNB captured 6:45 pm (released without details) No other bats trapped Total bats captured = 1	Sunset at c. 5:48 pm Ghost bat social call lure played at c. 6:30 pm (2 mins on then 2 mins off for c. 30 mins) 8 x bat flew through harps Numerous small bats observed avoiding traps. 2 x Ghost Bat observed flying investigating harp trap during call lure broadcast at 7:07 pm and 7:20 pm. All bats trapped during 'off' period' – when lure was not broadcast. Most small bat activity observed during 'off period'. Both Ghost observed during broadcast of call lure. Overall bat activity moderate Temp - 29 dc, 20% cloud cover, no wind, waxing crescent moon Noise from blasting obvious at start of trap session.
Harp trap site 5 -	Start c. 5:40 pm	1 x PLNB captured 6:49 pm (male)	Ghost bat social call lure played at c. 6:30 pm (2 mins on then 2 mins off for c. 30 mins)

Trap night /location	Effort	Trap results	Observations/ comments
24/08/20 Pool 12, wet creek	End C 10:30 pm 4 banks (each with 2 traps) x c. 5 hours	1 x PLNB captured 6:51 pm (male) No other bats trapped Total bats captured = 2	2 x bat flew through or bounced off harp Several small bats observed avoiding traps. All bats trapped during broadcast of call lure. Overall bat activity low Temp - 32 dc, 20% cloud cover, light wind, waxing crescent moon

3.2.2 Roost emergence surveys

Roost emergence surveys were undertaken within the survey area primarily for the purpose of determining roost occupation by Ghost Bat. Three surveys were undertaken of the South Star Pool cave complex, two surveys of Chateau Cave and one at Joe's Cave and Cave 13. The South Star Pool complex and Cave 13 are known diurnal roosting sites for the Ghost Bat. Long term monitoring using bat detectors and incidental observations at Joes Cave has revealed regular Ghost Bat activity within close proximity to sunset therefore warranting further assessment of this potential roost.

A summary of the key survey outcomes is presented below. Table 9 provides detailed results from the field survey observations and analysis of bat call detector data. Key findings include:

- Bats were recorded exiting each roost during the emergence survey
- The Ghost Bat was not observed exiting or entering any of the roost sites during any of the emergence surveys
- PLNB were confirmed exiting one roost site - Chateau Cave. A large portion of the small bats emerging from Chateau Cave during the October surveys were cautiously identified as PLNB based on body size, fur colour and flight pattern. Observations were supported following a review of the video footage from the survey and review of bat call analysis data.

Table 9 Summary of roost emergence survey results for each site

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
South Star Pool cave complex 22/08/2020 S – 5:50 pm, E – 8:30 pm Civil Twilight = 6:11 pm	Cave 1	6:10 6:11 6:16 6:17 6:24 6:33 6:46	1 x Small 1 x Small 1 x Medium 1 x Small 3 X Medium 1 x Medium 1 x Small	Not completed	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat 2 x Common Sheathtail in cave 5:57 pm Total number bats = 9 No Ghost Bat No bats entered cave during survey	No detector at Cave 1. Bat detector pla.ced at pool below dry waterfall (sm4u4) First PLNB call at approximately 6:33 (c. 22 mins past Civil Twilight (CT) from detector near pool. Majority of bat call activity attributed to Finalysons Cave Bat and Common Sheathtail Bat. No Ghost Bat calls. Vibrations and noise from blasting very obvious from site at c. 4:55 pm before emergence survey commenced.
	Cave 2	6:13 6:20 6:25 6:25	1 x Medium 1 x Medium 4 x Medium 1 x Medium	Not completed	Total number bats = 7 No Ghost Bat No bats entered cave during survey	No detector
	Cave 3	6:15 6:48 7:09 7:09 7:17	2 x Small 1 x Medium 1 x Medium 2 x PLNB (possible) 1 x small bat	Not completed	Total number bats = 7 No Ghost Bat No bats entered cave during survey Although 2 possible PLNB were observed exiting the cave at 7:09 pm the ultrasonic data does not support this finding.	Bat detector placed at entrance of Cave 3 (bdu18, sm4u2) First bat call from Cave 3 – Finlaysons Cave bat at 6:13 pm c. 2 mins past CT), PLNB at 6:43 pm (c. 32 mins past CT) No Ghost Bat calls recorded for this site during emergence survey Majority of bat call activity attributed to Finalysons Cave Bat and Common Sheathtail Bat.
	South flank cave	6:00 6:05	3 x Medium, 1 x Small 5 x Medium, 1 x Small	Not completed	2 x Common Sheathtail and 1 x Finlaysons Cave Bat cave 5:25 pm 1 x possible Ghost Bat 'chirp' call heard from inside cave – however was brief. No Ghost Bat observed, however c. 5 old	Bat detector placed at entrance of cave (bdu17, sm4u1) First bat call – Finlaysons Cave bat at 5:30 pm c. 41 mins before CT),

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
					Ghost Bat scat some with fur inside cave with large dome roof Total number bats = 8 No bats entered cave during survey	PLNB at 7:37 pm (> 70 mins past CT) No Ghost Bat calls recorded for this site during emergence survey Majority of bat call activity attributed to Finalysons Cave Bat and Common Sheathtail Bat.
South Star Pool cave complex 8/9/2020 S – 5:40 pm, E – 8:20 pm Civil Twilight = 6:15 pm	Cave 1	6:05 6:15 6:20 6:35	2 x Small 1 x Medium Ghost Bat Possible Ghost Bat	Not completed	1 x Ghost Bat observed flying in front of cave amongst River Red Gums near pool 6:20 pm 1 x Ghost Bat observed flying in front of caves 1-3 6:35 pm Total number bats = 3 No Ghost Bat observed exiting cave Inspected. No sign of Ghost Bat including scat or feeding	Detector not used for survey
	Cave 2	6:29	4 x Medium	Not completed	1 x PLNB observed hawking in front of caves 1-3 6:25 pm Total number bats = 4 No Ghost Bat observed exiting cave	
	Cave 3	6:01	2 x Medium	Not completed	Total number bats = 2 No Ghost Bat observed exiting cave	
	Cave 5		Not included	Not included	Inspected from entrance after emergence and appears shallow, occupied by 10 Common Sheathtail Bat Lots of small bat possibly Common Sheathtail Bat scat. No sign of Ghost Bat including scat or feeding.	

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
Chateau Cave 9/9/2020 S – 5:30 pm, E – 7:40 pm Civil Twilight = 6:16 pm	Main entrance	6:26 6:30 6:35	19 x Medium 17 x Medium/small 15 x PLNB (possible)	Not completed	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat 1 x possible Ghost Bat 'squabble' heard at 7:35 from outside cave Total number bats = 51 No Ghost Bat observed	Bat detector placed c. 1 m into passage from entrance of Chateau Cave (bdu15, sm4u4) NOTE: detector also used for in situ monitoring First bat call – Common Sheathtail Bat at 5:00 pm c. 76 mins before CT), PLNB at 5:01 pm (c. 75 mins before CT) Majority of calls between sunset (5:57 pm) and CT (6:16 pm) identified as Common Sheathtail or Finlaysons Cave Bat with few PLNB calls. Majority of calls from CT onwards for c. 45 mins identified as PLNB. No Ghost Bat calls recorded for this site during emergence survey using detectors
Chateau Cave 23/10/2020 S – 5:50 pm, E – 7:40 pm Civil Twilight = 6:30 pm	Main entrance	6:25	4 x small	2 x small	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat First bat small at 6:27 pm 6:28, 2 x possible PLNB flew out then into cave Total number bats out = 153 Total number bats in = 23 No Ghost Bats Dark night. Moon is half but behind cave so could not see moon from entrance.	1 x bat detector placed c. 1 m into passage from entrance of Chateau Cave (bdu21, smm4_455) 1 x bat detector placed c. 2 m from entrance of Chateau Cave (bdu20, smm4_456) First bat call – Common Sheathtail Bat at 5:58 pm bdu21 c. 32 mins before CT), PLNB at 6:28 pm bdu21 (c. 2 mins before CT) 6:35 pm bdu20 (c. 5 mins past CT). Majority of calls between sunset (6:10 pm) and CT (6:30 pm) identified as Common Sheathtail or Finlaysons Cave Bat with few PLNB calls. Majority of calls from
		6:30	1 x small	0		
		6:35	25 x small/medium (possibly PLNB)	2 x small		
		6:40	36 x small/medium (possibly PLNB)	3 x small/medium		
		6:45	36 x small/medium (possibly PLNB)	4 x small/medium		
		6:50	14 x small (possibly PLNB)	0		
		6:55	9 x small	0		
		7:00	6 x small/medium	2 x medium		
		7:05	4 x small/medium	0		
		7:10	13 x small (possibly PLNB)	5 x small/medium		

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
		7:15	5 x small	2 x small		CT onwards for c. 45 mins identified as PLNB. No Ghost Bat calls recorded
		7:20	0	0		
		7:25	0	3 x medium		
		7:30	0	0		
Joes Cave 24/10/2020 S – 5:50 pm, E – 7:40 pm Civil Twilight = 6:31 pm	Single main entrance	6:25	0	0	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat First bat small at 6:30 pm 6:28, 2 x possible PLNB flew out then into cave, however post survey bat call analysis did not support this observation Total number bats out = 66 Total number bats in = 10 No Ghost Bats observed Waxing gibbous moon at 70-80% - however mostly dark for survey, some clouds building	1 x bat detector placed c. 7 m into passage from entrance of Joe's Cave (bdu25, sm41u1) 1 x bat detector placed c. 5 m from entrance of Joes Cave (bdu28, smm4_455) First bat call – Common Sheathtail Bat at 5:41 pm bdu25 c. 51 mins before CT), PLNB at 6:43 pm bdu25 (c. 12 mins past CT) 6:53 pm bdu28 (c. 22 mins past CT). Majority of calls between sunset (6:11 pm) and CT (6:31 pm) identified as Common Sheathtail or Finlaysons Cave Bat. The majority of PLNB calls were recorded from c 12 mins past CT onwards. No Ghost Bat calls recorded for this site during emergence survey
		6:30	4 x small/medium	2 x small/medium		
		6:35	26 x medium	0		
		6:40	10 x medium	0		
		6:45	2 x medium	2 x small		
		6:50	14 x small/medium (possibly PLNB)	5 x small/medium		
		6:55	10 x small (possibly PLNB)	1 x small		
		7:00	0	0		
		7:05	0	0		
		7:10	0	0		
		7:15	0	0		
		7:20	0	0		
		7:25	0	0		
		7:30	0	0		
Cave 13 26/10/2020 S – 5:50 pm, E – 7:40 pm Civil Twilight = 6:31 pm	Main chamber entrance, east passage	6:25	0	0	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat First bat small at 6:31 pm Total number bats out = 10 Total number bats in = 5 No Ghost Bats observed Waxing moon bright	1 x bat detector placed in front of main chamber entrance of Cave 13 (bdu31, sm2u1). NOTE: detector also used for insitu monitoring 1 x bat detector placed at front of overhang entrance of Cave 13 (bdu27, smm4_455) First bat call – Little Broad-nosed Bat at 6:11 pm bdu28 c. 20 mins
		6:30	10 x small	5 x small		
		6:35	0	0		
		6:40	0	0		
		6:45	0	0		
		6:50	0	0		
		6:55	0	0		
		7:00	0	0		

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
		7:05	0	0		before CT), PLNB at 10:11 pm bdu27 (c. 5+ hours past CT). PLNB not recorded by bdu28. No Ghost Bat calls for either detector. Other species recorded – Common Sheathtail Bat and Finlaysons Cave Bat during period between sunset (6:11 pm) and CT (6:31 pm) and past CT.
		7:10	0	0		
		7:15	0	0		
		7:20	0	0		
		7:25	0	0		
		7:30	0	0		
	Central passage / western passage	6:25	0	0	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat First bat small at 6:31 pm Total number bats out = 4 Total number bats in = 5 No Ghost Bats	As above.
		6:30	3 x small	2 x small		
		6:35	0	0		
		6:40	1 x small	0		
		6:45	0	0		
		6:50	0	0		
		6:55	0	0		
		7:00	0	0		
		7:05	0	0		
		7:10	0	0		
		7:15	0	2 x small		
		7:20	0	0		
		7:25	0	0		
		7:30	0	0		
South Star Pool cave complex 28/10/2020 S – 5:40 pm, E – 7:40 pm Civil Twilight = 6:32 pm	Cave 1	6:15	1 x small	0	Small bat = Finlaysons Cave Bat/Small Broad-nosed Bat or PLNB, Medium bat = Common Sheathtail Bat First bat at 6:20 pm Total number bats out = 5 Total number bats in = 4 No Ghost Bats	No detector placed at cave
		6:20	2 x small	1 x small		
		6:25	1 x medium	1 x medium		
		6:30	0	0		
		6:35	1 x small	0		
		6:40	0	1 x small		
		6:45	0	1 x small		

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
		6:50	0	0	Dark night. Moon nearly full but dark in gorge. High bat activity in areas with lots flying but not coming from cave 1, 2 or 3	
		6:55	0	0		
		7:00	0	0		
		7:05	0	0		
		7:10	0	0		
		7:15	0	0		
		7:20	0	0		
	Cave 2	6:15	0	0	Small bat = Small and/or PLNB, Medium bat = Common Sheathtail Bat First bat at 6:20 pm Total number bats out = 7 Total number bats in = 2 No Ghost Bats observed	1 x bat detector placed just inside entrance of Cave 2 (bdu32, smm4_456) First bat call – Finlaysons Cave Bat Little Broad-nosed Bat at 6:15 pm c. 17 mins before CT, PLNB at 6:50 c. 18 mins past CT). No Ghost Bat calls recorded for this site during emergence survey Species recorded – Common Sheathtail Bat and Finlaysons Cave Bat during period between sunset (6:11 pm) and CT (6:32 pm) and past CT.
		6:20	0	1 x small		
		6:25	0	0		
		6:30	2 x small	0		
		6:35	0	1 x medium		
		6:40	4 x small/medium	0		
		6:45	1 x medium	0		
		6:50	0	0		
		6:55	0	0		
		7:00	0	0		
		7:05	0	0		
		7:10	0	0		
		7:15	0	0		
		7:20	0	0		
	Cave 3	6:15	0	0	Small bat = Small and/or PLNB, Medium bat = Common Sheathtail Bat First bat at 6:20 pm Total number bats out = 7 Total number bats in = 2 No Ghost Bats observed	1 x bat detector placed just inside entrance of Cave 3 (bdu33, sm41u2) NOTE: detector also used for insitu monitoring 1 x bat detector placed c. 3 m from entrance of Cave 3 (bdu35, smm4_455) First bat call – Common Sheathtail Bat and Finlaysons Cave Bat at 6:15 pm both detectors c. 17 mins before CT), PLNB at 7:02 pm
		6:20	5 x small	1 x small		
		6:25	1 x medium	0		
		6:30	1 x small	0		
		6:35	0	1 x medium		
		6:40	0	0		
		6:45	0	0		
		6:50	0	0		
		6:55	0	0		

Site, date, start, end	Entry/Exit	Time (pm)	Count out observation	Count in observation	Bat movement observations and notes	Summary of bat detector call analysis
		7:00	0	0		bdu35 (c. 30 mins past CT). PLNB not recorded by bdu33. No Ghost Bat calls recorded for this site during emergence survey Majority of calls between sunset (6:11 pm) and CT (6:32 pm) identified as Common Sheathtail or Finlaysons Cave Bat.
		7:05	0	0		
		7:10	0	0		
		7:15	0	0		
		7:20	0	0		

3.2.3 Bat call analysis

In situ ultrasonic bat detectors recorded bat calls from 27 sites for 178 nights and c. 1958 hours survey effort. In situ acoustic recorders were placed at three sites for 9 nights for c. 108 hours survey effort. The location of each ultrasonic detector and acoustic recorder site is provided in Appendix B and displayed on Figure 4. Appendix B consolidates the survey findings for each night at each site.

Nine bat species were identified from 377,837 wav files (see Appendix B). The Common Sheathtail Bat and Finlayson's Cave Bat were the most commonly recorded species (171 nights / 24 sites and 173 nights / 24 sites respectively). Other species identified from analysis include Pilbara Leaf-nosed Bat, Ghost Bat, Greater Northern Freetail-bat (*Chaerophen jobensis*), Gould's Wattled Bat (*Chalinolobus gouldii*), Yellow-bellied Sheath-tailed Bat (*Saccolaimus flaviventris*), White-striped Mastiff Bat (*Austronomus australis*), Little Broad-nosed Bat (*Scotorepens greyii*).

Pilbara Leaf-nosed Bat

PLNB was recorded for 150 of the 178 detector nights, from 22 of the 27 in situ ultrasonic survey sites. Table 10 provides a summary of the PLNB calls detected at each site for each night of the survey. The presence of PLNB at nearly all sites for the majority of survey nights demonstrates the importance of the survey area to the species. Sites with consecutive nights of activity, particularly moderate and high activity nights, were noted to be of particularly high value.

PLNB calls were recorded within 20 mins of civil twilight near dusk (CT PM) for 15 nights at five locations including Chateau Cave (see Table 10 and Table 11). Of particular interest are records from the South Star Pool complex, Joe's Cave and Python Cave (Table 11):

- South Star Pool (cave3) - the timing of records (e.g. some within 10 and 15 mins of CT PM) with some records occurring over consecutive nights suggests that the PLNB may have been using cave 3 of the South Star Pool cave complex as a diurnal roost for up to 6 nights of the survey period. The detector was placed at the entrance or just inside the entrance (pending date of survey), therefore it is more than likely that the records originated from inside the roost, and not from Chateau Cave, located approximately 2.4 km north of the site
- Joe's Cave – the timing of records (e.g. some within 15 mins of CT PM) with some records occurring over consecutive nights suggests that the PLNB may have been using Joe's Cave as a diurnal roost for up to 4 nights of the survey period. The detector was placed at the entrance of the cave; therefore, it is more than likely that the records originated from inside the roost, and not from Chateau Cave, located approximately 8 km east of the site
- Python Cave – the timing of records and positive confirmation of roosting bats during August demonstrates PLNB were using Python Cave as a diurnal roost for up to 3 nights during the survey period. As the detector was placed just inside the entrance, it is more than likely that the records originated from inside the roost, and not from Chateau Cave, located approximately 4.1 km north of the site.

Chateau Cave and the Pilbara Leaf-nosed Bat

Chateau Cave has been the subject of a long-term acoustic monitoring study for the PLNB. The most recently analysed partly continuous long-term acoustic monitoring survey (over 3 years from 2016-2018) revealed a number of important findings (see Specialised Zoological 2018) including:

- PLNB regularly emerged from the Chateau Cave roost within 20 minutes of dusk each night

- Regular activity within the roosting chamber of the cave was recorded throughout the night for most nights of the survey indicating that the chamber was probably used for roosting during the night
- For the majority of nights, peak activity was recorded just after dusk/early evening and then again later in the morning indicating a pattern of emergence following dusk and reoccupation prior to sunrise.

Detector surveys undertaken for 14 nights during November and December of 2019 within Chateau Cave (GHD 2020b) also revealed the same key findings and supported PLNB were using the cave as a diurnal roost.

Analysis of data from the August, September and October 2020 survey periods (Table 10) has revealed the PLNB was utilising the cave as a diurnal roost for the entire survey period. For most nights PLNB calls were recorded from the main chamber at least 10 minutes prior to civil twilight (dusk) and often 10 minutes or more post-civil twilight (dawn), meaning the species was inside the cave during daylight hours (see Table 10, Graph 1 and Graph 2). Data from the current survey also supports the historical findings including regular activity throughout the night, peak activity just after dusk into the early evening and again in the late morning and a pattern of emergence following dusk and reoccupation prior to sunrise. The detector for this roost was placed at least 2 m into the passage from the entrance to the cave, whereas previous long-term monitoring was undertaken using a microphone placed just inside the main chamber. Results are therefore similar but should not be directly compared because of the differences in detector type and position. This analysis of data reinforces the categorisation of this roost as a ‘permanent diurnal roost’ and is consistent with the findings of past monitoring events.

Table 10 Summary of PLNB activity and first detections for each insitu site for each night 2020

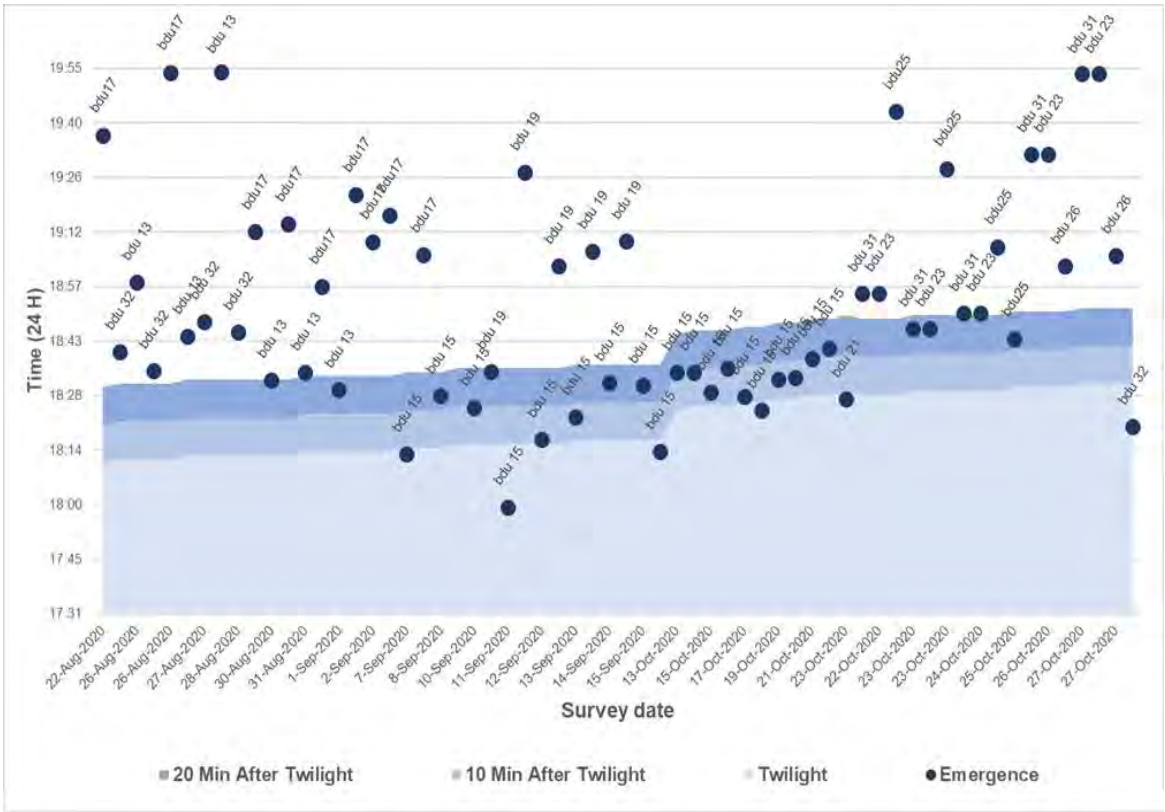
Site	Location	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
bdu1	-	May																															
bdu3	-	May																															
bdu4	-	May																															
bdu5	-	May																															
bdu6	-	May																						#									
bdu8	-	May																															
bdu9	SSPcave1	May																															
bdu11	SSPcave3	May																						#									
bdu13	Joe's	Aug																														#	#
bdu15	Chateau	Aug																							#	#	#	#	#	#	#	#	#
bdu17	SSPcave5	Aug																															
bdu18	SSPcave3	Aug																															#
bdu32	SSPcave2	Aug																															
bdu13	Joe's	Sept	#																														na
bdu14	-	Sept																															na
bdu15	Chateau	Sept	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#															na
bdu17	SSPcave5	Sept																															na
bdu18	SSPcave3	Sept	#		#		#	#																									na
bdu19	Python	Sept											#		#																		na
bdu13/25	Joe's	Oct																									#						
bdu15	Chateau	Oct													#	#	#	#	#	#	#	#	#	#	#								
bdu17	SSPcave5	Oct																															
bdu18	SSPcave3	Oct																															
bdu22	-	Oct																															
bdu23	FigPool	Oct																						#	#								
bdu26	Pool12	Oct																															
bdu30	Wallaby	Oct																															
bdu31	Cave13	Oct																															
bdu34	-	Oct																															

	grey square indicates absence of PLNB or extremely low detection rates within limitations (see section 2.2.5). blank squares = no survey effort
L	blue square indicates low PLNB activity (e.g. <10 calls per hour, less than 50 calls per night)
M	green square indicates moderate PLNB activity (e.g. > 10 - < 20 calls per hour, > 50 - < 200 calls per night)
H	red squares indicate high PLNB activity (e.g. > 20 calls per hour, > 200 calls per night throughout the night)
#	indicates detection of Pilbara Leaf-nosed Bat within 20 minutes of civil twilight PM (+/- 1 min)

Table 11 Summary of PLNB calls within 20 mins of CT

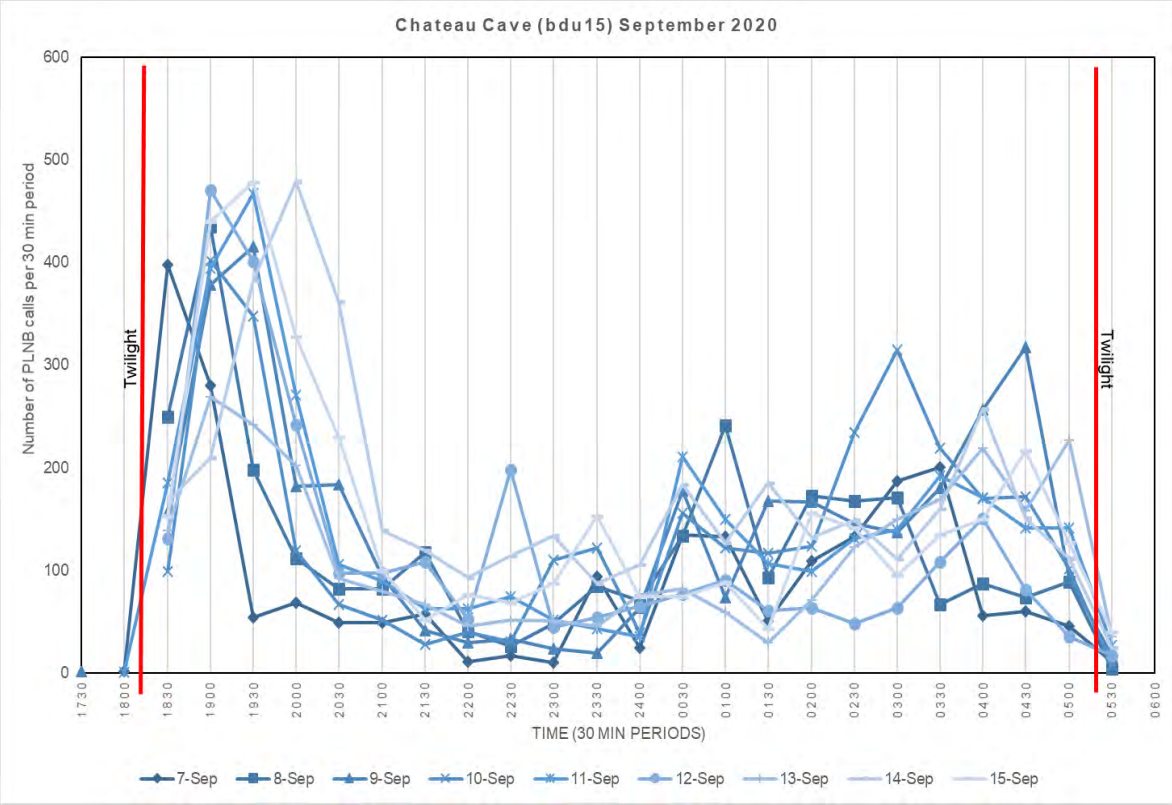
Site name/ location	Date	Sunset Civil Twilight	Time of first PLNB	Comments
bdu6 (located c. 30 m west of Python Cave in same gully)	22/05/2020	5:51:00 PM	5:55:00 PM	1 night from 3 nights of consecutive monitoring May 2020. Note last PLNB call recorded morning of the 21/5 at 5:49 am, C. 11 mins before CT AM at 6:01 am. Low activity (< 5 calls) each night.
bdu19 Python Cave	10/09/2020 13/09/2020	6:16:00 PM 6:17:00 PM	6:35:00 PM 6:35:00 PM	2 consecutive nights from 15 nights monitoring in Sept and Oct 20. Detector placed just inside roost entrance. Small cluster of 3 PLNB observed inside roost by GHD 10/9/20 (see GHD 2020b). Moderate levels of activity each night with late morning /dawn PLNB calls for the 11/9 (5:50 am), 14/9 (5:41 am), 15/9 (5:43 am).
bdu13 / bdu25 Joe's Cave	30/08/2020 ***31/08/2020*** ***1/09/2020*** 25/10/2020	6:13:00 PM ***6:14:00 PM*** ***6:14:00 PM*** 6:31:00 PM	6:32:00 PM ***6:34:00 PM*** ***6:30:00 PM*** 6:43:00 PM	3 consecutive and 1 non-consecutive nights from 15 nights monitoring during, Aug, Sept, Oct 20. Some first calls within 10 and 15 mins of CT ending. Low levels of activity each night with late morning near dawn PLNB calls for morning of the 29/8 (5:25 am), 31/8 (5:25 am).
bdu18 / bdu 11 SSP cave3	22/05/2020 ***31/08/2020*** ***1/09/2020*** 3/09/2020 5/09/2020 6/09/2020	5:51:00 PM ***6:14:00 PM*** ***6:14:00 PM*** 6:14:00 PM 6:15:00 PM 6:15:00 PM	6:12:00 PM ***6:33:00 PM*** ***6:24:00 PM*** 6:34:00 PM 6:31:00 PM 6:29:00 PM	Consecutive and non-consecutive nights from 41 nights monitoring during, Aug, Sept, Oct 20. Some first calls within 10 and 15 mins of CT PM ending. Moderate to high levels of activity each night with late morning near dawn PLNB calls for the 23/8 (5:36 am), 24/8 (5:34 am), (25/8 (5:27 am), 29/8 (5:37 am), 1/9 (5:46 am).
bdu23 Fig Pool	23/10/2020 24/10/2020	6:30:00 PM 6:30:00 PM	6:46:00 PM 6:50:00 PM	Two consecutive nights from 3 nights monitoring during Oct. No roosting habitat at site. Located 2.8 km from Chateau Cave.
bdu32 SSP cave2*	28/10/2020	6:32:00 PM	6:52:00 PM	Emergence survey record from detector placed just inside cave entrance. Most likely one off record with only 3 x PLNB records between 6:52 pm and 7:33 pm (end survey). 5 consecutive nights of monitoring in August did not detect any early calls. Cave located within 15 m of cave 3.

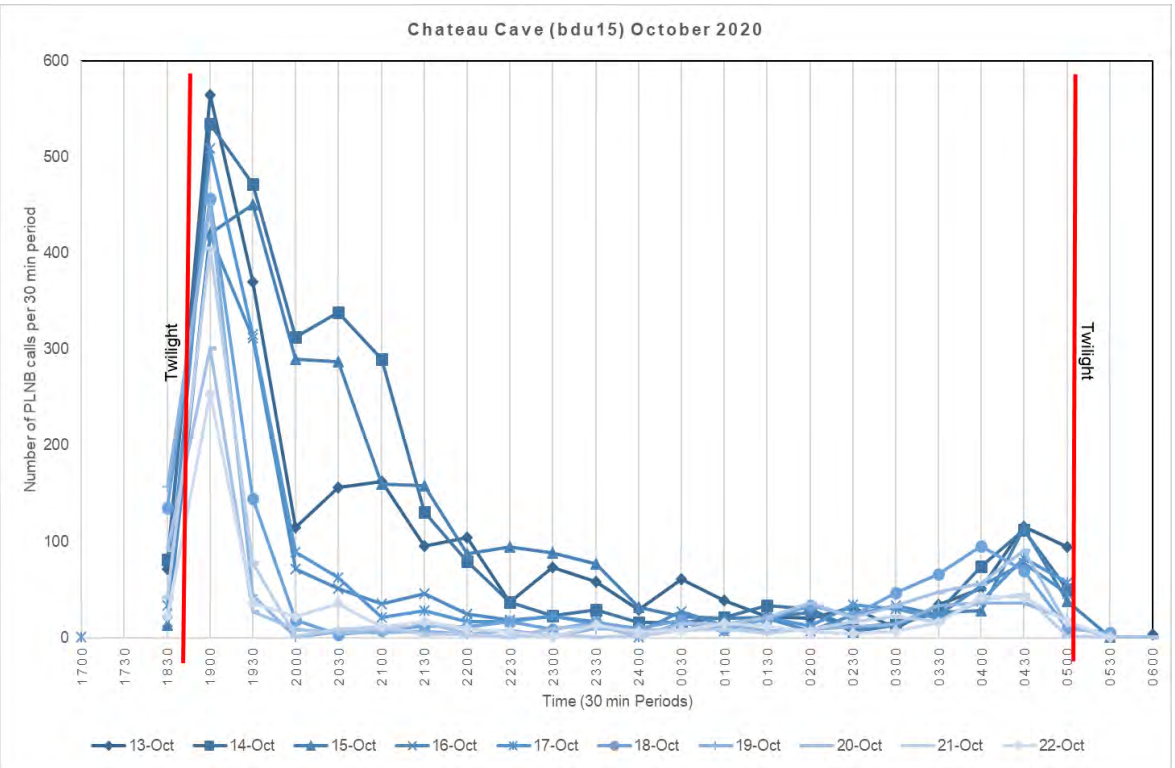
Table note: * indicates emergence survey. Chateau Cave results not included (see Graphs 2 and 3).



Graph 1 Pilbara Leaf-nosed Bat Emergence data - graph displaying the first PLNB call recorded compared to Civil Twilight (CT), 10 mins past CT and 20 mins past CT for each night and site

(NOTE: sites with first call greater than 2 hours past CT not displayed)





Graph 2 PLNB activity for Chateau Cave during September and October survey periods 2020.

Note: calls recorded during both periods prior to civil twilight (CT) PM and after CT AM indicating bats were within the roost during daylight hours. Although patterns of activity varied throughout the night for each survey period, a clear pattern of activity indicating emergence during dusk within 20 mins of CT PM and re-emergence just before dawn (CT AM) is evident for both survey periods.

Ghost Bat

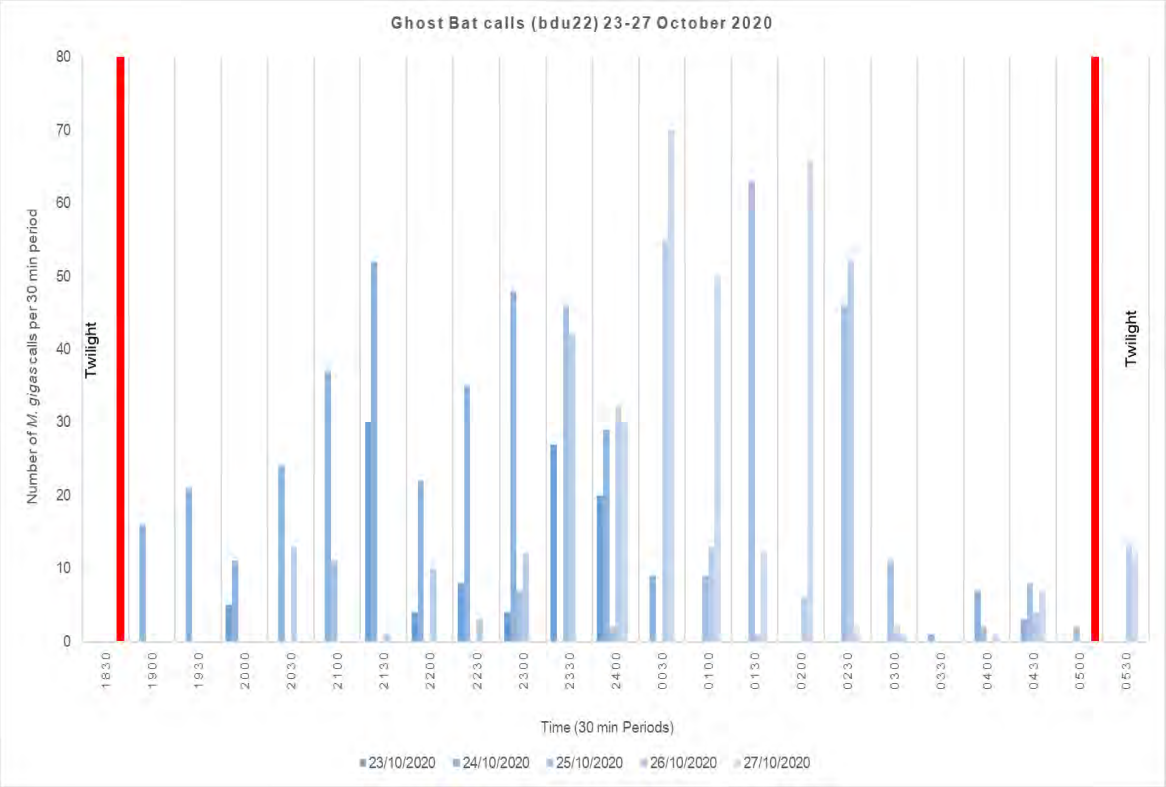
The Ghost Bat was recorded for 14 of the 178 detector nights, from 8 of the 27 in situ ultrasonic survey sites including:

- bdu 22 - located at rha1 (cave), approximately 12 km south of the GVSS survey area
- Python Cave - bdu19
- 30 m west of Python Cave - bdu6
- South Star Pool Complex – cave3 (bdu11) and cave 2 (bdu32)
- Fig Pool - bdu23
- Joes Cave - bdu13
- bdu3 – located approximately 1.3 km south-south-east of Python Cave in a small gully

Appendix B provides a summary of the Ghost Bat calls detected at each site for each night of the survey within the limitations of the analysis. Detection rates were low (between 1-3 nights per site with < 10 calls per night) for 7 of the 8 sites despite targeted survey effort including sampling at historical Ghost Bat sites (e.g. Joes Cave, Python Cave and South Star Pool complex).

Site bdu22 (rha1) recorded Ghost Bat activity for a period of four consecutive nights (Graph 3). Activity comprised of approximately 1131 social (chirp, trill and ultrasonic social) and echolocation calls for the four nights. Call activity patterns suggest mostly nocturnal usage of the roost for this period, although near emergence calls (n=9) were recorded between 7:00-7:05 pm 24/10/20. Calls were also recorded during the dawn period past CT AM for two mornings (26/10, n = 13, and 27/10, n = 12) suggesting diurnal roosting.

Site bdu3 recorded few Ghost Bat calls (all social chirp, n=9 and 1 for the 19/5 and 20/5/20), however first calls for both nights were not long after CT PM (5:52 pm) at 6:14 pm and 6:20 pm.



Graph 3 Ghost Bat activity at bdu22 during October.

Note: Calls recorded near emergence period for one night. Pattern of activity indicates nocturnal use of site, however data for two nights (post CT AM - 26/10 and 27/10/20) suggests diurnal usage. Periods of time without data removed.

3.2.4 Roost habitat survey results and categorisation of roost habitats

GHD investigated approximately 56 locations (e.g. slopes, gorges and near the top of ridges) on foot and/or by helicopter when undertaking searches for potential diurnal roost habitat (Figure 4). The habitat assessment category type (described in Section 2.2.3) applied to each of the locations visited following the analysis of all data to date is displayed on Figures 6 and 7 and described in Table 12 and Table 13 for each of the 56 locations. A summary of key survey results regarding roosting habitat is provided below:

- All sites investigated during 2020 were within the regional survey area. No new sites were investigated within the GVSS survey area. Two sites within the GVSS survey area (Python Cave and South Star Cave complex) and four sites within the regional survey area (Wallaby Cave, Joe's Cave, Bone Cave and Cave 13) were re-visited
- Five of the sites investigated were confirmed as new diurnal roosting (ongoing or occasional use) for the Ghost Bat (see rha1, rha2, rha9, rha10, rha17). No new breeding sites were recorded for the Ghost Bat. See Table 12, Plates 2 – 7 and Appendix A roost habitat assessment locations and results
- At least 10 new sites in addition to the five confirmed sites were determined to provide potential diurnal roosting and foraging habitat for the Ghost Bat. These sites appeared to suitable habitat (e.g. roost size and structure appeared suitable), however due to lack of evidence (e.g. absence of scat, species or other evidence), a category could not be applied
- One new permanent diurnal roost for the PLNB was recorded (rha12) approximately 28 km south-east of Cave 13 and 25.5 km south-east of South Star Pool cave complex. At least nine PLNB were recorded within the roost 26 October 2020 identified by their small size, orange body and dark wings (pers obs R. Browne-Cooper, Senior Zoologist GHD). Furthermore, the number of PLNB recorded, timing of records (i.e. at start of the maternity period), structure and size of roost and long-term ultrasonic monitoring since 2018 suggest the roost may also be important habitat during the breeding cycle of the PLNB. See Plate 8 and Appendix A roost habitat assessment locations and results
- At least 13 other sites were determined to provide potential diurnal roosting habitat for the PLNB. These sites appeared to suitable habitat (e.g. roost size and structure appeared suitable), however due to lack of evidence (e.g. absence of species or other evidence), categorisation could not be applied.

Plate 2 - entrance to rha1

Plate 3 - entrance to rha18

Plate 4 – rha3, top photo overhang and entrance (back bottom left of photo), bottom photo entrance

Plate 5 – rha9, top photo overhang and entrance (middle of photo), bottom photo entrance to chamber behind detector

Plate 6 – rha10, top photo main entrance, bottom photos chamber entrances

Plate 7 – rha10, top photo – Ghost Bat scat in chamber, bottom photo entrance to a chamber

Plate 8 - rha12. Top photo displays SM4 mic orientated toward assumed entrance to roost. Bottom photo, close-up of assumed roost entrance October 2020

Table 12 Summary of roost category records for Ghost Bat during 2020 surveys

Roost type	GVSS survey area	Regional survey area (excludes records from GVSS survey area)
Breeding roost	South Star Pool complex – during the survey no evidence was recorded to suggest this roost was occupied by Ghost Bat.	-
Diurnal roost ongoing use	Python Cave - fresh and historical scat September 2020.	rha1 – c. 10 fresh scat recorded (no historical), foraging evidence, cave size and structural suitable. Calls recorded for four consecutive nights during October 2020 (bdu22). rha9 – 3 x Ghost Bat, fresh and historical scat recorded, cave size and structure suitable rha10 – 1 x Ghost Bat and historical scat recorded, cave size and structure suitable
Diurnal roost occasional use	-	rha2 – cave size and structure suitable, some Ghost Bat scat recorded rha17 – few Ghost Bat scat, cave size and structure suitable rha26 (Bone Cave) – no Ghost Bat, no obvious scat rha25a (Wallaby Cave) – no Ghost Bat, no obvious scat Cave 13 – no evidence of Ghost Bat recorded Wayne Manor – 1 x Ghost Bat observed roosting during May 2021 (pers comm, Erin Westerhuis GHD ecologist 2021)
Potential diurnal roost – unknown category	-	rha5, rha6, rha7, rha12, rha18, ha6, ha27, rha25b, ha28
Nocturnal/feeding refuge	-	14 sites
Potential habitat	-	16 sites

Table 13 Summary of roost category records for PLNB during 2020 surveys

Roost type	GVSS survey area	Regional survey area (excludes records from GVSS survey area)
Permanent diurnal / non-permanent breeding roost	Chateau Cave - see emergence data (2.2.4) and bat call analysis (3.3.3)	rha12 - 10 x PLNB observed within roost. Log book reviewed in detector box at site revealing history of long-term monitoring since 2018. Since confirmed as a permanent diurnal roost following discussion between FMG and Atlas (May 2021)
Transitory diurnal roost	Python Cave - 3 x PLNB observed roosting September 2020, bat call data suggests diurnal and nocturnal usage. Approximately 3 individuals observed during May of 2021 (pers comm Erin Westerhuis GHD ecologist) South Star Pool complex – bat call data suggests diurnal and nocturnal usage (3.3.3)	Joe's Cave – bat call data indicates diurnal usage - see bat call analysis data Cave 13 – bat call data suggests nocturnal usage (3.3.3)
Potential diurnal roost – unknown category	-	rha2, rha3, rha5, rha6, rha10, rha7, rha17, rha18, rha25b rha26, ha6, ha27, ha28
Nocturnal refuge	-	12 sites
Potential habitat	-	15 sites

3.3 Habitat modelling

The distribution of potential roosting and foraging habitat for the PLNB and Ghost Bat was mapped (Figure 8) according to the process described in Section 2.1.2. Table 14 provides a summary of the extent of each habitat type with the survey area according to the habitat descriptions.

There is approximately 1982 ha of habitat type 1 within the GVSS survey area for both species of which approximately 61,812 ha occurs within the regional survey area. Habitat type 1 includes priority 1 (gorges with pools, watercourses in upland areas) and priority 3 (areas of exposed rock at top of rocky outcrops and mesa hills that contain caves and overhangs) habitat types. Both habitat types are conducive to cave and overhang formations which provide roosting and refuge opportunities for both species.

As is evident from viewing Figure 8 there is a strong relation between the distribution of known and potential roost locations and nocturnal refuge/feeding locations (see section 3.2.4) and the distribution of the priority 3 component of Habitat type 1, particularly where it is adjacent to the priority 1 component of habitat type 1. However, the modelled extent of habitat type 1 or 2 should be not relied on as a quantitative estimate of the availability of potential roosting habitat for both species as the modelling does not allow for the specific habitat requirements for each species at different times of year (e.g. breeding and non-breeding periods). As previously discussed, the requirements for each type of roost for each species (e.g. breeding roost compared to a temporary/occasional use diurnal roost and nocturnal refuge) is very different and cannot be incorporated into this form of modelling process. This is most evident where known nocturnal refuge habitat has been recorded alongside or nearby a known diurnal roost (e.g. west of Joes Cave) and is modelled under the same habitat type. However, based on the apparent correlation between the habitat modelling and field survey data, there is a high likelihood that additional roost habitat (of any type including nocturnal refuge habitat) could be located within the priority 3 areas of habitat 1, particularly areas adjacent to priority 1 habitat type 1 and priority 2 habitat type 2 locations.

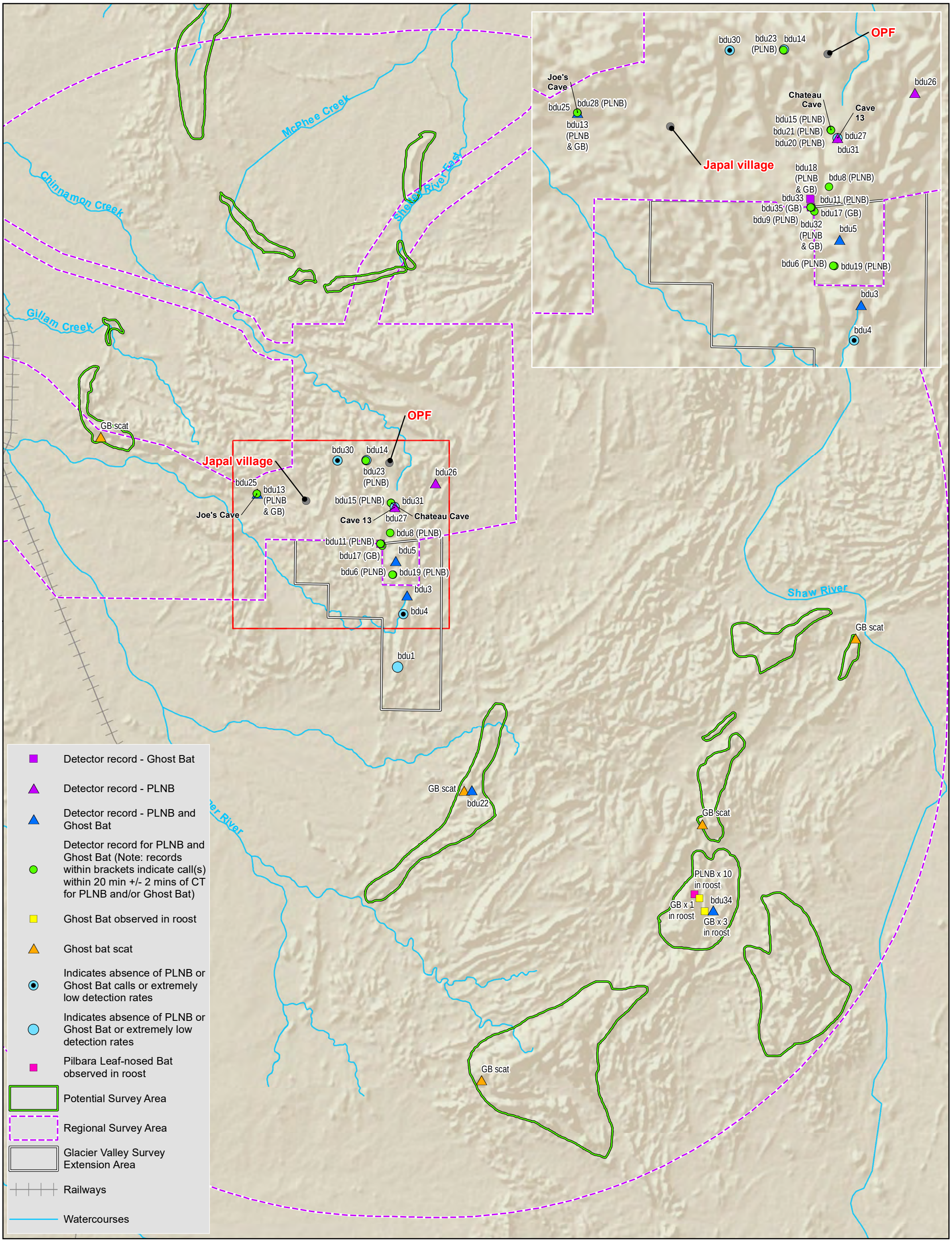
The distribution of records collected to date for the Ghost Bat and Pilbara Leaf-nosed Bat and information regarding the habitats and movements of both species in the nearby North Star area (e.g. recent radio-tracking studies of the PLNB), was also used to assist with understanding the extent of foraging habitat within the GVSS survey area. 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 GVSS survey area is used as foraging habitat by both the Ghost Bat and Pilbara Leaf-nosed Bat.

Table 14 Extent of each habitat type within regional survey area

Habitat Type	1. Regional survey area (including live FMG tenement) (ha)	1. Regional survey area including live FMG tenement (Area %)	2. Regional survey area excluding FMG live tenements (ha)	2. Regional survey area excluding live FMG tenements (Area %)	3. Existing live FMG tenement (ha)	3. Area % of regional area	4. North Star MDA (ha)	4. Area % of regional area (1)	5. Glacier Valley Survey Area (ha)	5. Area % of regional area (1)
Habitat Type 1 (Priority 1) – gorges with pools in upland areas, sometimes with caves	21677.11	5.54%	18813.59	5.53%	2863.52	13.21%	2317.97	10.69%	710.85	3.28%
Habitat Type 1 (Priority 3) – rocky outcrops areas of exposed rock at top of rocky outcrops and mesa hills that contain caves and overhangs	48134.85	12.30%	42117.03	12.39%	6017.83	12.50%	5054.65	10.50%	1271.02	2.64%
Habitat Type 2 (Priority 2) – gullies with primary drainage with limited riparian development in upland rocky habitats	456.13	0.12%	416.63	0.12%	39.51	8.66%	20.69	4.54%	18.81	4.12%
Habitat Type 3 (Priority 4) – major watercourses with riparian vegetation on flat land plus main gravelly or sand channel of the river bed	14153.17	3.62%	12792.84	3.76%	1360.33	9.61%	1903.48	13.45%	41.40	0.29%
Habitat Type 4 (Priority 5) – open grassland woodland, dominated by Triodia, on lowland plains colluvial slopes and hilltops.	306980.13	78.43%	265867.12	78.19%	41113.01	13.39%	36203.17	11.79%	3425.50	1.12%
Habitat type total area (ha)	**391401.39**		**340007.20**		**51394.20**		**45499.97**		**5467.58**	
Actual total area (ha)	391605.43		340206.29		51399.14		45505.45		5467.58	
Spatial error (ha)	204.04		199.09		4.95		5.49			

Table notes: spatial error most likely due to overlapping data boundaries, undescribed habitat areas (e.g. roads, developed areas etc).

The above calculations do not take into account all forms of development (non-habitat) area with the regional survey and are therefore considered to overestimate each of the habitat types by at least the area represented by the spatial error.



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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Fortescue Metals Group Ltd

Job Number	12528008
Revision	0
Date	24 Dec 2020

Survey results – bat detector and species records Figure 5

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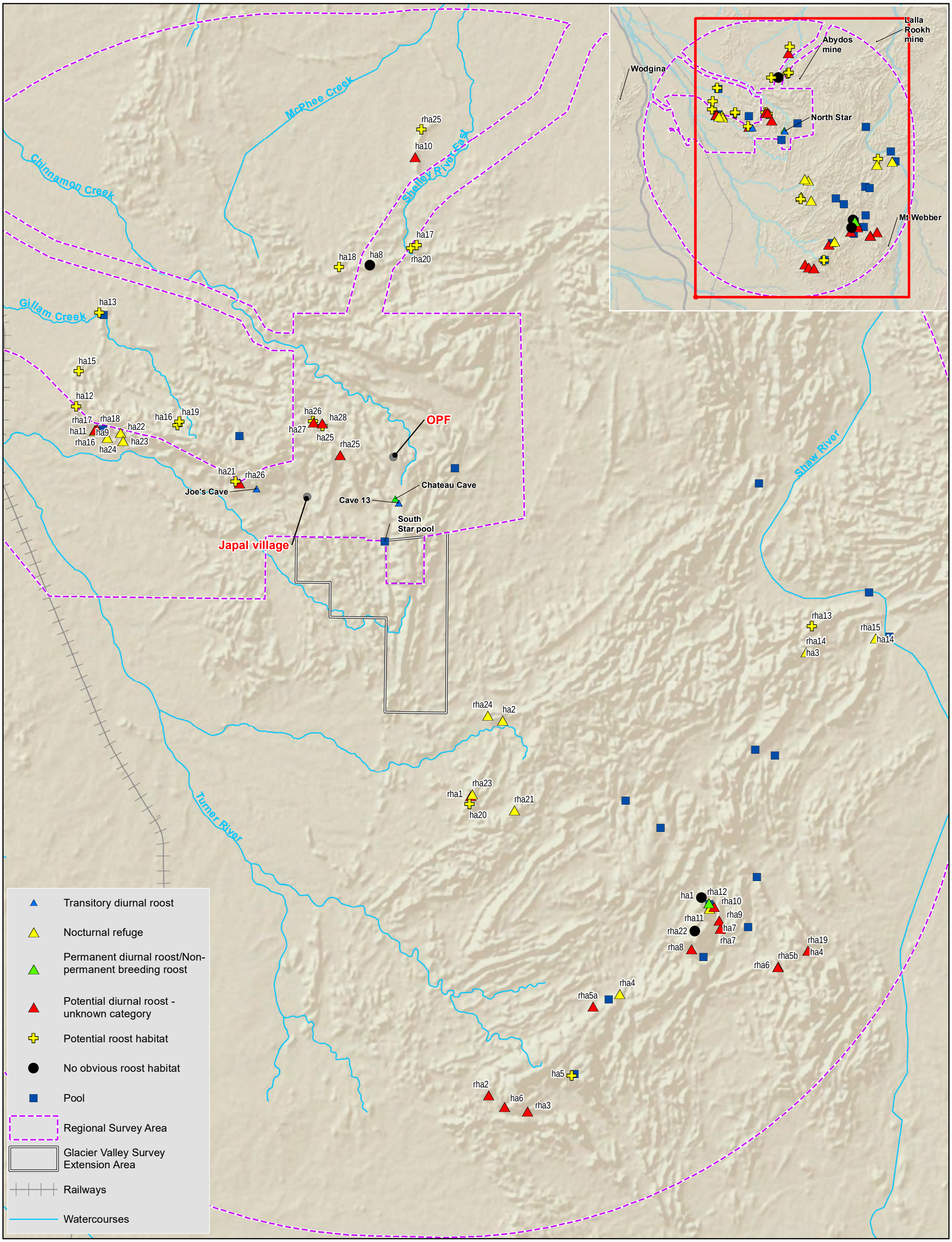
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS



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Roost habitat field results (Pilbara Leaf-nosed Bat)

Job Number	12528008
Revision	0
Date	24 Dec 2020

Figure 6

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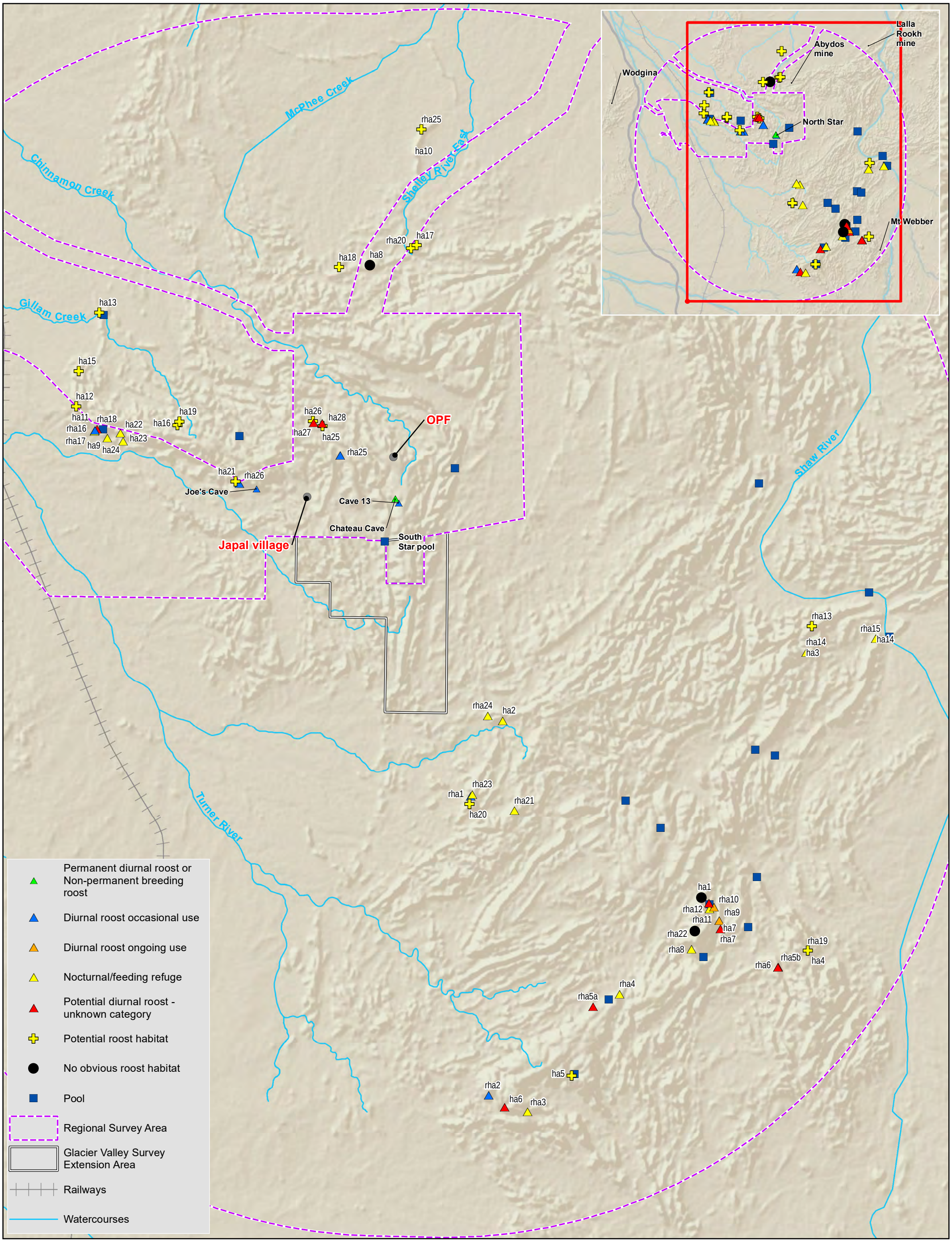
999 Hay Street Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS



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

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Fortescue Metals Group Ltd

Roost habitat field results (Ghost Bat)

Job Number	12528008
Revision	0
Date	24 Dec 2020

Figure 7

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

Data source: FMG: Bat Cave 13 - 20141007; GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS

Note: Data sourced from Figure 6 and 7

- Potential diurnal roost - unknown category
- Transitory diurnal roost
- Permanent diurnal roost or Non-permanent breeding roost
- Nocturnal refuge
- Pool
- Artificial pool
- Natural pool

Great Northern Hwy

Tank pool

Pool 1 BS
Pool 2 BS
Pool 3 BS
Nicko's Gorge pool (x2)
Craig's pool
Zane's Gorge pool (x2)
Dingo Lair pool
Joe's Cave
Japal village

Fig pool
Artificial pool
Artificial pool
OPF
Artificial pool
Artificial pool
Pool 12
Chateau Cave
Cow pool
Artificial pool
South Star pool
South Star pool

Great Northern Hwy

Great Northern Hwy

- Regional Survey Area
- Glacier Valley Survey Extension Area
- Railways
- Major Roads
- Habitat Type 1 (Priority 1)
- Habitat Type 1 (Priority 3)
- Habitat Type 2 (Priority 2)
- Habitat Type 3 (Priority 4)
- Habitat Type 4 (Priority 5)

Habitat Type 1 = 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
Habitat Type 1 = 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
Habitat Type 2 = 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
Habitat Type 3 = Major Watercourses (Priority 4) – 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.
Habitat Type 4 = Open Grassland and woodland (Priority 5) – dominated by Triodia, on lowland plains colluvial slopes and hilltops.

Paper Size A3

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Kilometres

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

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Fortescue Metals Group Ltd

Job Number	12528008
Revision	0
Date	25 May 2021

Bat habitat and roost

Figure 8

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

Data source: GHD: Proposed Mine Development Area and Associated Infrastructure, Study Area - 20160927; Geoscience Australia: GeoData Topo 250k Series III. Created by: BS

4. References

Armstrong, K. N., & Anstee, S. D. (2000). The ghost bat in the Pilbara: 100 years on. Australian Mammalogy 22, 93-101.

Armstrong, K. N. (2011). The current status of bats in Western Australia. In: 'The biology and conservation of Australasian bats.' (Eds B. Law, P. Eby, D. Lunney and L. Lumsden.) pp. 257–269. (Royal Zoological Society of New South Wales: Mosman.)

Armstrong, K. N., and Coles, R. B. (2007). Echolocation call frequency differences between geographic isolates of Rhinonicteris aurantia (Chiroptera: Hipposideridae): implications of nasal chamber size. Journal of Mammalogy 88, 94-104.

Augusteyn John, Hughes Jane, Armstrong Graeme, Real Kathryn, Pacioni Carlo (2017) Tracking and tracing central Queensland's Macroderma – determining the size of the Mount Etna ghost bat population and potential threats. Australian Mammalogy 40, 243-253.

Bat Call WA (2013). Fortescue Metals Group North Star Project, Pilbara leaf-nosed bat colony survey, April 2013. Unpublished report by Bat Call WA Pty Ltd for Fortescue Metals Group Ltd, 18 July 2013.

Bullen, R. D. and McKenzie, N. L. (2011). Recent developments in studies of the community structure, foraging ecology and conservation of Western Australian bats. In 'The biology and conservation of Australasian bats.' (Eds B. Law, P. Eby, D. Lunney and L. Lumsden.) pp. 31-43. (Royal Zoological Society of New South Wales: Mosman.)

Brown, W. B. Scroggie, M. P and Choquenot, D. (2008) Precision and accuracy counts of the common bent-wing bat (Miniopterus schreibersii). Acta Chiropterologica, 10(1): 145-151.

Churchill, S (2008). Australian Bats, Allen and Unwin, Australia.

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

Department of Agriculture, Water and Environment (2020a). Rhinonicteris aurantia (Pilbara form) in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: Rhinonicteris aurantia (Pilbara form) — Pilbara Leaf-nosed Bat (environment.gov.au) accessed November 16 2020.

Department of Agriculture, Water and Environment (2020a). Macroderma gigas – Ghost Bat in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: Macroderma gigas — Ghost Bat (environment.gov.au) accessed November 16 2020.

Duffy, AM, Lumsden, LF, Caddle, CR, Chick, RR & Newell, GR (2000). The efficacy of Anabat ultrasonic detectors and harp traps for surveying microchiropterans in southeastern Australia, Acta Chiropterologica 2: 127-144.

EPA (2016a). EPA Technical Guidance –Terrestrial Fauna Surveys, Perth, Environmental Protection Authority.

EPA (2016b). EPA Technical Guidance – Sampling methods for terrestrial vertebrate fauna, Perth, Environmental Protection Authority.

GHD 2015a (March 2015) Fortescue Metals Group Cave 13 Lateral Extent and Structural Assessment.

GHD 2015b (November 2015) Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Pilbara Leaf-nosed Bat roost habitat survey.

GHD 2016a (July 2016), Unpublished report for Fortescue Metals Group Iron Bridge, North Star Mine – Cave 13 Pilbara Leaf-nosed Bat Survey.

GHD 2016b (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 2017a (January 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Survey Plan for the Pilbara Leaf-nosed Bat.

GHD 2017b (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 (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 2017d (April 2017), Unpublished memorandum for Fortescue Metals Group Iron Bridge – Trial radio-tracking study, North Star mine site April 2017.

GHD 2017e (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Chateau Cave habitat assessment for the Pilbara Leaf-nosed Bat.

GHD 2017f (October 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Pilbara-leaf Nosed Bat radio-tracking survey: Survey results report.

GHD 2017g (December 2017), Unpublished report for Fortescue Metals Group Iron Bridge – Alternate Roost Sites for the Pilbara Leaf-nosed Bat.

GHD (2020a) Glacier Valley and South Star Fauna Surveys: Conservation Significant Fauna Survey report results, March 2020. Unpublished report for Fortescue Metals Group Iron Bridge

GHD (2020b), Pilbara Leaf-nosed Bat radio tracking survey 2019-2020 Survey report, May 2020. Unpublished report for Fortescue Metals Group Iron Bridge

Guppy, A., Coles, R. B. and Pettigrew, J. D. (1985). Echolocation and acoustic communication in the Australian Ghost Bat, Macroderma gigas (Microchiroptera: Megadermatidae). Australian Mammology 8, 299- 308.

Hanrahan, N. (2020). The acoustic ecology of the ghost bat (Macroderma gigas): form, function and applied uses of vocalisations. Ph.D. Thesis, Western Sydney University, Sydney.

Hanrahan, Nicola & Dalziell, Anastasia & Welbergen, Justin. (2021). Ghost bats exhibit informative daily and seasonal temporal patterns in the production of social vocalisations. Australian Journal of Zoology.

Hourigan, C. (2011). Ghost Bat, Macroderma gigas. Targeted species survey guidelines. Queensland Herbarium, Department of Science, Information Technology and Innovation, Brisbane.

Kulzer E., Nelson J.E., McKean J.L. and Moehres F.P. (1984). Prey-catching behaviour and echolocation in the Australian ghost bat, Macroderma gigas (Microchiroptera: Megadermatidae). Australian Mammalogy 7: 37–50.

McKenzie, N. L., and Bullen, R. D. (2009). The echolocation calls, habitat relationships, foraging niches and communities of Pilbara microbats. Records of the Western Australian Museum Supplement 78: 123–155.

McKenzie, N. L., and Bullen, R. D. (2012). An acoustic survey of zoophagic bats on islands in the Kimberley, Western Australia, including data on the echolocation ecology, organisation and habitat relationships of regional communities. Records of the Western Australian Museum Supplement 81: 67–108.

Mills, DJ, Norton, TW, Parnaby, HE, Cunningham, RB & Nix, HA (1996), Designing surveys for microchiropteran bats in complex forest landscapes – a pilot study from south-east Australia. Forest Ecology and management 85 (1-3):149-161.

Pettigrew, J., Baker, G. B., Baker-Gabb, D., Baverstock, R., Coles, R., Conole, S., Churchill, S., Fitzherbert, K., Guppy, A., Hall, L., Helman, P., Nelson, J., Priddel, D., Pulsford, I., Richards, G., Schulz, M. and Tidemann, C. R. (1986). The Australian ghost bat, Macroderma gigas, at Pine Creek, Northern Territory. Macroderma 2(1), 8-19.

Reardon, T. B., McKenzie, N. L., Cooper, S. J. B., Appleton., B., Carthew, S. and Adams, M (2014) A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian free-tailed bats Mormopterus (Chiroptera : Molossidae). Australian Journal of Zoology 62: 109-136.

Van Dyke. S, Gynther. I, and Baker. A. (2013). Field Companion To The Mammals of Australia. New Holland Publishers.

Specialised Zoological (2017). A review of past surveys for Pilbara bats of conservation significance. Critical review. Unpublished report to GHD Pty Ltd and Fortescue Metals Group Ltd, February 2017.

Specialised Zoological (2018). Long term trends in nightly activity of the Pilbara Leaf-nosed Bat at North Star, Western Australia. Technical acoustic analysis report. Unpublished report by Specialised Zoological for GHD Pty Ltd, December 2018.

Threatened Species Scientific Committee (2016a). Conservation Advice Rhinonicteris aurantia (Pilbara form) (Pilbara Leaf-nosed Bat). Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/82790-conservation-advice-10032016.pdf. In effect under the EPBC Act from 10-Mar-2016.

Threatened Species Scientific Committee (TSSC 2016b). Conservation Advice Macroderma gigas ghost bat. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/174-conservation-advice-05052016.pdf. In effect under the EPBC Act from 05-May-2016.

Toop, J. (1985). Habitat requirements, survival strategies and ecology of the ghost bat, Macroderma gigas Dobson (Microchiroptera, Megadermatidae) in central coastal Queensland. Macroderma 1(2), 37-41.

Woinarski, John & Burbidge, Andrew & Harrison, Peter. (2014). Action Plan for Australian Mammals 2012. CSIRO Publishing.

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Appendices

Appendix A – Roost habitat assessment results

Figure 4 - Habitat assessment – helicopter/foot locations

Figure label	Legend text	longitude	latitude
ha1	Habitat assessment - helicopter/foot	119.2261086	-21.46034195
ha2	Habitat assessment - helicopter/foot	119.1151149	-21.37019445
ha3	Habitat assessment - helicopter/foot	119.2815917	-21.3329472
ha4	Habitat assessment - helicopter/foot	119.2862922	-21.48749447
ha5	Habitat assessment - helicopter/foot	119.1558889	-21.55343644
ha6	Habitat assessment - helicopter/foot	119.1189865	-21.57005678
ha7	Habitat assessment - helicopter/foot	119.238091	-21.47585918
ha8	Habitat assessment - helicopter/foot	119.0385793	-21.13577273
ha9	Habitat assessment - helicopter/foot	118.8882738	-21.22390463
ha10	Habitat assessment - helicopter/foot	119.0627127	-21.0795331
ha11	Habitat assessment - helicopter/foot	118.8878737	-21.22324852
ha12	Habitat assessment - helicopter/foot	118.8776738	-21.21061045
ha13	Habitat assessment - helicopter/foot	118.8898082	-21.16198855
ha14	Habitat assessment - helicopter/foot	119.3204474	-21.32533553
ha15	Habitat assessment - helicopter/foot	118.8787197	-21.19238408
ha16	Habitat assessment - helicopter/foot	118.9335902	-21.2197195
ha17	Habitat assessment - helicopter/foot	119.0641021	-21.12511025
ha18	Habitat assessment - helicopter/foot	119.0216016	-21.13702239
ha19	Habitat assessment - helicopter/foot	118.9345644	-21.21784828
ha20	Habitat assessment - helicopter/foot	119.0973849	-21.41358277
ha21	Habitat assessment - helicopter/foot	118.9659975	-21.24853204
ha22	Habitat assessment - helicopter/foot	118.9021883	-21.22397908
ha23	Habitat assessment - helicopter/foot	118.9036808	-21.22829624
ha24	Habitat assessment - helicopter/foot	118.8949463	-21.22672728
ha25	Habitat assessment - helicopter/foot	119.0134879	-21.21930757
ha26	Habitat assessment - helicopter/foot	119.0082571	-21.21685337
ha27	Habitat assessment - helicopter/foot	119.0086847	-21.21745472
ha28	Habitat assessment - helicopter/foot	119.0133338	-21.21778105

Figure 4 – Roost habitat assessment locations

Figure label	Legend text	longitude	latitude
rha1	Roost habitat assessment	119.0979809	-21.40953445
rha2	Roost habitat assessment	119.1100576	-21.56407553
rha3	Roost habitat assessment	119.1318096	-21.57222637
rha4	Roost habitat assessment	119.1816892	-21.51073618
rha5a	Roost habitat assessment	119.1671589	-21.51740643
rha5b	Roost habitat assessment	119.2690904	-21.4954963
rha6	Roost habitat assessment	119.2688259	-21.49571753
rha7	Roost habitat assessment	119.2368	-21.47626598
rha8	Roost habitat assessment	119.2210381	-21.48709053
rha9	Roost habitat assessment	119.2362136	-21.47199212
rha10	Roost habitat assessment	119.2331561	-21.46516072
rha11	Roost habitat assessment	119.2306117	-21.46611942
rha12	Roost habitat assessment	119.2303866	-21.46305397
rha13	Roost habitat assessment	119.2850183	-21.3191732
rha14	Roost habitat assessment	119.2819546	-21.33265728

Figure label	Legend text	longitude	latitude
rha15	Roost habitat assessment	119.3201806	-21.32515802
rha16	Roost habitat assessment	118.8882174	-21.22288643
rha17	Roost habitat assessment	118.8882163	-21.2227763
rha18	Roost habitat assessment	118.8892652	-21.22223222
rha19	Roost habitat assessment	119.2853604	-21.48709967
rha20	Roost habitat assessment	119.0611307	-21.1266989
rha21	Roost habitat assessment	119.1222304	-21.41666578
rha22	Roost habitat assessment	119.2227746	-21.47768425
rha23	Roost habitat assessment	119.0989332	-21.40858125
rha24	Roost habitat assessment	119.1067557	-21.36785212
rha25a	Roost habitat assessment	119.0235011	-21.23417617
rha25b	Roost habitat assessment	119.0660443	-21.06529911
rha26	Roost habitat assessment	118.9681911	-21.24946067

Figure 6 – Ghost Bat Roost habitat categorisation results for each habitat (foot/helicopter) and roost habitat assessment location

Figure label	Category	Field notes	longitude	latitude
ha1	no obvious roost habitat	No caves foot search	119.2261	-21.4603
ha2	Nocturnal/feeding refuge	Thorough fly by no caves visible, shallow overhangs	119.1151	-21.3702
ha3	no obvious roost habitat	-	119.2816	-21.3329
ha4	no obvious roost habitat	-	119.2863	-21.4875
ha5	Potential roost habitat	Potential caves not accessible	119.1559	-21.5534
ha6	Potential diurnal roost - unknown category	Potential GB cave in LUC area, close to permanent water gorge, but only visible from helicopter, not on-ground,	119.119	-21.5701
ha7	-	Helicopter not on-ground	119.2381	-21.4759
ha8	no obvious roost habitat	No caves, crumbly geology pool cave formation	119.0386	-21.1358
ha9	-	Helicopter not on-ground	118.8883	-21.2239
ha10	-	Potential PLNB habitat, many small holes	119.0627	-21.0795
ha11	Nocturnal/feeding refuge	Low, suitable shallow overhang	118.8879	-21.2232
ha12	Potential roost habitat	Potential caves	118.8777	-21.2106
ha13	Potential roost habitat	Potential caves	118.8898	-21.162
ha14	-	Helicopter not on-ground	119.3204	-21.3253
ha15	Potential roost habitat	Potential caves	118.8787	-21.1924
ha16	Potential roost habitat	Several large caves, appear deep	118.9336	-21.2197
ha17	Potential roost habitat	Potential caves	119.0641	-21.1251
ha18	Potential roost habitat	Shallow caves	119.0216	-21.137
ha19	Potential roost habitat	Several big caves	118.9346	-21.2178
ha20	Potential roost habitat	Several potential caves, no accessible	119.0974	-21.4136
ha21	Potential roost habitat	UC2 - Not accessible on foot, caves located side of vertical narrow gorge	118.966	-21.2485

Figure label	Category	Field notes	longitude	latitude
ha22	Nocturnal/feeding refuge	No foraging evidence or scat but did not enter cave. Potential Ghost Bat foraging cave.	118.9022	-21.224
ha23	Nocturnal/feeding refuge	Potential foraging cave, not entered, one chute 1 m by 40cm in ceiling. Potential for Ghost Bat.	118.9037	-21.2283
ha24	Nocturnal/feeding refuge	No foraging evidence or scat but did not enter cave. Potential Ghost Bat foraging cave.	118.8949	-21.2267
ha25	Potential roost habitat	No access - too steep. Two caves. one upper slope entrance c. 1 m x 1.5 m. Other mid slope entrance c. 3 m x 1.5 m. Would have seasonal water at base.	119.0135	-21.2193
ha26	Potential roost habitat	Did not enter. Potential PLNB. single passage way. Could not see back but had cob webs.	119.0083	-21.2169
ha27	Potential diurnal roost - unknown category	Scattered feathers, main chamber has smaller chamber at back. Entrance size of back chamber 50 cm wide x 30 cm wide. Did not enter cave.	119.0087	-21.2175
ha28	Potential diurnal roost - unknown category	Did not enter. Possible Ghost Bat foraging cave. Too steep to climb into. Could not see if additional chamber at back. Water at entrance is seasonal.	119.0133	-21.2178
rha1	Diurnal roost occasional use	See assessment sheet	119.098	-21.4095
rha2	Diurnal roost occasional use	See assessment sheet	119.1101	-21.5641
rha3	Nocturnal/feeding refuge	See assessment sheet	119.1318	-21.5722
rha4	Nocturnal/feeding refuge		119.1817	-21.5107
rha5a	Potential diurnal roost - unknown category	See assessment sheet	119.1672	-21.5174
rha5b	Potential diurnal roost - unknown category	Extensive cave system	119.2691	-21.4955
rha6	Potential diurnal roost - unknown category	See assessment sheet	119.2688	-21.4957
rha7	Potential diurnal roost - unknown category	Potential cave for Ghost Bat roost in small gorge, too steep to access cave inside, can't determine depth	119.2368	-21.4763
rha8	Nocturnal/feeding refuge	Large dome overhang, no Ghost Bat sign but lots of T. georgianus/smaller bat scat. 3 x T.georgianus	119.221	-21.4871
rha9	Diurnal roost ongoing use	See assessment sheet	119.2362	-21.472
rha10	Diurnal roost ongoing use	See assessment sheet	119.2332	-21.4652
rha11	Nocturnal/feeding refuge	On foot. Extensive overhang, not cave roost	119.2306	-21.4661
rha12	Potential diurnal roost - unknown category	See assessment sheet	119.2304	-21.4631
rha13	Potential roost habitat	Potential cave not accessible too steep	119.285	-21.3192
rha14	Nocturnal/feeding refuge	Wide low overhang, 8 m wide x 10 m wide x 1 m high, not suitable for Ghost Bat or PLNB and no signs, 3 T.georgianus present	119.282	-21.3327
rha15	Nocturnal/feeding refuge	Potential feeding cave for Ghost Bat, 3-4 old Ghost Bat scats present toward front of overhang.	119.3202	-21.3252

Figure label	Category	Field notes	longitude	latitude
		But low suitability roost, shallow overhang, too shallow/ light for roost.		
rha16	Potential diurnal roost - unknown category	Potential PLNB cave, narrow horizontal pipe, may open into chamber, not accessible, approx 12 m long, 50 cm x 50 cm.	118.8882	-21.2229
rha17	Diurnal roost occasional use	Potential temporary roost, feeding cave, shallow, 7 m deep x 1.3 m ht x 2 m wide, with few old Ghost Bat scats.	118.8882	-21.2228
rha18	Potential diurnal roost - unknown category	See assessment sheet	118.8893	-21.2222
rha19	Potential roost habitat	Good cave, caves however could not complete due to aggressive bees	119.2854	-21.4871
rha20	Potential roost habitat	Potential PLNB cave habitat	119.0611	-21.1267
rha21	Nocturnal/feeding refuge	On foot, shallow caves, no evidence of Ghost Bat, potential refuge habitat. Small unknown microbats roosting in martin mud nests in overhang	119.1222	-21.4167
rha22	no obvious roost habitat	Area checked on foot, no caves	119.2228	-21.4777
rha23	Nocturnal/feeding refuge	Are checked on foot, shallow caves/overhangs	119.0989	-21.4086
rha24	Nocturnal/feeding refuge	Accessed via helicopter, then on foot. No significant caves	119.1068	-21.3679
rha25a	Diurnal roost occasional use	Wallaby Cave - No Ghost Bats, or scat. 4 x microbats (probably V. finlaysoni)	119.066	-21.0653
rha25b	Potential roost habitat	Potential PLNB habitat. Many small holes, caves	119.0235	-21.2342
rha26	Diurnal roost occasional use	Bone Cave - No Ghost Bats, or scat. 12 x T. georgianus, 1 x V. finlaysoni	118.9682	-21.2495

Figure 7 – PLNB Roost habitat categorisation results for each habitat assessment location

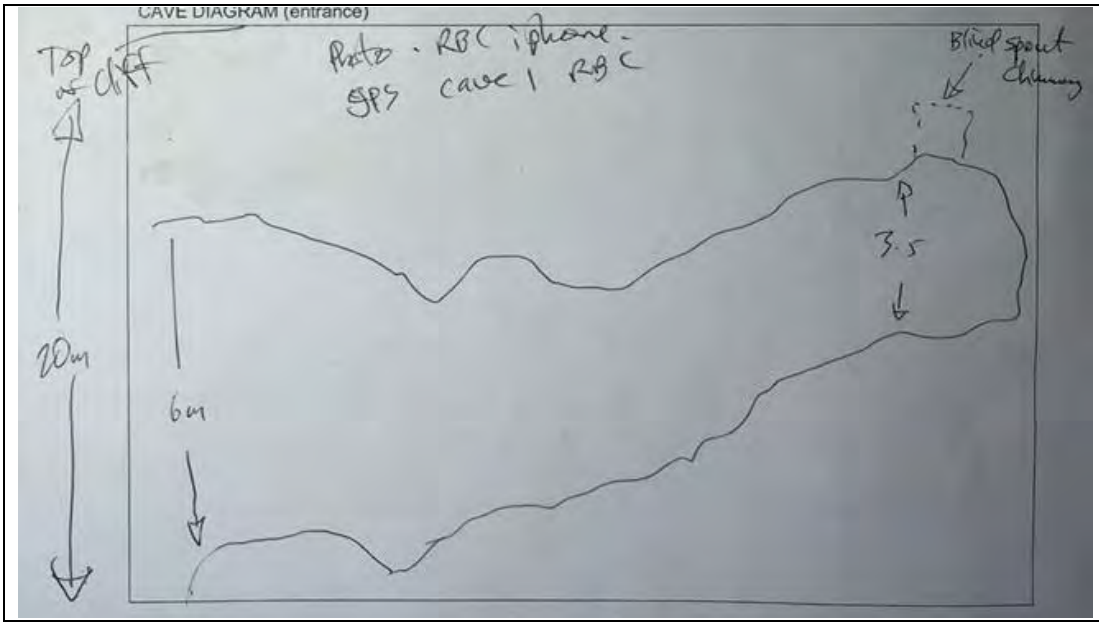
Figure label	Category	Field notes	longitude	latitude
ha1	no obvious roost habitat	No caves foot search	119.2261	-21.4603
ha2	Nocturnal refuge	Thorough fly by no caves visible, shallow overhangs	119.1151	-21.3702
ha3	no obvious roost habitat	-	119.2816	-21.3329
ha4	no obvious roost habitat	-	119.2863	-21.4875
ha5	Potential roost habitat	Potential caves not accessible	119.1559	-21.5534
ha6	Potential diurnal roost - unknown category	Potential GB cave in LUC area, close to permanent water gorge, but only visible from helicopter, not on-ground,	119.119	-21.5701
ha7	-	Helicopter not on-ground	119.2381	-21.4759
ha8	no obvious roost habitat	No caves, crumbly geology pool cave formation	119.0386	-21.1358
ha9	-	Helicopter not on-ground	118.8883	-21.2239
ha10	Potential diurnal roost - unknown category	Potential PLNB habitat, many small holes	119.0627	-21.0795
ha11	Nocturnal refuge	Low, suitable shallow overhang	118.8879	-21.2232

Figure label	Category	Field notes	longitude	latitude
ha12	Potential roost habitat	Potential caves	118.8777	-21.2106
ha13	Potential roost habitat	Potential caves	118.8898	-21.162
ha14	-	Helicopter not on-ground	119.3204	-21.3253
ha15	Potential roost habitat	Potential caves	118.8787	-21.1924
ha16	Potential roost habitat	Several large caves, appear deep	118.9336	-21.2197
ha17	Potential roost habitat	Potential caves	119.0641	-21.1251
ha18	Potential roost habitat	Shallow caves	119.0216	-21.137
ha19	Potential roost habitat	Several big caves	118.9346	-21.2178
ha20	Potential roost habitat	Several potential caves, no accessible	119.0974	-21.4136
ha21	Potential roost habitat	UC2 - Not accessible on foot, caves located side of vertical narrow gorge	118.966	-21.2485
ha22	Nocturnal refuge	No foraging evidence or scat but did not enter cave. Potential Ghost Bat foraging cave.	118.9022	-21.224
ha23	Nocturnal refuge	Potential foraging cave, not entered, one chute 1 m by 40cm in ceiling. Potential for Ghost Bat.	118.9037	-21.2283
ha24	Nocturnal refuge	No foraging evidence or scat but did not enter cave. Potential Ghost Bat foraging cave.	118.8949	-21.2267
ha25	Potential roost habitat	No access - too steep. Two caves. one upper slope entrance c. 1 m x 1.5 m. Other mid slope entrance c. 3 m x 1.5 m. Would have seasonal water at base.	119.0135	-21.2193
ha26	Potential roost habitat	Did not enter. Potential PLNB. single passage way. Could not see back but had cob webs.	119.0083	-21.2169
ha27	Potential diurnal roost - unknown category	Scattered feathers, main chamber has smaller chamber at back. Entrance size of back chamber 50 cm wide x 30 cm wide. Did not enter cave.	119.0087	-21.2175
ha28	Potential diurnal roost - unknown category	Did not enter. Possible Ghost Bat foraging cave. Too steep to climb into. Could not see if additional chamber at back. Water at entrance is seasonal.	119.0133	-21.2178
rha1	Potential diurnal roost - unknown category	See assessment sheet	119.098	-21.4095
rha2	Potential diurnal roost - unknown category	See assessment sheet	119.1101	-21.5641
rha3	Potential diurnal roost - unknown category	See assessment sheet	119.1318	-21.5722
rha4	Nocturnal refuge		119.1817	-21.5107
rha5a	Potential diurnal roost - unknown category	See assessment sheet	119.1672	-21.5174
rha5b	Potential diurnal roost - unknown category	Extensive cave system	119.2691	-21.4955
rha6	Potential diurnal roost - unknown category	See assessment sheet	119.2688	-21.4957
rha7	Potential diurnal roost - unknown category	Potential cave for Ghost Bat roost in small gorge, too steep to access cave inside, can't determine depth	119.2368	-21.4763

Figure label	Category	Field notes	longitude	latitude
rha8	Potential diurnal roost - unknown category	Large dome overhang, no Ghost Bat sign but lots of T. georgianus/smaller bat scat. 3 x T.georgianus	119.221	-21.4871
rha9	Potential diurnal roost - unknown category	See assessment sheet	119.2362	-21.472
rha10	Potential diurnal roost - unknown category	See assessment sheet	119.2332	-21.4652
rha11	Nocturnal refuge	On foot. Extensive overhang, not cave roost	119.2306	-21.4661
rha12	Permanent diurnal roost/Non-permanent breeding roost	See assessment sheet	119.2304	-21.4631
rha13	Potential roost habitat	Potential cave not accessible too steep	119.285	-21.3192
rha14	Nocturnal refuge	Wide low overhang, 8 m wide x 10 m wide x 1 m high, not suitable for Ghost Bat or PLNB and no signs, 3 T.georgianus present	119.282	-21.3327
rha15	Nocturnal refuge	Potential feeding cave for Ghost Bat, 3-4 old Ghost Bat scats present toward front of overhang. But low suitability roost, shallow overhang, too shallow/ light for roost.	119.3202	-21.3252
rha16	Potential diurnal roost - unknown category	Potential PLNB cave, narrow horizontal pipe, may open into chamber, not accessible, approx 12 m long, 50 cm x 50 cm.	118.8882	-21.2229
rha17	Potential diurnal roost - unknown category	Potential temporary roost, feeding cave, shallow, 7 m deep x 1.3 m ht x 2 m wide, with few old Ghost Bat scats.	118.8882	-21.2228
rha18	Potential diurnal roost - unknown category	See assessment sheet	118.8893	-21.2222
rha19	Potential diurnal roost - unknown category	Good cave, caves however could not complete due to aggressive bees	119.2854	-21.4871
rha20	Potential roost habitat	Potential PLNB cave habitat	119.0611	-21.1267
rha21	Nocturnal refuge	On foot, shallow caves, no evidence of Ghost Bat, potential refuge habitat. Small unknown microbats roosting in martin mud nests in overhang	119.1222	-21.4167
rha22	no obvious roost habitat	Area checked on foot, no caves	119.2228	-21.4777
rha23	Nocturnal refuge	Are checked on foot, shallow caves/overhangs	119.0989	-21.4086
rha24	Nocturnal refuge	Accessed via helicopter, then on foot. No significant caves	119.1068	-21.3679
rha25a	Potential roost habitat	Wallaby Cave - No Ghost Bats, or scat. 4 x microbats (probably V. finlaysoni)	119.066	-21.0653
rha25b	Potential diurnal roost - unknown category	Potential PLNB habitat. Many small holes, caves	119.0235	-21.2342
rha26	Potential diurnal roost - unknown category	Bone Cave - No Ghost Bats, or scat. 12 x T. georgianus, 1 x V. finlaysoni	118.9682	-21.2495

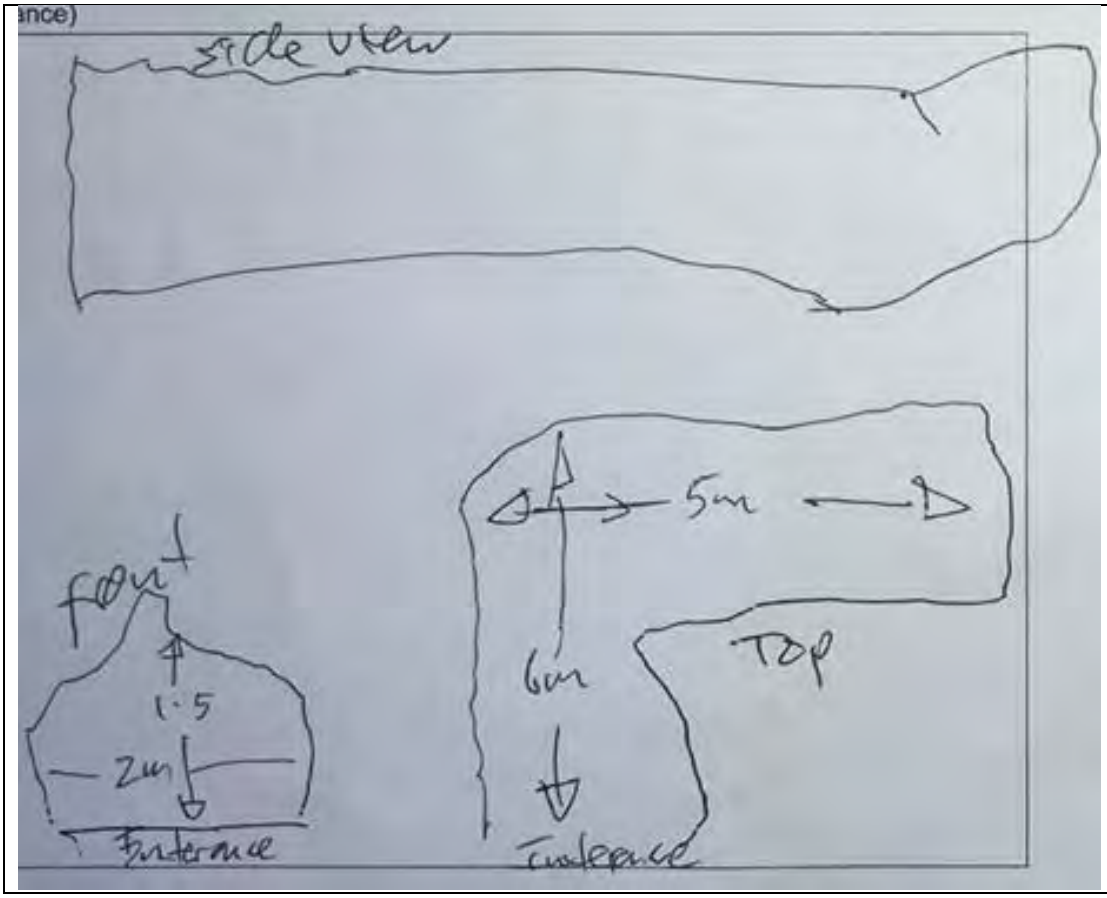
GHD – Roost/cave habitat assessment form	
Cave observer: RBC	Date/time: 23/10/20 Cave no/name: Cave 1 RBC (rha1)
Elevation: 484	Location (GPS and map ref): Latitude: 21.4083S Longitude: 119.09896E
Position (geography e.g top of BIF, midway etc)	Upper (near top)
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	6 m H, 5 m W
Entrance aspect:/ position (of opening e.g ground level, elevated)	Northwest facing entrance
Floor / ceiling type (sloping, flat, rough)	Flaky (bedded) BIF
Entrance condition (stability, fallen debris)	Fallen flakes/chips/slabs
Entrance temperature / humidity/ airflow	28 deg c, low airflow, mod/low humidity
Bat evidence / other comments	Approximately 10 ghost bat scats, mod fres, composed of fur and a few feathers
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number (of)	One main chamber
Entrance shape / height m/ width m / orientation/ position	3 m H, 2.5 m W, depth 20 m
Chamber shape/ width m/ height m	Roundish
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Slight upward slope, fallen large rocks
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough and flaky
Condition (stability, fallen debris)	Moderately stable
Temperature and humidity	Moderately high temp (humidity low)
Airflow / evidence of moisture/water (seepage pools etc)	Mod air flow due to large entrance, no moisture
Bat evidence / other comments	Around 20 T. georgianus roosting, potential temp roost/feeding cave for M.gigas
Bat evidence / other comments	M. gigas scats, approx 10, mod fresh forage (few feathers)
DETECTOR DETAILS	Date: 23/10/20 Deployment time:
Type:	Serial no: SM4 S4408812 GHD no:
Time on:	Latitude: 21.40858 s Longitude: 119.098933 E

CAVE DIAGRAM rha1



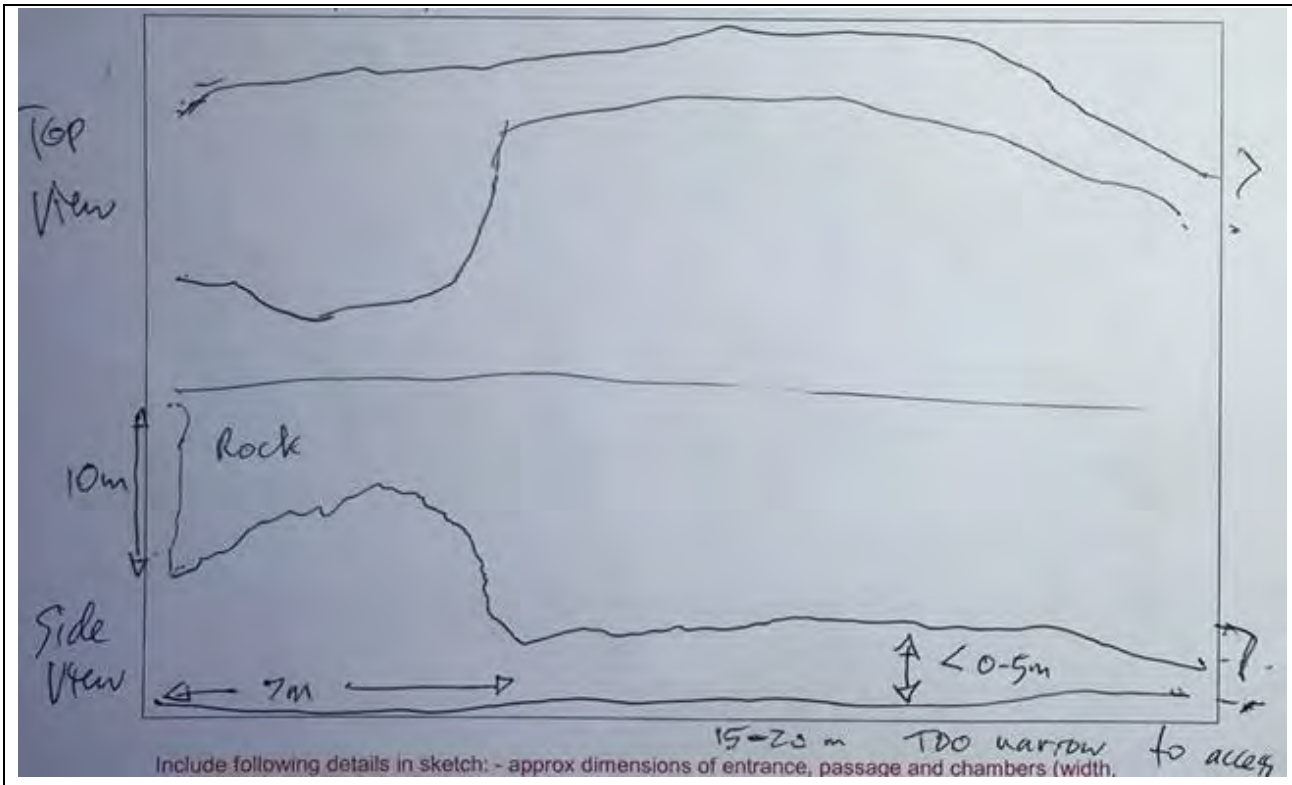
GHD – Roost/cave habitat assessment form	
Cave observer: RBC	Date/time:24/10/20 Cave no/name: Cave 2 RBC (rha2)
Elevation:	Location (GPS and map ref): Latitude: 21.5654 Longitude: 119.1107
Position (geography e.g top of BIF, midway etc)	Top of BIF
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	H 2 x 1.5 W
Entrance aspect:/ position (of opening e.g ground level, elevated)	approx north
Floor / ceiling type (sloping, flat, rough)	Rough, stoney
Entrance condition (stability, fallen debris)	Fallen rocks, stones, pebbles
Entrance temperature / humidity/ airflow	Same as ambient air at around 21 deg c
Bat evidence / other comments	Few T.georgianus and M. gigas scats. 1 x T. georgianus roosting
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Entrance shape / height m/ width m / orientation/ position	1.5 H, 1.5 w, 13 m steep
Chamber shape/ width m/ height m	L shape
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Slightly upward slope rocky
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Mod rough ceiling
Condition (stability, fallen debris)	Mod stable
Temperature and humidity	Same as ambient temp approx 27 deg c, humidity approx 40%
Bat evidence / other comments	Few T.georgianus and M. gigas scats (containing fur) Cave 2 is potential day roost/feeding cave for M.gigas

CAVE DIAGRAM rha2



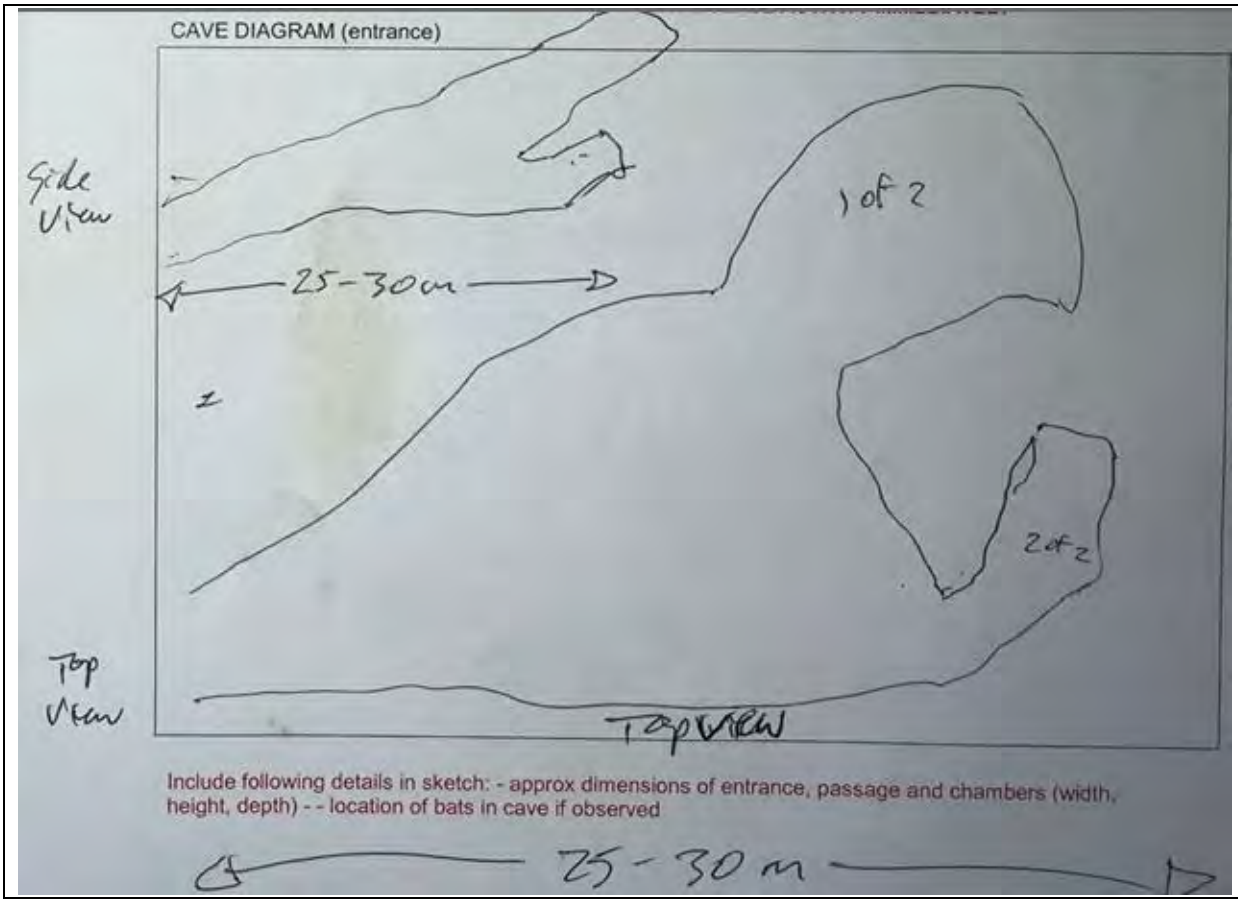
GHD – Roost/cave habitat assessment form	
Cave observer: RBC	Date/time: 24/10/20 Cave no/name:Cave 3 RBC (rha3)
Elevation:upper 15 m from top	Location (GPS and map ref): Latitude: 21.57308S Longitude: 119.13219E
Position (geography e.g top of BIF, midway etc)	Upper
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	Oval/round
Entrance aspect:/ position (of opening e.g ground level, elevated)	South
Floor / ceiling type (sloping, flat, rough)	Slight upward slope
Entrance condition (stability, fallen debris)	Stable, small fallen rocks, pebbles
Entrance temperature / humidity/ airflow	Ambient 29ºC, low/mod airflow
Bat evidence / other comments	No scats, 2 x T. georgianus
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number (of)	Shaft
Entrance shape / height m/ width m / orientation/ position	Oval h- 0.5 m, w – 1.0 m
Chamber shape/ width m/ height m	No chamber visible
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Slight upward
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough, no chambers, chimney visible
Condition (stability, fallen debris)	Stable
Temperature and humidity	30ºC, moderate humidity
Airflow / evidence of moisture/water (seepage pools etc)	No airflow
Bat evidence / other comments	1 x T. georgianus Cave 3 is potential PLNB roost cave but probably too narrow for M. gigas roost
DETECTOR DETAILS	Date: Deployment time:
Type:	Serial no: GHD no:
Time on:	Latitude: Longitude:

CAVE DIAGRAM rha3



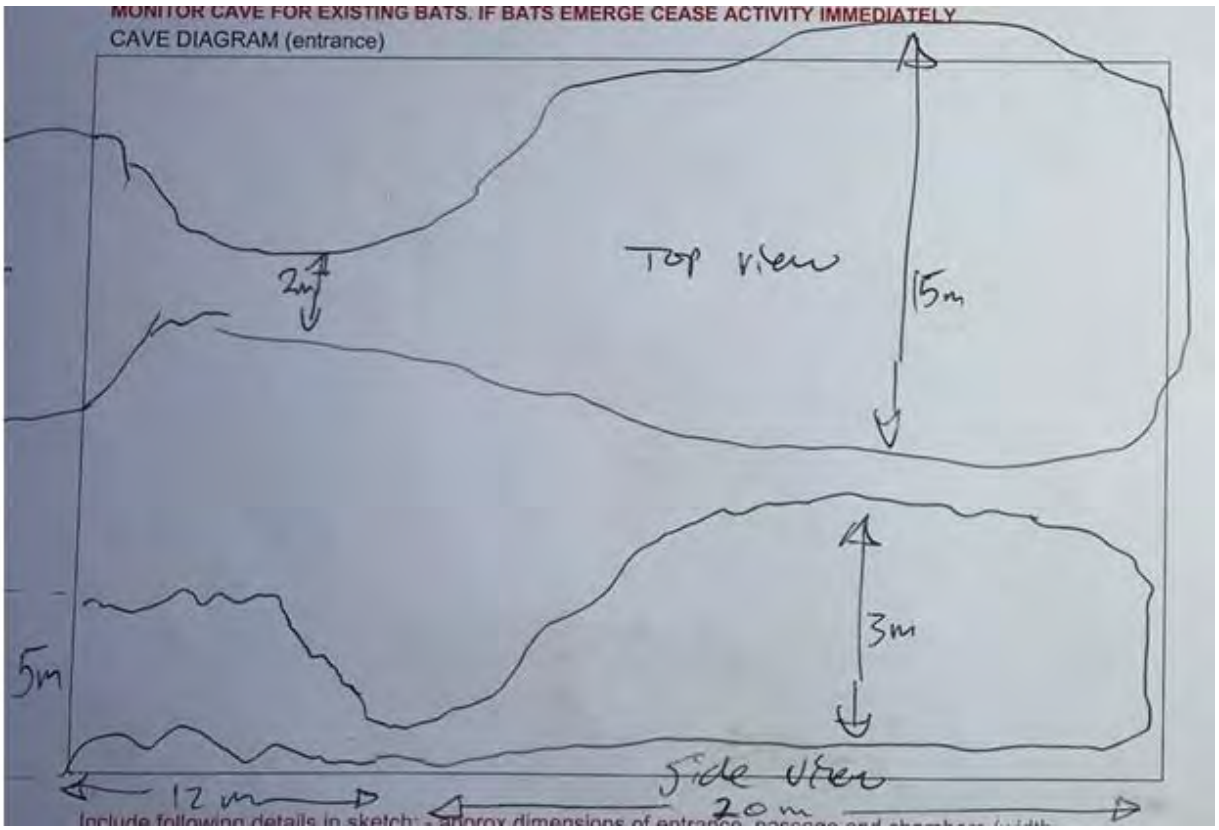
GHD – Roost/cave habitat assessment form	
Cave observer: RBC	Date/time: 24/10/20 Cave no/name: Cave 5 RBC (rha5)
Elevation: 449m	Location (GPS and map ref): Latitude:21.51711 Longitude: 119.16727
Position (geography e.g top of BIF, midway etc)	Upper
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	2.5 x 2.5 m
Entrance aspect:/ position (of opening e.g ground level, elevated)	North
Floor / ceiling type (sloping, flat, rough)	Rough
Entrance condition (stability, fallen debris)	Stable, fallen rocks
Entrance temperature / humidity/ airflow	Low airflow, humid (mod)
Bat evidence / other comments	Numerous approx. 30 x T. georgianus, approx..10 x smaller microbats (probably V. finlaysoni), lots of small bat scat
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number (of)	1 of 2
Entrance shape / height m/ width m / orientation/ position	1.5 m h x 2.5 m w, sloping upwards
Chamber shape/ width m/ height m	1.5 h – 4 w
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Mod level
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough, several crevices, no other off chambers
Condition (stability, fallen debris)	Mod stable
Temperature and humidity	Temp approx. 30ºC, humidity approx. 50-60%
Airflow / evidence of moisture/water (seepage pools etc)	Ni/negative airflow, no moisture
Bat evidence / other comments	Numerous approx. T. georgianus, smaller microbats (probably V. finlaysoni), lots of small bat scat
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number (of)	2 of 2
Entrance shape / height m/ width m / orientation/ position	1 x 1.5 m
Chamber shape/ width m/ height m	2 x 1.5 m
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Mod level, slight downward slope
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough, crevices
Condition (stability, fallen debris)	Mod stable
Temperature and humidity	As for Chamber 1
Airflow / evidence of moisture/water (seepage pools etc)	No moisture
Bat evidence / other comments	T. georgianus present
DETECTOR DETAILS	Date: 24/10/20 Deployment time:
Type:	Serial no: SM4 S4408815 GHD no:
Time on:	Latitude: see cave location Longitude:

CAVE DIAGRAM rha5



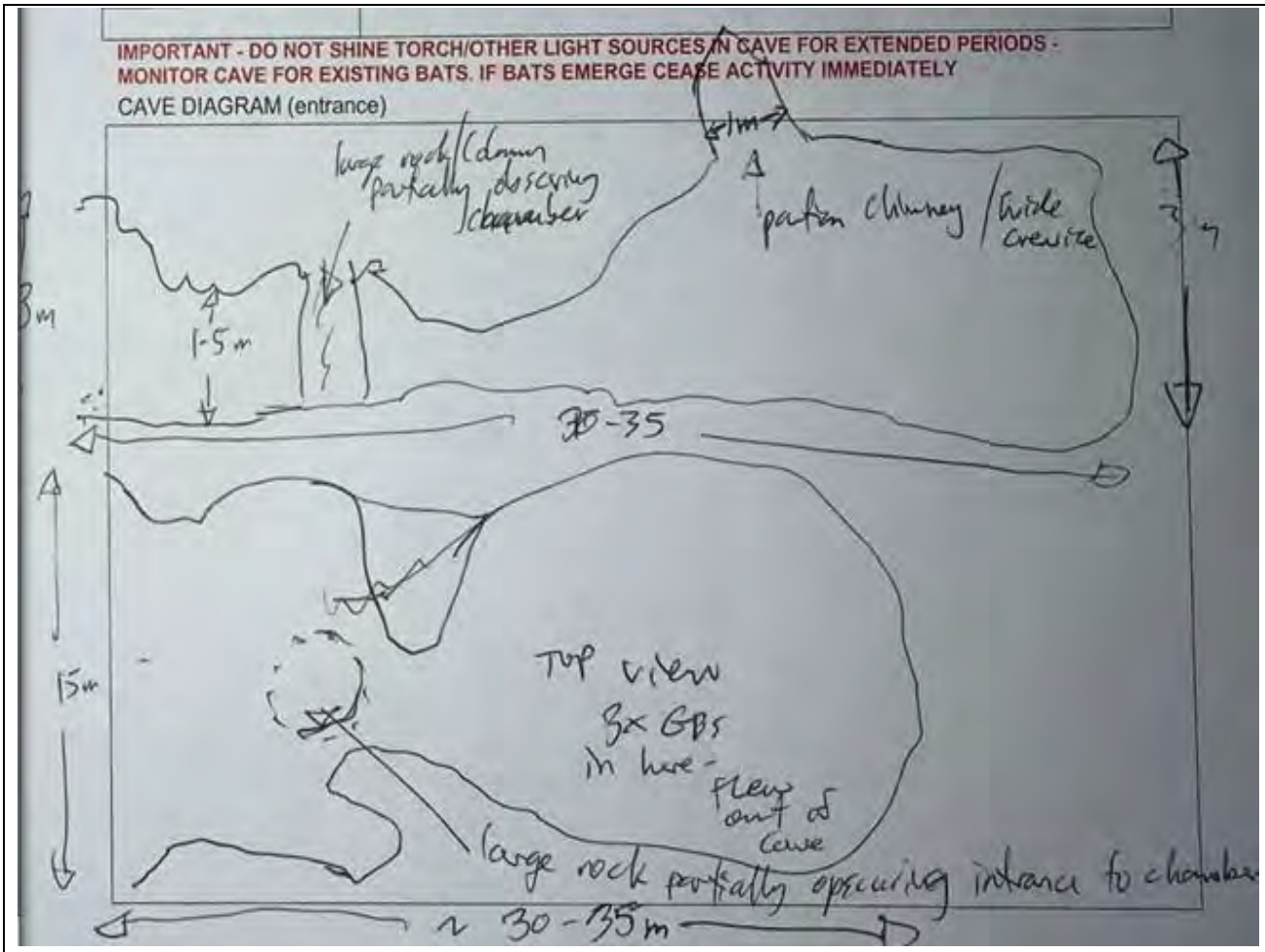
GHD – Roost/cave habitat assessment form	
Cave observer:RBC	Date/time: 25/10/20 Cave no/name: Cave 6 RBC (rha6)
Elevation: 300 m	Location (GPS and map ref): Latitude: 21.49534 s Longitude: 119.26893E
Position (geography e.g top of BIF, midway etc)	20-25 m from top of hill, BIF/quartzite
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	Crescent
Entrance aspect:/ position (of opening e.g ground level, elevated)	South east elevated a steep rocky slope
Floor / ceiling type (sloping, flat, rough)	Slight incline, rocky rough
Entrance condition (stability, fallen debris)	Low stability, loose rock on ceiling
Entrance temperature / humidity/ airflow	Low, good airflow
Bat evidence / other comments	Nil
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number 1 of 1	
Entrance shape / height m/ width m / orientation/ position	Slit 
Chamber shape/ width m/ height m	3 m H, 15 w, 20 m deep front to back
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Rough with some narrow long cracks/crevices, no passages
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Moderate stability
Condition (stability, fallen debris)	High temp and humidity, 27-28 deg c around 60-70% humidity
Temperature and humidity	Very low air flow, mod dark
Airflow / evidence of moisture/water (seepage pools etc)	
Bat evidence / other comments	1 x T. georgianus No M. gigas scat or signs of feeding. The open cavity looks like good roost for M. gigas or PLNB. no signs

CAVE DIAGRAM rha6



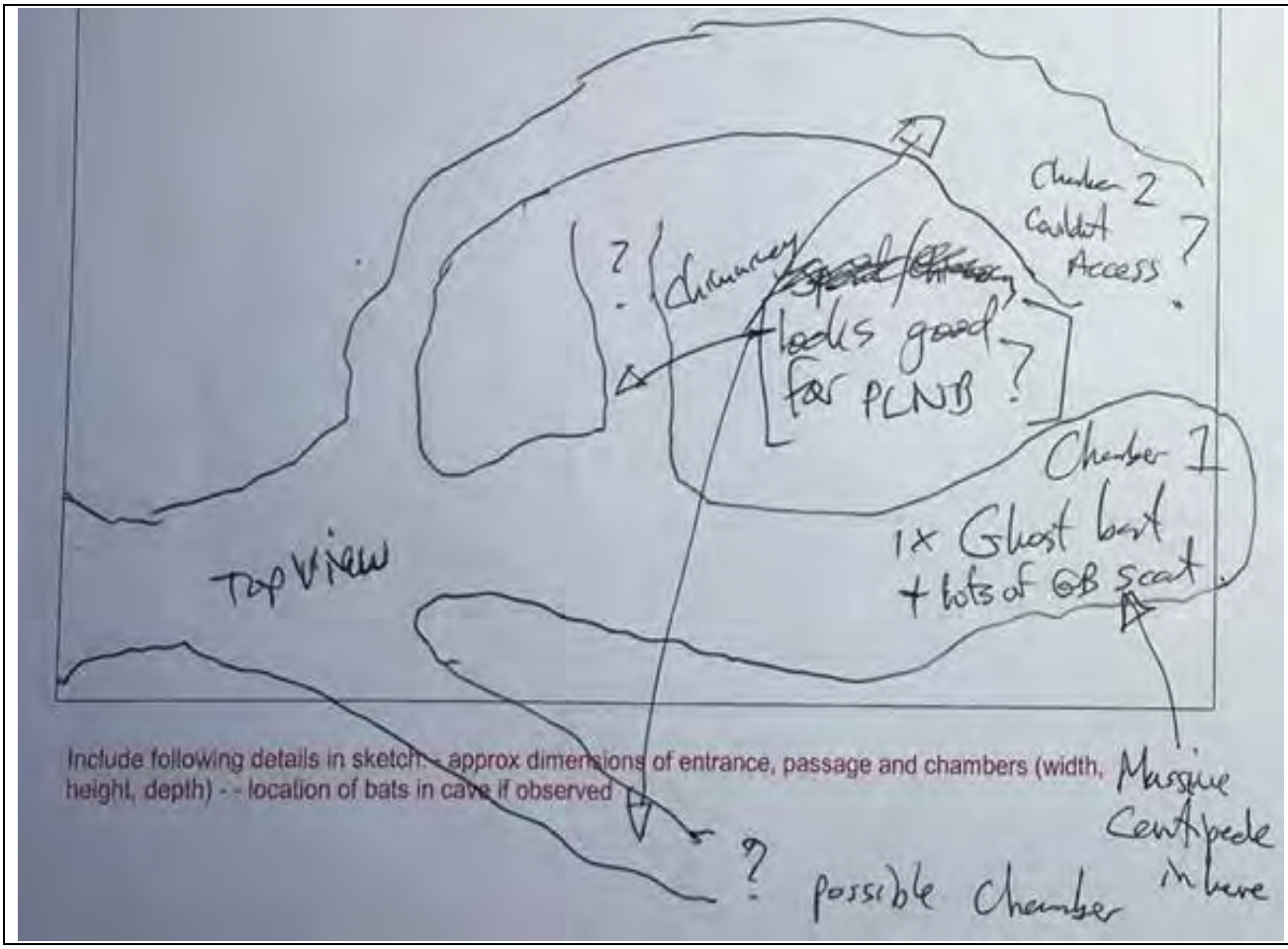
GHD – Roost/cave habitat assessment form	
Cave observer:RBC	Date/time: 26/10/20 830AM Cave no/name: Cave 9 RBC (rha9)
Elevation:330 m	Location (GPS and map ref):Latitude: 21.47196 s Longitude: 119.23637 E
Position (geography e.g top of BIF, midway etc)	Upper 25 m from top of breakaway
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	 Large crescent/slit
Entrance aspect:/ position (of opening e.g ground level, elevated)	ESE high up slope
Floor / ceiling type (sloping, flat, rough)	Ceiling rough floor very gentle up slope. Rocky/large boulder obscures the entrance to chamber.
Entrance condition (stability, fallen debris)	Some large fallen rocks.
Entrance temperature / humidity/ airflow	Mod temp, Ambient air at 27-28 de c. Humidity low/ambient, exposed airflow (mod)
Bat evidence / other comments	In chamber - 3 x M. gigas exited cave under red light left cave to avoid more disturbance
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number 1/1	
Entrance shape / height m/ width m / orientation/ position	Oval/round 1.5 w x 1m h behind large obscuring boulder
Chamber shape/ width m/ height m	Oval with partial chimney/slit (wide)
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Stony (mod) flat, mod dust
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough, with wide slit/partial chimney. One more chamber (I didn't stay long at cave)
Condition (stability, fallen debris)	Same fallen small rocks
Temperature and humidity	Mod high temp/humidity 27deg c 50-60% humidity
Airflow / evidence of moisture/water (seepage pools etc)	Low airflow, no moisture
Bat evidence / other comments	3 x M. gigas - did not stay long in cave to reduce disturbance therefore no scat found. Several T. georgianus also in roost
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
DETECTOR DETAILS	Date: 26/10/20 Deployment time: 850 AM
Type: SM2	Serial no: SN14908 GHD no: FMG uit FMG SN14908
Time on:	Latitude: 21.4714 s Longitude: 119.23614 E

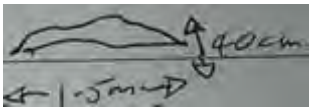
CAVE DIAGRAM rha9



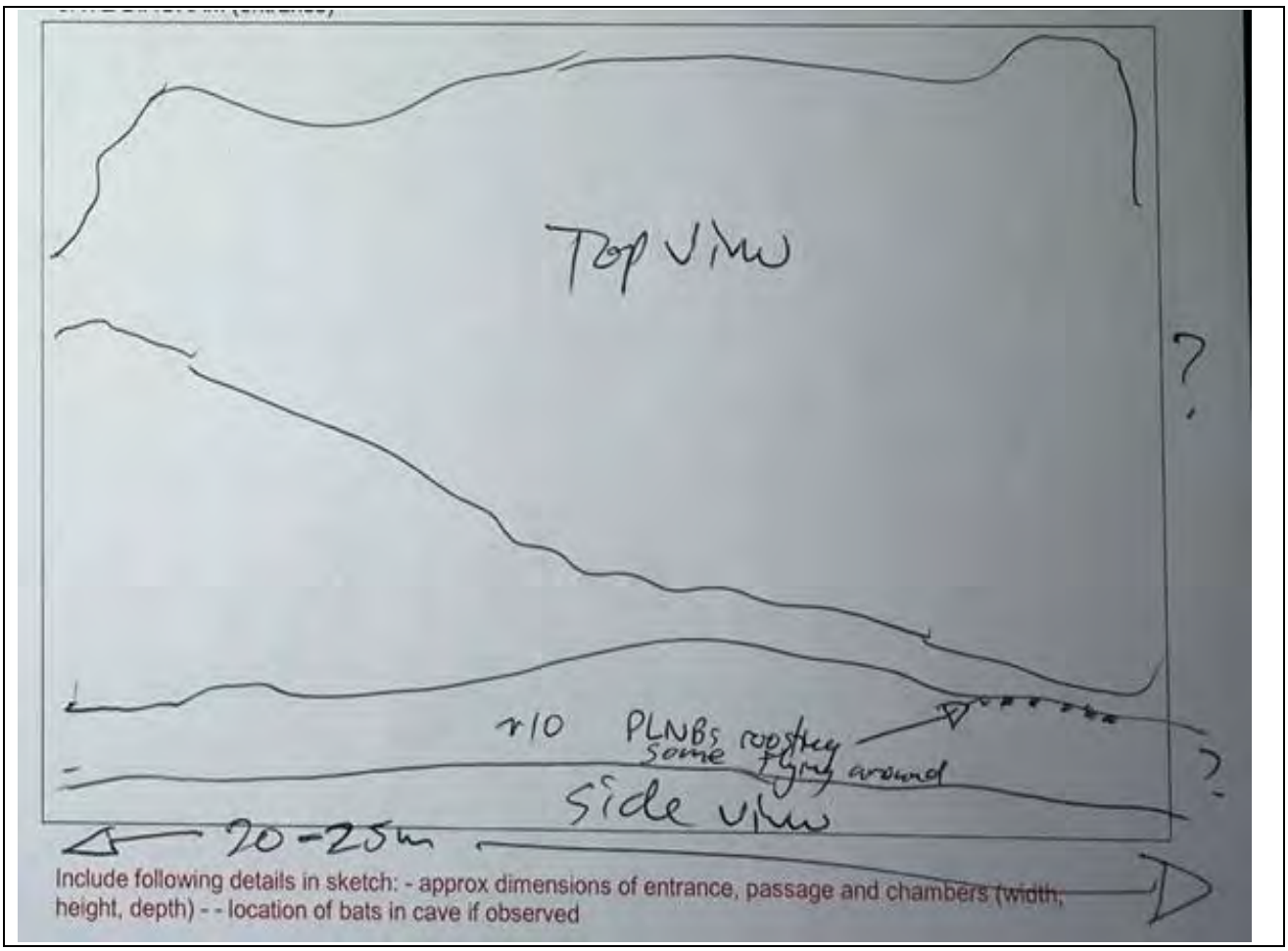
GHD – Roost/cave habitat assessment form	
Cave observer: RBC	Date/time: 26/10/20 Cave no/name: Cave 10 RBC (rha10)
Elevation:296 m	Location (GPS and map ref): Latitude: 21.46507 s Longitude: 119.23325
Position (geography e.g top of BIF, midway etc)	Around 20 m from top of cave, upper position
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	3m w x 2.5m h
Entrance aspect:/ position (of opening e.g ground level, elevated)	East, high elevation on moderate slope
Floor / ceiling type (sloping, flat, rough)	Rough but stable, no loose rock ceiling floor few rocks
Entrance condition (stability, fallen debris)	Not much fallen debris
Entrance temperature / humidity/ airflow	Around 28 deg c, mod low humidity
Bat evidence / other comments	Some microbat scat
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number 1/2	
Entrance shape / height m/ width m / orientation/ position	0.5 oval/round smooth “pipe” right of chamber
Chamber shape/ width m/ height m	1.5 m H oval, 1 m w
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Slope up clear smooth, lots of M.gigas scat
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Smooth, one chimney with possible chamber 45 deg angle, looks like water erosions/water stains?
Condition (stability, fallen debris)	Very stable – smooth no loose
Temperature and humidity	High humidity around 70%
Airflow / evidence of moisture/water (seepage pools etc)	Very low air flow, signs of possible water flow, stain but dry
Bat evidence / other comments	1 x M.gigas flew out, lots of M.gigas scat, frequent roost. One chimney at 45 deg incline from this chamber 1
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number 2/2	
Entrance shape / height m/ width m / orientation/ position	Oval flat low left of chamber 1
Chamber shape/ width m/ height m	Vertical oval 1.0 m w, 1.5 h
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Dusty, small stones, not much fallen debris
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough, stable, uneven
Condition (stability, fallen debris)	Stable
Temperature and humidity	Around 28 deg c, 70% humidity
Airflow / evidence of moisture/water (seepage pools etc)	Low aiflow, dry
Bat evidence / other comments	Small scats (microbat scats)

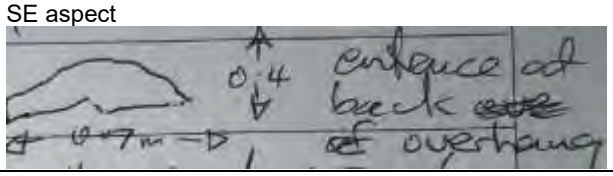
CAVE DIAGRAM rha10



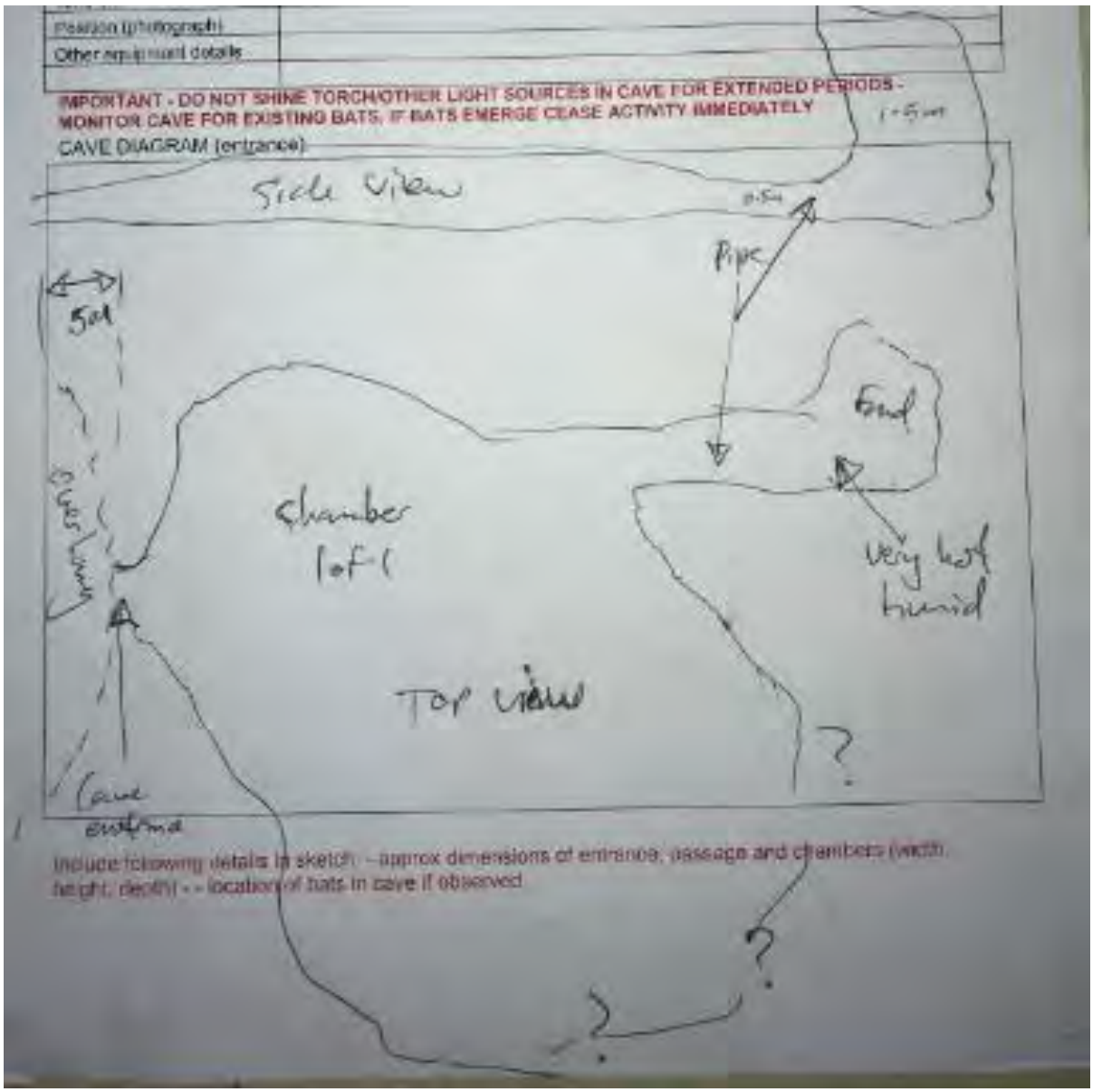
GHD – Roost/cave habitat assessment form	
Cave observer: RBC	Date/time: 26/10/20 Cave no/name: Cave 12 RBC (rha12)
Elevation: 360 m	Location (GPS and map ref): Latitude: 21.46309 Longitude: 119.23039
Position (geography e.g top of BIF, midway etc)	Upper around 10-15 m from top of Breakaway
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	Narrow low slit 
Entrance aspect:/ position (of opening e.g ground level, elevated)	East, base of low cliff
Floor / ceiling type (sloping, flat, rough)	Irregular, dusty, a few small rocks
Entrance condition (stability, fallen debris)	Stable
Entrance temperature / humidity/ airflow	Mod, as for external temp/humidity
Bat evidence / other comments	SM4 (not GHD) has already been set here since 2018- SMA 4421 - S4404421 (not GHDs, no data collected)
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number 1/1	Due to PLNBs present - did not enter the cave very far
Entrance shape / height m/ width m / orientation/ position	
Chamber shape/ width m/ height m	Very low flat and deep H 0.5 m depth > 20 m W around 15 m
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Dusty, uniform, no large rocks, level floor
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Low, mod level/flat other chambers passages unknown
Condition (stability, fallen debris)	Stable
Temperature and humidity	High
Airflow / evidence of moisture/water (seepage pools etc)	Low air flow, dry
Bat evidence / other comments	At least 10 PLNB present

CAVE DIAGRAM rha12


Top view
?
~10 PLNBs roosting some flying around
Side view
20-25m
Include following details in sketch: - approx dimensions of entrance, passage and chambers (width, height, depth) - - location of bats in cave if observed

GHD – Roost/cave habitat assessment form	
Cave observer:RBC	Date/time: 27/10/20 Cave no/name: cave 18 RBC (rha18)
Elevation: 247 m	Location (GPS and map ref): Latitude: 21.22236 Longitude: 118.8893
Position (geography e.g top of BIF, midway etc)	Upper slope
Cave morphology – ENTRANCE (describe number of entrances, size, shape, position - floor)	
Entrance shape / height (m) / width (m)	0.7m w x 0.4 m h
Entrance aspect:/ position (of opening e.g ground level, elevated)	SE aspect 
Floor / ceiling type (sloping, flat, rough)	Rough stable entrance is partially blocked with stones (cultural)
Entrance condition (stability, fallen debris)	Stable
Entrance temperature / humidity/ airflow	High temp (warm/hot day) moderate humidity
Bat evidence / other comments	Nil
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Chamber number (1 of 1)	
Entrance shape / height m/ width m / orientation/ position	Cave entrance opens into chamber
Chamber shape/ width m/ height m	Oval (approx.) 0.5 high, 15-20 m w
Floor type (sloping, flat, rough) debris/fallen rocks/dust	Dusty, dirty, some fallen rocks too low and rocky to access fully
Ceiling type (smooth, cracking/crevices – add sub passages/chambers)	Rough, stable large flat area
Condition (stability, fallen debris)	Stable
Temperature and humidity	High temperature, mod humidity (32 deg c 60% humidity)
Airflow / evidence of moisture/water (seepage pools etc)	Low flow, no water
Bat evidence / other comments	A few small microbats scat
Cave morphology – CHAMBER (describe chamber entrances, size, shape, ceiling, floor, position)	
Entrance shape / height m/ width m / orientation/ position	Horizontal pipe (see diagram)
Bat evidence / other comments	This cave is potential PLNB cave but not present. Similar low expansive shape as cave 12 rbc (rha12)

CAVE DIAGRAM rha18


Position (photograph)
Other equipment details
IMPORTANT - DO NOT SHINE TORCH/OTHER LIGHT SOURCES IN CAVE FOR EXTENDED PERIODS - MONITOR CAVE FOR EXISTING BATS. IF BATS EMERGE CEASE ACTIVITY IMMEDIATELY
CAVE DIAGRAM (entrance)
Side View
Pipe
5m
End
chamber
1 of 1
Very hot humid
Top view
Cave entrance
Include following details in sketch: - approx dimensions of entrance, passage and chambers (width, height, depth) - - location of bats in cave if observed

Appendix B – Bat call survey results

Bat detector site name	Longitude	Latitude
bda1	119.0483659	-21.27811546
bda2	119.0483659	-21.27811546
bda3	119.0486019	-21.27810632
bdu1	119.059120	-21.343812
bdu2#	119.060024	-21.326443
bdu3	119.063943	-21.305434
bdu4	119.062050	-21.315554
bdu5	119.057182	-21.287112
bdu6	119.055435	-21.294520
bdu7#	119.054265	-21.269961
bdu8	119.053815	-21.272215
bdu9	119.0483659	-21.27811546
bdu10	119.0483659	-21.27811546
bdu11	119.0486019	-21.27810632
bdu12	119.0397483	-21.2335646
bdu13	118.9776597	-21.25221167
bdu14	119.0397479	-21.2335693
bdu15	119.054124	-21.25613097
bdu16*	118.977676	-21.25221386
bdu17	119.0494799	-21.2792141
bdu18	119.0485801	-21.27807058
bdu19	119.0557502	-21.2945817
bdu20	119.054204	-21.25620525
bdu21	119.0542009	-21.25620153
bdu22	119.0985525	-21.40956207
bdu23	119.0395609	-21.23367163
bdu24*	119.2363304	-21.47198658
bdu25	118.9776645	-21.25224902
bdu26	119.0793507	-21.24532442
bdu27	119.0562413	-21.2584147
bdu28	118.9776475	-21.25218408
bdu29	119.0540973	-21.25616525
bdu30	119.0233788	-21.23394055
bdu31	119.0562295	-21.2583951
bdu32	119.0483659	-21.27811546
bdu33	119.0484437	-21.27806745
bdu34	119.2361476	-21.471354
bdu35	119.0486019	-21.27810632

Table notes: * - possible faulty microphone or configuration issue # - no data collected, possible configuration or card format issue.

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu1	-	I	GVBAT1 6282	18/05/2020	5:52:00 PM	11:21:00 PM		D		D	D	D	D		D	PR	D			D
bdu1	-	I	GVBAT1 6282	19/05/2020	5:52:00 PM	.		.					D			D	D			D
bdu1	-	I	GVBAT1 6282	20/05/2020	5:52:00 PM	7:01:00 PM		D					D			D	D			D
bdu2	-	I	GVBAT2 6270	NO DATA				.												
bdu3	-	I	GVBAT3 6174	19/05/2020	5:52:00 PM	11:49:00 PM	6:14 PM	D	D				D				D			D
bdu3	-	I	GVBAT3 6174	20/05/2020	5:52:00 PM	12:25:00 AM	6:20 PM	D					D				D			D
bdu3	-	I	GVBAT3 6174	21/05/2020	5:52:00 PM	2:22:00 AM		D					D				D			D
bdu4	-	I	GVBAT4 6272	19/05/2020	5:52:00 PM	9:09:00 PM		D					D			D	D			D
bdu4	-	I	GVBAT4 6272	20/05/2020	5:52:00 PM			.					D				D			D
bdu4	-	I	GVBAT4 6272	21/05/2020	5:52:00 PM	6:54:00 PM		D					D				D			D
bdu5	-	I	GVBAT5 6269	20/05/2020	5:52:00 PM	6:21:00 PM		D	PR				D				D			D
bdu5	-	I	GVBAT5 6269	21/05/2020	5:52:00 PM	7:25:00 PM		D					D				D			D
bdu5	-	I	GVBAT5 6269	22/05/2020	5:51:00 PM	6:22:00 PM		D												
bdu6	-	I	GVBAT6 6256	21/05/2020	5:52:00 PM	7:32:00 PM		D	D				D							D
bdu6	-	I	GVBAT6 6256	22/05/2020	5:51:00 PM	5:55:00 PM		D	PR				D				D			D
bdu6	-	I	GVBAT6 6256	23/05/2020	5:51:00 PM	7:01:00 PM		D												

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu7	-	I	GVBS22BAT 6174	NO DATA																
bdu8	-	I	GVBS23BAT 6272	22/05/2020	5:51:00 PM	7:27:00 PM		D					D							D
bdu8	-	I	GVBS23BAT 6272	23/05/2020	5:51:00 PM	8:09:00 PM		D					D				D			D
bdu9	SSP Cave1	I	GVSSPoolL28 _Cave1_SM46252	21/05/2020	5:52:00 PM	6:25:00 PM		D	PR				D				D			D
bdu9	SSP Cave1	I	GVSSPoolL28 _Cave1_SM46252	22/05/2020	5:51:00 PM	6:18:00 PM		D					D				D			D
bdu9	SSP Cave1	I	GVSSPoolL28 _Cave1_SM46252	23/05/2020	5:51:00 PM	6:28:00 PM		D					D				D			D
bdu10	SSP Cave 2	I	GVSSPoolL29 _Cave2_SM46270	NO DATA		.		.												
bdu11	SSP Cave 3	I	GVSSPoolL30 _Cave3_SM46282	21/05/2020	5:52:00 PM	6:17:00 PM		D	D				D							D
bdu11	SSP Cave 3	I	GVSSPoolL30 _Cave3_SM46282	22/05/2020	5:51:00 PM	6:12:00 PM		D					D				D			D
bdu11	SSP Cave 3	I	GVSSPoolL30 _Cave3_SM46282	23/05/2020	5:51:00 PM	6:40:00 PM		D					D				D			D
bdu13	Joe's Cave	I	SMM_1_456	25/08/2020	6:12:00 PM	8:11:00 PM		D	D				D				D			D
bdu13	Joe's Cave	I	SMM_1_456	26/08/2020	6:12:00 PM	6:58:00 PM		D	D				D				D			D
bdu13	Joe's Cave	I	SMM_1_456	27/08/2020	6:13:00 PM	6:44:00 PM		D					D				D			D
bdu13	Joe's Cave	I	SMM_1_456	28/08/2020	6:13:00 PM	7:54:00 PM		D					D				D			D
bdu13	Joe's Cave	I	SMM_1_456	29/08/2020	6:13:00 PM	3:39:00 AM		D					D							D
bdu13	Joe's Cave	I	SMM_1_456	30/08/2020	6:13:00 PM	6:32:00 PM		D	D				D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu13	Joe's Cave	I	SMM_1_456	31/08/2020	6:14:00 PM	6:34:00 PM		D					D							D
bdu13	Joe's Cave	I	SMM_1_456	1/09/2020	6:14:00 PM	6:30:00 PM		D					D							D
bdu13	Joe's Cave	I	SMM_1_456	2/09/2020	6:14:00 PM	2:13:00 AM		D					D							D
bdu13	Joe's Cave	I	SMM_1_456	3/09/2020	6:14:00 PM	11:31:00 PM		D					D							D
bdu13	Joe's Cave	I	SMM_1_456	4/09/2020	6:15:00 PM	.		.					D							D
bdu13	Joe's Cave	I	SMM_1_456	5/09/2020	6:15:00 PM	.		.					D							D
bdu13	Joe's Cave	I	SMM_1_456	6/09/2020	6:15:00 PM	.		.					D							D
bdu13	Joe's Cave	I	SMM_1_456	7/09/2020	6:15:00 PM	.		.					D							D
bdu13	Joe's Cave	I	SMM_1_456	8/09/2020	6:15:00 PM	.		.					D							D
bdu14	-	I	SM2_FMG _SN_14908	7/09/2020	6:15:00 PM	6:45:00 PM		PR					.							.
bdu14	-	I	SM2_FMG _SN_14908	8/09/2020	6:15:00 PM	.		.					.							.
bdu14	-	I	SM2_FMG _SN_14908	9/09/2020	6:16:00 PM	.		.					.							PR
bdu14	-	I	SM2_FMG _SN_14908	10/09/2020	6:16:00 PM	.		.					.							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	23/08/2020	6:12:00 PM	6:09:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	24/08/2020	6:12:00 PM	6:23:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	25/08/2020	6:12:00 PM	6:19:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	26/08/2020	6:12:00 PM	6:14:00 PM		D					D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu15	Chateau Cave	I	SM4_u4-S4U04382	27/08/2020	6:13:00 PM	6:14:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	28/08/2020	6:13:00 PM	6:19:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	29/08/2020	6:13:00 PM	6:12:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	30/08/2020	6:13:00 PM	6:16:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	31/08/2020	6:14:00 PM	6:19:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	1/09/2020	6:14:00 PM	6:09:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	2/09/2020	6:14:00 PM	6:14:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	3/09/2020	6:14:00 PM	6:11:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	4/09/2020	6:15:00 PM	6:12:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	5/09/2020	6:15:00 PM	6:13:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	6/09/2020	6:15:00 PM	6:14:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	7/09/2020	6:15:00 PM	6:13:00 PM		D					D				D			D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	8/09/2020	6:15:00 PM	5:52:00 PM		D					D							D
bdu15	Chateau Cave	I & ES	SM4_u4-S4U04382	9/09/2020	6:16:00 PM	5:01:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	10/09/2020	6:16:00 PM	6:25:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	11/09/2020	6:16:00 PM	6:13:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	12/09/2020	6:16:00 PM	6:30:00 PM		D					D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu15	Chateau Cave	I	SM4_u4-S4U04382	13/09/2020	6:17:00 PM	6:23:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	14/09/2020	6:17:00 PM	6:32:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	15/09/2020	6:17:00 PM	6:31:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	16/09/2020	6:17:00 PM	6:30:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	13/10/2020	6:25:00 PM	6:34:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	14/10/2020	6:26:00 PM	6:34:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	15/10/2020	6:26:00 PM	6:29:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	16/10/2020	6:26:00 PM	6:35:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	17/10/2020	6:27:00 PM	6:28:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	18/10/2020	6:27:00 PM	6:24:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	19/10/2020	6:28:00 PM	6:27:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	20/10/2020	6:28:00 PM	6:27:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	21/10/2020	6:29:00 PM	6:28:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	22/10/2020	6:29:00 PM	6:29:00 PM		D					D							D
bdu15	Chateau Cave	I	SM4_u4-S4U04382	23/10/2020	6:30:00 PM	6:27:00 PM		D					D							D
bdu16	-	I	SM2_3	NO DATA																
bdu17	SSP cave 5	I & ES	SM4_u1	22/08/2020	6:11:00 PM	7:37:00 PM		D	PR				D				D			D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu17	SSP cave 5	I	SM4_u1	23/08/2020	6:12:00 PM	8:11:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	24/08/2020	6:12:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	25/08/2020	6:12:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	26/08/2020	6:12:00 PM	7:54:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	27/08/2020	6:13:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	28/08/2020	6:13:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	29/08/2020	6:13:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	30/08/2020	6:13:00 PM	7:13:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	31/08/2020	6:14:00 PM	6:57:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	1/09/2020	6:14:00 PM	7:21:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	2/09/2020	6:14:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	3/09/2020	6:14:00 PM	7:16:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	4/09/2020	6:15:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	5/09/2020	6:15:00 PM	9:40:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	6/09/2020	6:15:00 PM	.		.					D							D
bdu17	SSP cave 5	I	SM4_u1	7/09/2020	6:15:00 PM	7:05:00 PM		D					D							D
bdu17	SSP cave 5	I	SM4_u1	8/09/2020	6:15:00 PM	.		.					D							D

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bdu18	SSP cave 3	I & ES	SM4_u2	22/08/2020	6:11:00 PM	6:43:00 PM		D	PR	D		D	D		PR	D				D
bdu18	SSP cave 3	I	SM4_u2	23/08/2020	6:12:00 PM	6:46:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	24/08/2020	6:12:00 PM	6:53:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	25/08/2020	6:12:00 PM	7:00:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	26/08/2020	6:12:00 PM	6:48:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	27/08/2020	6:13:00 PM	6:48:00 PM		D	PR				D							D
bdu18	SSP cave 3	I	SM4_u2	28/08/2020	6:13:00 PM	6:49:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	29/08/2020	6:13:00 PM	6:47:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	30/08/2020	6:13:00 PM	6:57:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	31/08/2020	6:14:00 PM	6:33:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	1/09/2020	6:14:00 PM	6:24:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	2/09/2020	6:14:00 PM	6:37:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	3/09/2020	6:14:00 PM	6:34:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	4/09/2020	6:15:00 PM	6:36:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	5/09/2020	6:15:00 PM	6:31:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	6/09/2020	6:15:00 PM	6:29:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	7/09/2020	6:15:00 PM	6:49:00 PM		D					D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu18	SSP cave 3	I	SM4_u2	8/09/2020	6:15:00 PM	6:42:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	9/09/2020	6:16:00 PM	6:44:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	10/09/2020	6:16:00 PM	6:40:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	11/09/2020	6:16:00 PM	6:54:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	12/09/2020	6:16:00 PM	6:43:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	13/09/2020	6:17:00 PM	6:47:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	14/09/2020	6:17:00 PM	6:46:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	15/09/2020	6:17:00 PM	6:46:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	16/09/2020	6:17:00 PM	6:41:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	17/09/2020	6:18:00 PM	6:47:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	18/09/2020	6:18:00 PM	8:03:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	19/09/2020	6:18:00 PM	6:39:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	20/09/2020	6:18:00 PM	6:50:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	21/09/2020	6:18:00 PM	6:41:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	9/10/2020	6:24:00 PM	6:45:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	10/10/2020	6:24:00 PM	6:45:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	11/10/2020	6:25:00 PM	6:59:00 PM		D					D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu18	SSP cave 3	I	SM4_u2	12/10/2020	6:25:00 PM	6:52:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	13/10/2020	6:25:00 PM	6:51:00 PM		D					D							D
bdu18	SSP cave 3	I	SM4_u2	14/10/2020	6:26:00 PM	6:53:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	10/09/2020	6:16:00 PM	6:35:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	11/09/2020	6:16:00 PM	7:27:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	12/09/2020	6:16:00 PM	7:02:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	13/09/2020	6:17:00 PM	6:35:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	14/09/2020	6:17:00 PM	7:09:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	15/09/2020	6:17:00 PM	8:41:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	16/09/2020	6:17:00 PM	6:49:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	17/09/2020	6:18:00 PM	8:27:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	13/10/2020	6:25:00 PM	4:13:00 AM		D					D							D
bdu19	Python Cave	I	SM2_u2	14/10/2020	6:26:00 PM	9:31:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	15/10/2020	6:26:00 PM	7:49:00 PM		D	D				D							D
bdu19	Python Cave	I	SM2_u2	16/10/2020	6:26:00 PM	3:28:00 AM		D					D							D
bdu19	Python Cave	I	SM2_u2	17/10/2020	6:27:00 PM	8:43:00 PM		D					D							D
bdu19	Python Cave	I	SM2_u2	18/10/2020	6:27:00 PM	1:22:00 AM		D					D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu19	Python Cave	I	SM2_u2	19/10/2020	6:28:00 PM	.		.					D							D
bdu20	Chateau Cave	ES	SMM_1_456	23/10/2020	6:30:00 PM	6:35:00 PM		D					D				D			D
bdu21	Chateau Cave	ES	SMM_2_455	23/10/2020	6:30:00 PM	6:28:00 PM		D					D				D			D
bdu22	-	I	SM4_SU08812	23/10/2020	6:30:00 PM	.	8:02 PM	.	D		PR		D				D			D
bdu22	-	I	SM4_SU08812	24/10/2020	6:30:00 PM	10:26:00 PM	6:58 PM	D	D				D				D			D
bdu22	-	I	SM4_SU08812	25/10/2020	6:31:00 PM		8:11 PM	.	D				D				D			D
bdu22	-	I	SM4_SU08812	26/10/2020	6:31:00 PM		8:02 PM	.	D				D				D			D
bdu23	Fig Pool	I	SM2_u1	22/10/2020	6:29:00 PM	6:55:00 PM		D	PR	D	PR		D				D			D
bdu23	Fig Pool	I	SM2_u1	23/10/2020	6:30:00 PM	6:46:00 PM		D	D				D				D			D
bdu23	Fig Pool	I	SM2_u1	24/10/2020	6:30:00 PM	6:50:00 PM		D					D				D			D
bdu24	-	I	SM2_FMG _SN_14908	NO DATA				.												
bdu25	Joe's Cave	I	SM4_u1	22/10/2020	6:29:00 PM	7:43:00 PM		D	PR				D							D
bdu25	Joe's Cave	I	SM4_u1	23/10/2020	6:30:00 PM	7:28:00 PM		D					D							D
bdu25	Joe's Cave	I	SM4_u1	24/10/2020	6:30:00 PM	7:01:00 PM		D					D							D
bdu25	Joe's Cave	I & ES	SM4_u1	25/10/2020	6:31:00 PM	6:43:00 PM		D												
bdu26	Pool 12	I	SM4_u1	26/10/2020	6:31:00 PM	7:02:00 PM		D					D							D
bdu26	Pool 12	I	SM4_u1	27/10/2020	6:32:00 PM	7:05:00 PM		D					D							D

Site name	Location name	Survey type (I = insitu, ES = emergence survey)	Detector name/number	Date	Sunset Civil Twilight	Time of first R. aurantia call	Time of first M. gigas call	Rhinonicteris aurantia	Macroderma gigas	Austronomus australis	Chaerephon jobensis	Saccolaimus flaviventris	Taphozous georgianus	Taphozous hilli	Mormopetrus Ozimops lumsdenae	Chalinolobus gouldii	Scotorepens greyii	Nyctophilus sp.	Chalinolobus morio	Vespadelus finlaysoni
bdu27	Cave 13	ES	SMM_2_455	26/10/2020	6:31:00 PM	.		.					D							D
bdu28	Joe's Cave	ES	SMM_2_455	25/10/2020	6:31:00 PM	6:53:00 PM		D	PR				D				D			D
bdu30	Wallabay Cave	I	SMM_2_455	26/10/2020	6:31:00 PM	.		.					D							D
bdu30	Wallabay Cave	I	SMM_2_455	27/10/2020	6:32:00 PM	.		.					D							D
bdu31	Cave 13	I	SM2_u1	25/10/2020	6:31:00 PM	.		.					D				D			D
bdu31	Cave 13	I & ES	SM2_u1	26/10/2020	6:31:00 PM	10:11:00 PM		D					D				D			D
bdu31	Cave 13	I	SM2_u1	27/10/2020	6:32:00 PM	7:53:00 PM		D					D				D			D
bdu32	SSP cave2	I	SMM_2_455	25/08/2020	6:12:00 PM	6:40:00 PM		D					D				D			D
bdu32	SSP cave2	I	SMM_2_455	26/08/2020	6:12:00 PM	6:35:00 PM		D					D				D			D
bdu32	SSP cave2	I	SMM_2_455	27/08/2020	6:13:00 PM	6:50:00 PM		D					D				D			D
bdu32	SSP cave2	I	SMM_2_455	28/08/2020	6:13:00 PM	6:45:00 PM		D									D			D
bdu32	SSP cave2	ES	SMM_1_456	28/10/2020	6:32:00 PM	6:50:00 PM		D	D	D			D				D			D
bdu33	SSP cave3	ES	SM4_u2	28/10/2020	6:32:00 PM			.					D				D			D
bdu34	-	I	SM4_SU08815	24/10/2020	6:30:00 PM	3:20:00 AM		D					D				D			D
bdu34	-	I	SM4_SU08815	25/10/2020	6:31:00 PM			.					D				D			D
bdu34	-	I	SM4_SU08815	26/10/2020	6:31:00 PM	9:35:00 PM		D					D				D			D
bdu35	SSP cave3	ES	SMM_2_455	28/10/2020	6:32:00 PM	7:02:00 PM		D												

Table notes: - Time of first call – due to the large volume of data not all first calls were reported for sites beyond two hours past sunset. - The analysis process focussed on R. aurantia and M. gigas and consequently the presence of other bat species may be under reported – Due to the constraints associated with analysing calls for M. gigas some calls from the period 2 hours after sunset onwards may have been missed and the species may be underreported at some sites, however the manual review process greatly reduces the possibility of missing calls during the emergence period for this species.

GHD

Level 2, 45 Brougham Street
Geelong VIC 3220
T: 61 3 5273 1800 F: 61 3 5273 1801 E: gexmail@ghd.com

24DJSZNHUEPC-1850682920-13/https://projectsportal.ghd.com/sites/pp17_05/batsurveysforspectru/ProjectDocs/12528008-DEL-GHD_Targeted_Bat_survey_report_DRAFT_B_20210531.docx

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