North Star Magnetite Project: Proposed Expansion - Cumulative Impact Assessment for Terrestrial Fauna

PREPARED FOR FORTESCUE METALS GROUP LIMITED | April 2025

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Revision Schedule

Rev No	Date	Description	Signature of Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
A	12/05/2023	Draft Report for Client Review	SP	PT	BH	BH
B	23/05/2023	Draft Report Client Comments Addressed	SP/JD	SP	SP	PT
0	17/08/2023	Final Report	SP/JD	SP	SP	PT
1	19/10/2023	Updated Final Report	JD	PT	PT	LR
2	02/11/2023	Revised Final Report	JD	PT	PT	LR
3	30/01/2025	Revised Final Report EPA Comments Addressed	JD	SP	SP	LR
3A	28/03/2025	Draft Report - Inclusion of Updated Data	JD	EJ	SP	KK
4	16/04/2025	Revised Final Report Inclusion of Updated Data	JD	EJ	PT	KK

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Abbreviations

Abbreviation	Definition
BC Act	*Biodiversity Conservation Act 2016*
DPIRD	Department of Primary Industries and Regional Development
DSO	Direct shipping ore
DWER	Department of Water and Environmental Regulation
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERD	Environmental Review Document
FMG	Fortescue Metals Group
FMGIB	FMG Iron Bridge
ha	Hectares
IBRA	Interim Biogeographic Regionalisation for Australia
km	Kilometre
NRAG	Natural Resources Assessment Group
MINEDEX	Mines and Mineral Deposits

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1 Introduction

FMG Iron Bridge (Aust) Pty Ltd (FMGIB) operates the existing North Star Magnetite Project (Approved Proposal), located approximately 110 kilometres (km) southeast of Port Hedland in the Pilbara region of Western Australia. North Star comprises an open cut iron ore mine and associated infrastructure, including roads, administration buildings, accommodation camp, aerodrome, borefield and slurry/ raw water pipeline(s). The current mine has a Development Envelope of 5,276 hectares (ha) and a Disturbance Footprint of 3,493 ha. An amendment has been sought through the Environmental Protection Authority (EPA) under section s 38 of the *Environmental Protection Act 1986* (EP Act) to increase the Development Envelope to 6,702.4 ha and the Disturbance Footprint to 4,099.9 ha to enable the development of new mine pits (the Proposed Amendment).

Fortescue Metals Group (FMG) engaged Stantec Australia Pty Ltd (Stantec) to undertake a cumulative impact assessment (the Assessment) to address the following regulatory comment from the EPA with regard to cumulative impact assessment for terrestrial fauna in relation to the North Star Magnetite Project Proposed Expansion (the Proposed Amendment):

> '*Describe the assessment(s) undertaken for the cumulative impacts on significant fauna habitat in a regional context (including, but not limited to bat roosting sites and permanent water pools), to ensure the extent and significance of impact from the amended proposal on threatened fauna species is clear and adequate*'.

The Proposed Amendment has the potential to cumulatively impact terrestrial fauna habitats and species present within the Revised Development Envelope and surrounding region. All significant fauna species that occur, or are likely to occur, within the Approved Proposal and Proposed Amendment may be affected by cumulative impacts from existing or foreseeable projects within the bioregion.

Potential cumulative impacts to terrestrial fauna include the cumulative total of land disturbance (direct impact) and cumulative disturbance due to vehicle strike, introduced species, increased levels of light, vibration and noise, dust, changed fire and water regimes (indirect impacts) resulting in the following:

- cumulative habitat loss/ degradation;
- increases in habitat fragmentation; and
- responses to disturbance or other behavioural changes in individual animals.

2 Methods

Cumulative impacts to significant terrestrial fauna from the North Star Proposed Amendment were assessed at a local, landscape, and bioregional scale where possible, defined as follows:

- Local scale: expressed as the cumulative increase in impacts to significant terrestrial fauna from the North Star Magnetite Project (Approved Proposal) combined with impacts from the North Star Magnetite Project (Proposed Amendment); includes the area around the impact site that has similar geology, topography, soils to the Approved Project.
- Landscape scale: expressed as the cumulative impacts from third-party projects within 100 km of the Approved Proposal.
- Bioregional scale: expressed as the cumulative impacts from third-party projects within the same Interim Biogeographic Regionalisation for Australia (IBRA) bioregion (e.g. Pilbara bioregion).

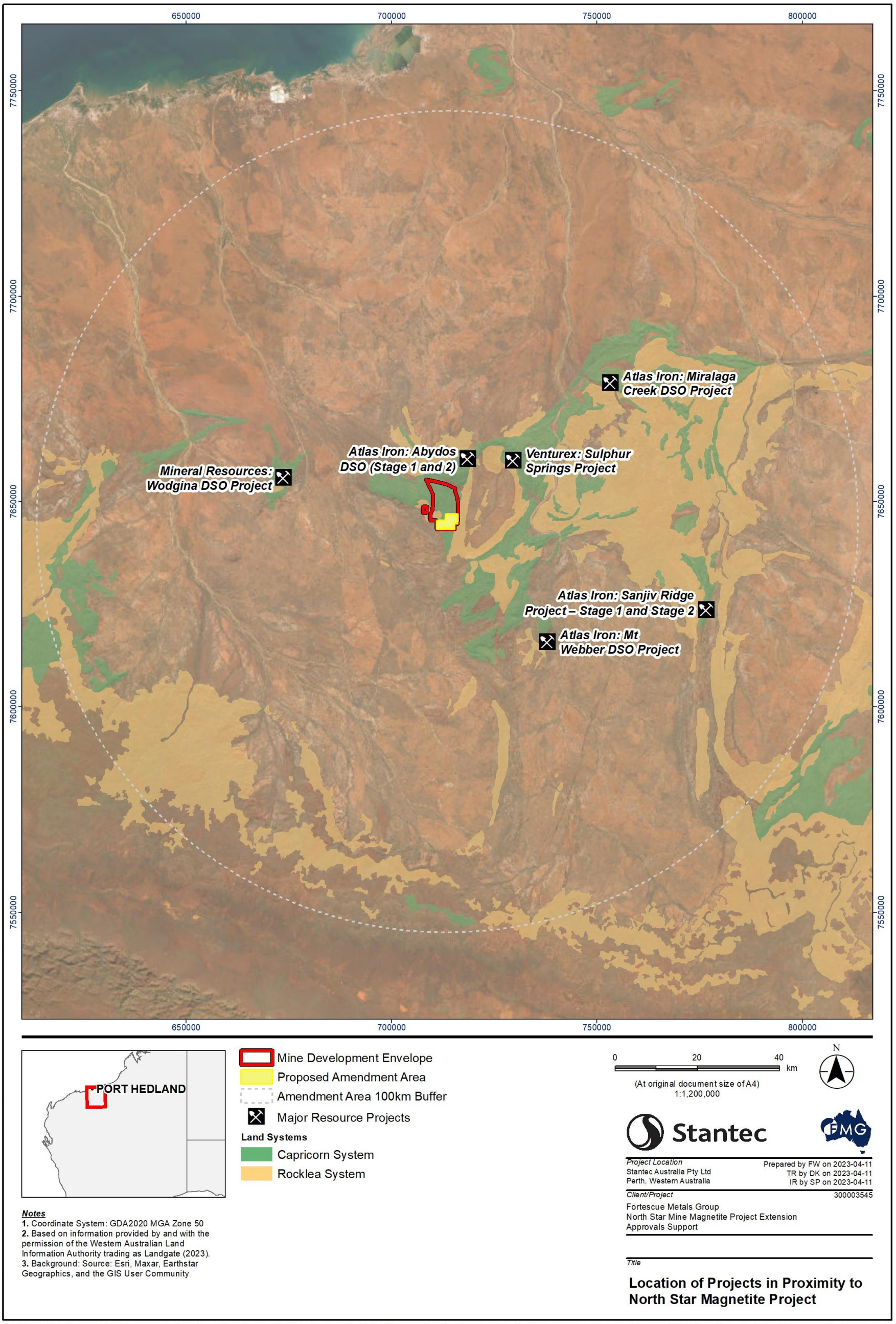
There is no central consolidated database that provides the extent of cumulative impacts of native vegetation clearing on fauna habitat in the Pilbara bioregion. The following publicly available information sources can assist with informing the cumulative impact assessment to terrestrial fauna at a landscape scale:

- DBCA Statewide Vegetation Statistics (updated in 2021) (Department of Biodiversity Conservation and Attractions, 2019);
- Environmental Offsets Register (Government of Western Australia, 2011);
- Proposal Search (Environmental Protection Authority, 2023);
- Mines and Mineral Deposits (MINEDEX) online search (Department of Mines Industry Regulation and Safety, 2023); and
- Clearing referrals and other matters not for public comment or appeal search (Department of Water and Environmental Regulation, 2023).

Projects within a 100 km radius of the Proposed Amendment which occur within comparable land systems to the Proposed Amendment (**Figure 2-1**) and have publicly accessible data were investigated to determine their impact on significant terrestrial fauna and their habitats. The 100 km radius was chosen as it covers a significant amount of the Capricorn Land System and the mines, operating and approved, that sit within that land system. Given the variability of data available for different projects, and there being no regional dataset for vertebrate fauna habitat in the Pilbara, to effectively undertake cumulative assessment the approach was to use land systems, together with consolidating the mapping to fauna habitat, to identify where there were likely to be impacts on the significant species found in the North Star survey area. This approach draws focus in on the projects most likely to impact on the relevant species and provides more confidence in the outcome of the cumulative impacts study than a broad-brush approach. Scholarly articles demonstrate support for environmental surrogates for biodiversity in conservation planning, specifically the use of land systems and similarly derived land classifications. Each type of land system supported components of biodiversity either not found, or found infrequently, on other land systems, suggesting that land systems function as surrogates for biodiversity, and that conservation-area networks representing land-system diversity will also represent biological diversity (Oliver et al, 2004). Existing and reasonably foreseeable third-party projects which may contribute to cumulative impacts with the Proposed Amendment include:

- Fortescue Metals Group: North Star Magnetite Project (Approved Proposal);
- Atlas Iron: Sanjiv Ridge Project – Stage 1 and Stage 2;
- Atlas Iron: Miralaga Creek DSO Project;
- Atlas Iron: Abydos DSO (Stage 1 and 2);
- Atlas Iron: Mt Webber DSO Project;
- Atlas Iron: Wodgina DSO Project (Stage 1 and 2); and
- Venturex: Sulphur Springs Project.

Where possible, the cumulative impacts relevant to the Proposed Amendment have been calculated based on the third-party projects' indicative disturbance footprint. Alternatively, a more conservative estimate is provided using the Development Envelope, where values for the indicative disturbance footprint are not publicly available. Subsequently, the percentage increase in cumulative impacts attributed to the Proposed Amendment were ranked, defined as Low (0- 10%); Moderate (>10%- 30%) and High (>30%). This Assessment takes into consideration mitigation, monitoring and adaptive management measures applied by proponents to minimise potential impacts.



Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Figure 2-1: Assessed third-party projects within 100 km of Proposed Amendment.

2.1 Limitations and Assumptions

In undertaking the Assessment, in the context of the Proposal within the Pilbara bioregion, a number of limitations and assumptions apply:

- Although land clearing or degradation may be estimated, the final impact to the local population or regional distribution of a species is difficult to quantify based on information available in the public domain.
- There is a lack of consistency in naming convention for fauna habitat. Consolidation of fauna habitat mapping across third-party foreseeable projects has been consolidated as far as practicable to allow for cumulative assessment. For example, the broad fauna habitat type 'Rocky Escarpment' is not a common descriptor within fauna habitat mapping undertaken for projects within the bioregion and is usually encompassed by more broad habitat types. Therefore, for the purposes of this cumulative impact assessment, it has been merged with the 'Gorges & Gullies' fauna habitat type.
- Survey effort within the Pilbara bioregion is largely undertaken within mining tenure; therefore, there will be a bias in the occurrence of species on mining and exploration tenements due to the focused survey effort.
- Bioregional records of species often contain limited information or do not assign roost category to Ghost Bat (GB) and Pilbara Leaf-nosed Bat (PLNB) caves, the number of regional caves depicted in **Figure 3-1** and **Figure 3-2** are likely to be underestimated and are based on publicly available information from regulatory guidance, third-party approvals documentation and internal FMG database records, noting that:
    - Regional data sets available for the Ghost Bat are limited (unable to determine whether the majority of regional roost caves are subject to impact, publicly available regional Ghost Bat roost data does not assign Ghost Bat roost category information). The majority (75%) of third-party approvals documentation reviewed for this assessment does not contain information in relation to the category of Ghost Bat roosts (Bat Call WA, 2021a).
    - A more comprehensive regional data set was available for the Pilbara Leaf-nosed Bat at the time of reporting which assigned Pilbara Leaf-nosed Bat roosts according to roost category (Bat Call WA, 2021b; TSSC, 2016a) **(Table 3-5)**
    - The regional data set is compiled from multiple data sources, (Bullen et al., 2023), third-party Approvals documents and FMG regional PLNB roost data, therefore it is possible that a double up may occur for regional roost locations layer which was extrapolated. Within a 100km radius of the Proposed Amendment, it is estimated that potentially 49 roost caves from the data set may overlap, and potential duplications in data were addressed through removing the regional data set point, however it is not possible to determine conclusively if they are the same roost cave.
- Cumulative impact assessment calculations do not take into consideration areas outside of those assessed by each relevant third-party proposal.
- Cumulative impacts to terrestrial fauna and fauna habitats resulting from third-party projects are conservative and based on information available in the public domain and may not represent the most accurate levels of disturbance.
- The extent and magnitude of indirect impacts, such as noise, light, or changed fire regimes, have not been well documented within publicly available information for terrestrial fauna species of the Pilbara bioregion; therefore, this Assessment is limited in its accuracy.
- It is assumed that other terrestrial fauna within the Proposed Amendment, including common and widespread species, would also be subject to a similar range of impacts.
- Direct and indirect impacts that may affect terrestrial fauna can be difficult to quantify and predict in advance of development occurring.

3 Cumulative Impacts: Terrestrial Fauna

3.1 Significant Fauna Species

For the purposes of this Assessment, terrestrial fauna species considered to be of significance are those that are listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or the Western Australian *Biodiversity Conservation Act 2016* (BC Act). Potential cumulative impacts to significant terrestrial fauna include:

- direct impacts through the removal of terrestrial fauna habitat (**Section 3.2**);
- the combined increase of indirect impacts (vehicle strike, introduced species, increased levels of light, vibration and noise, dust, changed fire and water regimes); and
- potential increases to the abundance of introduced species due to the localised cumulative impacts from the Proposed Amendment and the Approved Proposal could result in increased pressure from predation, competition for food resources, and further habitat degradation for significant fauna species.

Although direct impacts (through habitat loss from land clearing) can be calculated, indirect impacts to local and regional populations are difficult to quantify.

Cumulative impacts to significant terrestrial fauna resulting from the Proposed Amendment may have the potential to impact the carrying capacity (i.e. maximum number of species or individuals that the environment can support) within the area for some significant terrestrial fauna species, which is largely dependent on the species' specific resource requirements and home range. Where cumulative habitat loss occurs to species which have exclusive home ranges and specific habitat requirements within the species home range, there is the potential for the cumulative disturbance to result in a reduced maximum population size for the species into the future. Examples of significant species with exclusive home ranges and specific habitat requirements relevant to the Proposed Amendment include the:

- Ghost Bat (*Macroderma gigas*; Vu, BC Act; Vu, EPBC Act), which relies on the presence of roost caves and, to a lesser extent, water pools;
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*; Vu, BC Act; Vu, EPBC Act), which relies on the presence of roost caves and water pools;
- Pilbara Olive Python (*Liasis olivaceus barroni*; Vu, BC Act; Vu, EPBC Act) which relies on the presence of permanent water pools and rocky habitat for denning; and
- Northern Quoll (*Dasyurus hallucatus*; En, BC Act; En, EPBC Act), which relies on rocky habitat for denning.

The confirmed records for significant terrestrial fauna species, and those considered likely to occur across relevant assessed third-party projects within 100 km of the Proposed Amendment within comparable land systems, are shown in **Table 3-1**. The following species have been recorded or are considered likely to occur across all third-party projects, the Approved Proposal, and the Proposed Amendment:

- Northern Quoll;
- Ghost Bat;
- Pilbara Leaf-nosed Bat;
- Western Pebble-mound Mouse (*Pseudomys chapmani*; P4, BC Act).

This indicates that these significant terrestrial fauna species are likely to be subject to cumulative impacts from development at a landscape scale within the bioregion. There is a strong correlation between significant terrestrial fauna species recorded across all projects within 100 km of the Proposed Amendment, and their specific habitat requirements, with 'Gorges and Gullies' habitat and, to a lesser extent, 'Hills, Ranges and Plateaux' habitat providing supporting habitat for significant fauna species. This is linked to the regular occurrence of caves and/or water sources which are important for breeding, shelter, and foraging for these species.

Table 3-1: Significant terrestrial fauna species Confirmed, Highly Likely, or Likely to occur at existing and reasonably foreseeable Projects assessed within 100 km of the Proposed Amendment within comparable land systems.

Significant Terrestrial Fauna	Conservation Status[1]		Proposed Amendment[2]	Approved Proposal[3]	Atlas Iron: Abydos DSO Stage 1 Study Area[4]	Atlas Iron: Abydos DSO Stage 2 Study Area[5]	Atlas Iron: Miralga Creek DSO[6]	Venturex: Sulphur Springs Project[7]	Atlas Iron: Sanjiv Ridge Stage 1[8]	Atlas Iron: Sanjiv Ridge Stage 2[9]	Atlas Iron: Mt Webber DSO Project[10]	Atlas Iron Wodgina DSO Project (Stage 1 and 2)[11]
	EPBC Act	BC Act										
Mammals												
Northern Quoll (*Dasyurus hallucatus*)	EN	EN	√	√	√	√	√	√	√	√	√	√
Greater Bilby (*Macrotis lagotis*)	VU	VU	-	Likely	Likely	-	-	-	-	-	-	-
Ghost Bat (*Macroderma gigas*)	VU	VU	√	√	√	√	√	√	√	√	√	-
Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*)	VU	VU	√	√	√	√	√	√	√	√	√	√
Western Pebble-mound Mouse (*Pseudomys chapmani*)	-	P4	Likely	√	√	Highly likely	√	√	√	Highly likely	√	-
Long-tailed Dunnart (*Sminthopsis longicaudata*)	-	P4	Likely	√	√	-	-	√	Likely	Likely	-	
Spectacled Hare-wallaby (*Lagorchestes conspicillatus leichardti*)	-	P4	-	Likely	√	-	Likely	-	√	Highly Likely	Likely	-
Crest-tailed Mulgara (*Dasycercus cristicauda*)	VU	VU	-	Likely	Likely	-	Likely	-	-	-	Likely	-
Brush-tailed Mulgara (*Dasycercus blythii*)	-	P4	-	Likely	Likely	-	Likely	-	-	-	Likely	-

Significant Terrestrial Fauna	Conservation Status[1]		Proposed Amendment[2]	Approved Proposal[3]	Atlas Iron: Abydos DSO Stage 1 Study Area[4]	Atlas Iron: Abydos DSO Stage 2 Study Area[5]	Atlas Iron: Miralga Creek DSO[6]	Venturex: Sulphur Springs Project[7]	Atlas Iron: Sanjiv Ridge Stage 1[8]	Atlas Iron: Sanjiv Ridge Stage 2[9]	Atlas Iron: Mt Webber DSO Project[10]	Atlas Iron Wodgina DSO Project (Stage 1 and 2)[11]
	EPBC Act	BC Act										
Lakeland Downs Mouse (*Leggadina* lakedownensis)	-	P4	-	-	-	-	-	-	-	-	Likely	-
Birds												
Peregrine Falcon (*Falco peregrinus*)	-	OS	√	Likely	-	Likely	√	-	√	Highly Likely	√	-
Grey Falcon (*Falco hypoleucos*)	VU	VU	Likely	√	Likely	Likely	√	-	-	-		-
Fork-tailed Swift (*Apus pacificus*)	MI	Mi	Likely	√	-	-	-	-	-	-	Likely	-
Eastern Great Egret (*Ardea modesta*)	MI		-	Likely	-	-	-	-	-	-	-	-
Reptiles												
Pilbara Olive Python (*Liasis olivaceus barroni*)	VU	VU	√	√	√	-	Likely	-	√	Highly Likely	√	Likely
Gane's Blind Snake (*Anilios ganei*)	-	P1	Likely	Likely	-	Likely	Likely	-	Likely	-	√	-
Black-lined Ctenotus (*Ctenotus nigrilineatus*)	-	P1	-	-	-	-	Likely	-	-	-	-	-

Note: √ = significant fauna species confirmed to occur within the Development Envelope; Highly Likely = significant fauna species considered Highly Likely to occur within the respective Development Envelope or Study Area Likely = significant fauna species considered Likely to occur within the respective Approved Proposal Development Envelope; [1]Conservation status' definitions as per (DBCA, 2016; DCCEEW, 2023); [2](FMG, 2022);[3](FMG, 2013);[4](Coffey, 2012);[5](Coffey, 2013);[6](Atlas, 2020);[7](MBS Environmental, 2016);[8](Atlas, 2019);[9](Atlas, 2021);[10](Outback Ecology, 2013);[11](Atlas, 2011).

3.2 Terrestrial Fauna Habitat

Overall, habitat removal and degradation are together considered to be the primary impact to significant terrestrial fauna species within the Proposed Amendment. Fauna habitats may be significant if they provide habitat important to the life history of a significant species (i.e. breeding, feeding, and roosting or aggregation areas), or where they are unique or isolated habitats (e.g. wetlands) in the landscape or region (Environmental Protection Authority, 2016). These significant fauna habitats are also a focus of this Assessment.

Detailed fauna habitat mapping has been completed for the Proposed Amendment. However, terrestrial fauna habitat has not been mapped at a comparable scale for the wider Pilbara bioregion; therefore, cumulative impacts for terrestrial fauna habitat cannot be assessed at a bioregional scale. Land system mapping has been undertaken by the Natural Resources Assessment Group (NRAG) from the Department of Primary Industries and Regional Development (DPIRD; formerly the Department of Agriculture and Food (DAFWA) and this allows for assessing cumulative impacts with respect to broad landscape units as a surrogate for broad fauna habitat. In contrast, the consolidation of broad fauna habitat mapping across third-party projects at a landscape scale allows for the assessment of the cumulative disturbance to broad fauna habitats. The cumulative impact, expressed as disturbance to land systems is discussed in **Section 3.2.1** and the cumulative impact expressed as consolidated fauna habitats occurring within the Proposed Amendment Area from third-party projects occurring within comparative land systems within 100 km of the Proposed Amendment is discussed in **Section 3.2.2.**

3.2.1 Land Systems

There are three land systems within the Proposed Amendment Area comprising; Talga, Capricorn and Rocklea, two of which are proposed to be impacted: Capricorn and Rocklea (**Figure 2-1**). The Capricorn land system predominately comprises steep ridges, hills and upper slopes of sandstone and dolomite, supporting stony soils and shrubby hard and soft spinifex grasslands (Van Vreeswyk et al., 2004). Rocky ridges provide important terrestrial fauna habitats such as den and roost sites, while gullies and stony soils can support the formation of water pools that persist into dry periods. Significant fauna species including Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python are likely to use these areas. Due to their inaccessibility and vegetation that is not preferred by livestock, these areas are often largely undisturbed and provide safe refuges for fauna species. The vegetation condition of the Capricorn land system is generally very good. The proposed clearing will result in a 50% reduction of the local extent of this land system in the Proposed Amendment Area, which will result in localised impacts to significant fauna species utilising habitats within the Capricorn land system.

The Rocklea land system is one of the largest in the Pilbara, covering 2,299,300 ha. A large proportion of the Rocklea land system comprises hills, ridges and plateau with stony soils, and lower slopes and stony plains that support hard hummock grasslands and occasionally soft grassy shrublands. A small proportion of the land system supports upper drainage lines and drainage floors and channels. The rocky ridges provide shelter for significant fauna species including Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python, while the drainage channels support tall shrublands or woodlands of *Acacia* and *Eucalyptus* spp. which provide important foraging and dispersal habitat for the Northern Quoll, Ghost Bat and Pilbara Leaf-nosed Bat. The proposed clearing will result in a reduction of 0.6% of its local area extent of the Rocklea land system; therefore, it is unlikely to have a significant impact to fauna species utilising habitats within this land system given the remaining extent available within the Proposed Amendment and surrounds.

Cumulative impacts to land systems from the Proposed Amendment and third-party projects within 100k m of the Proposed Amendment are shown in **Table 3-2**. The extent of the Capricorn land system is 529,600 ha with cumulative impacts within 100 km of the Proposal expected to total 7,292.9 ha. The Proposed Amendment contributes a 9% (low) increase to the total extent of cumulative impact to this land system at a landscape scale. A 0.3% (negligible) increase in cumulative impacts to clearing within the Rocklea land system is attributed to the Proposed Amendment.

Noting the overall scale of the Proposed Amendment, clearing associated with the Proposed Amendment will not lead to a significant increase in cumulative impacts to these land systems at a bioregional scale, with approximately 85% and 92% of the land systems occurring within the Proposed Amendment remaining when considering the cumulative disturbance attributed to third-party projects within 100 km of the Proposed Amendment.

Considering the above, and that all land systems within the Proposed Amendment Development Envelope will have greater than 30% of their pre-European extent remaining, it is unlikely that clearing will result in a significant cumulative impact to associated land systems.

Table 3-2: Cumulative impact to land systems within the Proposed Amendment.

Land System		Capricorn	Rocklea
Pilbara Bioregion	Extent (ha)	529,600	2,299,300
Proposed Amendment	Extent Indicative Footprint (ha)	604.8	2.1
Approved Proposal	Extent Indicative Footprint (ha)	2,686	177.3
Third-party Projects*	Extent Disturbance (ha)	~4,000	~500
Total Impact attributed to Third-party Projects and Approved Proposal	Extent Disturbance (ha)	6,686	677.3
Cumulative Impact	Total Cumulative Disturbance (ha)	7,292.90	679.4
	% increase cumulative Impacts attributed to the Proposed Amendment (cumulative impacts significance rating)	9% (Low)	0.3% (Negligible)
% remaining within Pilbara Bioregion		85.10%	92.00%

* Atlas Iron: Sanjiv Ridge Project – Stage 1 and Stage 2, Atlas Iron: Miralaga Creek DSO Project, Atlas Iron: Wodgina DSO Project; and Venturex: Sulphur Springs Project, Atlas Iron: Abydos DSO Project Stage 1 and Stage 2

3.2.2 Broad Fauna Habitat

For the purpose of this Assessment, broad terrestrial fauna habitat within the Proposed Amendment was categorised into three types to allow for consolidation and comparison with third-party projects assessed:

- *Gorges and Gullies*: considered of High habitat significance as it provides potential denning and foraging habitat for the Northern Quoll and Pilbara Olive Python. This habitat also provides primary foraging habitat for the Ghost Bat and the Pilbara Leaf-nosed Bat, as well as roosting habitat for the Ghost Bat and potential nocturnal refuges for the Pilbara Leaf-nosed Bat.
- *Hills, Ranges and Plateau*: considered of High habitat significance as it provides supporting habitat for the Northern Quoll and Pilbara Olive Python. The Peregrine Falcon may also use the cliff areas for breeding habitat. This habitat type also supports numerous caves that are considered significant habitat for the Ghost Bat and Pilbara Leaf-nosed Bat.
- *Minor Drainage Line*: considered of Low to Moderate habitat significance as it provides dispersal and foraging habitat for the Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat, Pilbara Olive Python, potential foraging and breeding habitat for the Grey Falcon, and foraging habitat for the Peregrine Falcon.

The Regional Occurrence of fauna habitats considered in cumulative impact assessment are presented in **Table 3-3**. Cumulative potential disturbance to consolidated broad terrestrial fauna habitats occurring within the Proposed Amendment, as a result of third-party projects occurring within comparable land systems within 100 km, are presented in **Table 3-4**.

All broad terrestrial fauna habitats within the Proposed Amendment are well represented in the wider region and the cumulative impacts to terrestrial fauna habitat from the Proposed Amendment will not result in an increase in cumulative impact to any specific broad fauna habitat type by more than 10%. Increase in cumulative impacts to consolidated broad fauna habitats attributed to the Proposed Amendment include:

- Gorges and Gullies- 8.5% (Low) increase in cumulative impacts attributed to the Proposed Amendment
- Hills, Ranges & Plateau- 9.4% (Low) increase in cumulative impacts attributed to the Proposed Amendment
- Minor Drainage Line- 3.4% (Low) increase in cumulative impacts attributed to the Proposed Amendment.

However, the percentage increases attributed to the Proposed Amendment are unlikely to result in a significant impact to significant fauna through the removal of fauna habitat, as discussed below. Total cumulative disturbance through removal of (14% mapped extent) Gorges and Gullies habitat across third-party projects within 100km may impact the denning, roosting and foraging ability of 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*) (Spectrum Ecology, 2021a). Gorges and Gullies has been consolidated to include the “Rocky Escarpment”

habitat type, which has been identified as critical habitat for these species that are associated with the typical rocky ridges, outcropping, cliffs and caves found in this habitat type (Spectrum Ecology, 2021a). It may also contain potential breeding habitat of Peregrine Falcon (*Falco peregrinus*) which may utilise high ledges along cliffs for nesting (Spectrum Ecology, 2021a). Although the cumulative increase attributed to the Proposed Amendment is 'Low', the critical habitat Rocky Escarpment is likely to be overrepresented due to the consolidation of habitat within Gorge and Gullies.

The Hills, Ranges and Plateaux habitat is considered foraging and refugia habitat and the removal of (9.7% of the mapped extent) Hills, Ranges and Plateaux habitat mapped across third-party projects could potentially impact the ability of the Northern Quoll (*Dasyurus hallucatus*) whilst foraging within this habitat as well as potential breeding habitat for the Peregrine Falcon. There may also be impacts to Long-tailed Dunnart (*Sminthopsis longicaudata*) and Western Pebble-mound Mouse (*Pseudomys chapmani*) that occur in this habitat (Spectrum Ecology, 2021a).

The Minor Drainage Lines habitat type does not typically provide critical habitat for any conservation significant species. However, cumulative removal of (5.7% mapped extent across third-party projects) of this habitat within the landscape scale may result in low impacts to the foraging and dispersal ability of 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*).

Cumulative disturbance is likely to be of greater consequence for terrestrial fauna of significance such as the Ghost Bat, Pilbara Leaf-nosed Bat, and Pilbara Olive Python which utilise 'Gorges and Gullies' habitat that is important for the persistence of these species within an area, due to the regular occurrence of caves and water pools.

While clearing may result in localised impacts to individuals within the disturbance footprint, considering that these habitat types occur extensively throughout the Pilbara and are well represented in the vicinity of the Proposed Amendment, no significant impacts to terrestrial fauna are expected on a regional or local scale as a result of clearing terrestrial fauna habitat.

Cumulative impacts to significant terrestrial fauna habitat features comprising caves and water pools are discussed in further detail in **Section 3.2.3** and **Section 3.2.4**, respectively.

Table 3-3: Regional Occurrence of Fauna habitats considered in cumulative impact assessment.

Consolidated Fauna Habitat	Regional Occurrence of Habitat
Gorges & Gullies	Within the Pilbara region, Rocky Ridge and Gorge habitat is relatively widespread; however, is also highly variable in the suitability of habitat provided for conservation significant species across its extent (i.e., quantity of cracks and cervices and/or caves provided). Rocky Ridge and Gorge habitat of equivalent value is not considered common throughout the Chichester subregion.
Hills, Ranges & Plateau	Within the Pilbara Bioregion: • Stony Rise habitat is widespread throughout the region. • Rocky Foothills habitat is common and widespread across the region. The Rocky Foothills habitat type is considered widespread in the Pilbara and provides quality refugia, shelter and caves for conservation significant fauna species. Ridgelines, boulders, crevices and caves provide shelter, denning and roosting habitat for species including the Northern Quoll, Pilbara Leaf-nosed Bat, Ghost Bats and the Pilbara Olive Python.
Minor Drainage Line	Minor drainage lines are of low to moderate conservation value as they provide foraging and dispersal habitat for fauna. Conservation significant species known to utilise drainage lines to forage include Pilbara leaf-nosed bat and Ghost Bat, while Northern Quolls utilise predominantly major drainage lines for dispersal for foraging. May contain temporary-permanent water sources. Linear form connecting to other habitat types. This habitat is well represented in the Pilbara region but limited in extent.

Table 3-4: Cumulative impacts to broad terrestrial fauna habitat.

Consolidated Fauna Habitat	Proposed Amendment[1]		Approved Proposal[2]		Venturex Sulphur Springs Project[3]		Atlas Miralga Creek DSO Project[4]		Atlas Sanjiv Ridge Project (Stage 1 + Stage 2)[5]		Atlas Mt Webber DSO Project[6]		Atlas Abydos Project Stage 1[7] + Stage 2[8]		Atlas Wodgina DSO Project (Stage 1 & 2)[9]		Cumulative Impact				
	Indicative Footprint (ha)	Total mapped habitat extent (ha)	Indicative Footprint (ha)	Total mapped habitat extent	DE Extent (ha)	Total mapped habitat extent	DE Extent (ha)	Total mapped habitat extent	IF (ha)	Total mapped habitat extent	Impact Footprint (ha)	Total mapped habitat extent	Extent in DE (ha)	Total mapped habitat extent (ha)	Impact (ha)	Total mapped habitat extent (ha)	Total Impact of Third-party Projects and Approved Proposal (ha)	Total Cumulative Disturbance Inclusive of Proposed Amendment (ha)	Increase In Cumulative Impacts Attributed to Proposed Amendment	Total mapped habitat extent across assessed Projects (ha)	Total Cumulative Disturbance (%)
Gorges & Gullies	**Total 37.4 including:** • 19.1 Rocky escarpment • 18.3 Gorge & gullies	**Total 140.6 including:** • 99.1 Rocky escarpments • 41.5 Gorges & gullies	95	520	26.9	210.7	0.8	4.58	67.3	1,766	182	182	**Total 21 including:** • 8 Ironstone and sandstone gorges • 13 Minor shallow gorges and gullies	**Total 265 including:** • 237 Ironstone and sandstone gorges • 28 Minor shallow gorges and gullies	4.7	15.1	397.7	435.1	**8.5% (Low)**	**3,104**	14
Hills, Ranges & Plateau	563.8	5,509.6	3,584	25,223	**Total 289.9:** • 149.3 Rocky Foothills • 96.8 Scree Slopes • 43.8 Spinifex Stony Plains.	6,594	**Total 226.3:** • 167.4 Low Stony Hills • 58.9 Hill Crest and Hill Slope.	3,016.1	**Total 356.4** • 15.7 Rocky Foothills • 256 Iron stone ridge top • 85 Stony Rises	**Total 14,232** • 4,986 Rocky Foothills • 1,543 Iron stone ridge top • 7,703Stony Rises	221*	221*	**Total 561 including:** • 163 Ironstone ridges • 116 Sandstone ridges • 205 Spinifex stony plain • 77 Stony rises	**Total 5,517 including:** • 762 Ironstone ridges • 1164 Sandstone ridges • 1989 Spinifex stony plain • 1602 Stony rises	**Total 143 including:** • 25 Hillcrest • 18 Ironstone ridges • 75 Stony rise • 25 Scree slope	**Total 456.8 including:** • 60.5 Hillcrest • 75.9 Ironstone ridges • 140.1 Stony rise • 180.3 Scree slope	5,381.6	5,945.4	**9.4% (Low)**	**60,769.5**	9.7
Minor Drainage Line	6.2	117.6	28	1,528	4.7	215.2	19.6	996.3	0	0	96	96	10	180.3	18.3	52	176.6	182.8	**3.4% (Low)**	**3,185.4**	5.7

Note: Extent of clearing for all mapped fauna habitats was not provided in the publicly available DWER clearing permit decision report 5457/1 for the Mt Webber DSO project; the clearing permit decision report for Mt Webber DSO states the extent of vegetation to be cleared (total 499 hectares); the indicative project footprint submitted to DWER by Atlas Iron Limited will result in the clearing of approximately 182 hectares of rocky ridges and gorges habitat and 96 hectares of drainage lines, within the application area. These values have been applied in the table accordingly. A conservative approach of applying the maximum remaining clearing extent of the 221 ha (remaining amount to be cleared) has been applied to Hills, Ranges and Plateau consolidated fauna habitat in the absence of this information. Total cumulative disturbance includes the Proposed Amendment.

[1](FMG, 2022; Spectrum Ecology, 2021b);[2](FMG, 2013);[3](MBS Environmental, 2016);[4](Atlas, 2020);[5](Atlas, 2019);[6](Outback Ecology, 2013);[7](Coffey, 2012);[8](Coffey, 2013);[9](Atlas, 2011).

3.2.3 Caves

Caves are particularly important features within a landscape, particularly in the arid zones, often providing stable microclimates, shelter and protection (Medellin et al., 2017). The presence of diurnal roosts and/or maternity roosts in an area is the most important indicator of critical habitat for the Ghost Bat and Pilbara Leaf-nosed Bat, and these caves are generally the primary focus of conservation and/or monitoring (Cramer et al., 2016). Roost caves situated within proximity to mining development have the potential to be directly (through clearing) or indirectly (increased noise, light and vibration) impacted.

3.2.3.1 Roost Categorisation

The (TSSC, 2016a, 2016b) and (Bat Call WA, 2021a, 2021b) have categorised Ghost Bat caves and Pilbara Leaf-nosed Bat caves according to their habitat value, established by occupancy and usage as shown in **Table 3-5.** Roost category has been incorporated into the assessment where possible, within the limitations of the regional data set and publicly available information (**Section 2.1**). A total of 256 Pilbara Leaf-nosed Bat roost caves and 199 Ghost Bat roost caves in the regional data set have been assigned a roost category where possible (**Table 3-7;Table 3-8**), of which 37 Ghost Bat roost caves (15 direct impacts and 22 are subject to indirect impacts) and 54 (22 directly impacted and 32 are subject to indirect impacts) Pilbara Leaf-nosed Bat roost category caves will be cumulatively impacted within 100km radius of the Proposed Amendment.

The classification of Ghost Bat roost caves for the Proposed Amendment have been categorised according to a methodology that utilises a revised scheme for assessment of Ghost Bat roost classification developed by Dr Kyle Armstrong ((Specialised Zoological, 2025); **Appendix A**). The revised scheme retains the original four cave classification categories as described in (TSSC, 2016a, 2016b) and (Bat Call WA, 2021a, 2021b); (**Table 3-5**), however the scheme also incorporates a scoring system to allocate roost category whereby relative habitat importance of the roost (i.e. Critical, Important, Low-priority and Marginally Significant habitat) for the Ghost Bat is assigned based on consideration of the following factors; diurnal occupancy, colony size and breeding activity (**Table 3-6)**. The revised scheme states that 'provisional' roost categorisations can still be made when 'detection of presence' has been the only means of assessment, however the 'provisional' status should be considered in the context of adequacy of assessment, and whether further data is likely to change the categorisation – e.g. if the roost structure is unlikely to support permanent roosting etc. Categorisation of caves in the Proposed Amendment Area according to Specialised Zoological (2025) is shown in **Table 3-6** below.

Table 3-5: Roost cave and habitat classifications as per (TSSC, 2016a, 2016b) and (Bat Call WA, 2021a, 2021b)

Categorisation	Roost Categorisation			
	Permanent Diurnal Roost	Non-permanent Diurnal Roost	Transitory Diurnal Roost	Nocturnal Refuges
Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia* [Pilbara Form])				
Categorisation as per (TSSC, 2016a)	**Priority 1** Occupied year-round and likely the involved in part of the 9-month breeding cycle.	**Priority 2** Evidence of usage during some part of the breeding cycle (July – March).	**Priority 3** Occupied diurnally for part of the year, outside the breeding cycle. Facilitates long distance dispersal, particularly in autumn.	**Priority 4** Occupied/entered at night for resting, feeding or other purposes.
Categorisation as per (Bat Call WA, 2021b) The PLNB roost utilization is likely more nuanced and variable than these four categories and may change throughout years depending on various environmental and	**Category 1** (Permanent diurnal maternity roosts) Seasonal presence of young is proven.	**Category 2 (Permanent diurnal roost)** # Occupied year round without the proven presence of young.	**Category 3** (Semi-permanent diurnal roost) If associated with nearby Category 1 and/or Category 2 roosts, it is a 'satellite roost'.	**Category 4** Occupied/entered at night for resting, feeding or other purposes.

other factors (GHD, 2025)				
As per (TSSC, 2016a)and (Bat Call WA, 2021b)	**Critical habitat**	**Critical habitat**	**Critical habitat**	**Not considered critical habitat but important for persistence locally**
Ghost Bat (*Macroderma gigas*)				
Categorisation as per (Bat Call WA, 2021a) and (TSSC, 2016b)	**Category 1** Either natural or manmade caves that have a permanent presence of Ghost Bats. Where permanent presence at Category 1 roosts is proven, they must all be assumed to be maternity caves.	**Category 2** Regular, but not continuous, presence (~25-75% occupancy) of Ghost Bats over several months, but then may be abandoned for weeks or even months. Usually several other caves, shelters, and overhangs within a few hundred metres forming 'apartment block' groupings. **Must be assumed to be capable of supporting reproducing females and offspring**.	**Category 3** Category 3 diurnal caves are usually shallower or do not have a stable microclimate in an elevated roosting chamber, but usually have a roosting chamber with a ceiling over 1.5 m high and usually, but not always, have significant scats and food middens. Caves where one or a few Ghost Bats roost occasionally. These are less well-developed structures and are often feeding sites with evidence of middens with food scraps or small scat piles (50 - 2,000). **Isolated Category 3** caves are not considered critical habitat essential to the long-term viability of a local population. However, these may facilitate long-distance movement and therefore contribute to genetic exchange between neighbouring colonies. Not used as maternity caves.	**Category 4** Shallow caves shelters and overhangs used opportunistically by itinerant Ghost Bats. This may be anything from a single foraging visit to a longer visit with a resting period or possibly a feeding session. Evidence includes small numbers of scat and/or food scraps or occasional echolocation calls recorded during surveys.
Categorisation as per (Bat Call WA, 2021a)	**Critical habitat**	**Critical habitat**	**Critical habitat** only when **Category 3 cave is adjacent** to Category 2 caves forming part of an 'apartment block'	**Not considered critical habitat**

Table 3-6: Roost cave and habitat classifications for Ghost Bat as per Dr K. Armstrong (Specialised Zoological, 2025).

Categorisation	Roost Categorisation			
	Permanent Diurnal Roost	Regular Diurnal Roost	Occasional Diurnal Roost	Nocturnal Refuge
Ghost Bat (*Macroderma gigas*)				
Categorisation as per Dr K. Armstrong (Specialised Zoological, 2025)	**Category 1**	**Category 2**	**Category 3**	**Category 4**
	Critical Habitat	**Important Habitat**	**Low-priority Habitat**	**Marginal Significance**

3.2.3.2 Regional Dataset

The confirmed Ghost Bat and Pilbara Leaf-nosed Bat roost caves that were identified from publicly available information are shown in **Figure 3-1** and **Figure 3-2**, although the number of confirmed roosts is likely to be an underestimate given that survey coverage is largely associated with mining tenure in the Pilbara bioregion. A total of 188 Ghost Bat roost records (**Table 3-7**) and 273 Pilbara Leaf-nosed Bat roost records (**Table 3-8)** were compiled regionally from publicly available information to provide a dataset for the Pilbara Bioregion to provide context for this Assessment, as shown on **Figure 3-1** and **Figure 3-2**. This dataset comprises of roost records compiled from publicly available regional data points which were extrapolated, third party approval projects, the regional assessment of Pilbara Leaf-nosed Bats (Bat Call WA, 2021b) and a Stantec internal database informed by Fortescue. Ghost Bat caves within the regional data set have been classified according to the Threatened Species Scientific Committee (TSSC, 2016a, 2016b) and Bat Call WA (Bat Call WA, 2021a, 2021b) Ghost Bat roost classification system.

There are a total of 188 regional Ghost Bat roost caves in Pilbara dataset (Table 3-7), comprising:

- 2 Category 1 roosts;
- 10 Category 2 roosts;
- 18 Category 3 roosts;
- 23 Category 4 roosts; and
- 135 Unknown Category roosts.

There are a total of 273 regional Pilbara Leaf-nosed Bat roost caves in Pilbara dataset (Table 3-8), comprising:

- 44 Category 1/ 2 roosts;
- 21 Category 3 roosts;
- 91 Category 4 roosts; and
- 117 Unknown Category roosts.

One Category 3 roost (Python Cave) and two Category 4 roosts (Cave 32 and 33) of the total confirmed regional Pilbara Leaf-nosed Bat and Ghost Bat roost caves in the dataset are subject to significant impacts following mitigation measures for the Proposed Amendment. Python Cave is used primarily as a Priority 4 nocturnal refuge, and occasionally as a Priority 3 transitory diurnal roost for PLNB (GHD, 2025). As Cave 32 and 33 are low-priority habitat for the Ghost Bat and Pilbara Leaf-nosed Bat, mitigation of indirect impacts is not proposed, therefore they are considered subject to significant impacts. These roost caves equate to 1.1% of the total known Pilbara Leaf-nosed Bat and 1.6% of the Ghost Bat regional roost dataset, and therefore significant cumulative impacts to roost caves attributed to the Proposed Amendment, expressed as known regional roost caves, is regarded as '**Low**'.

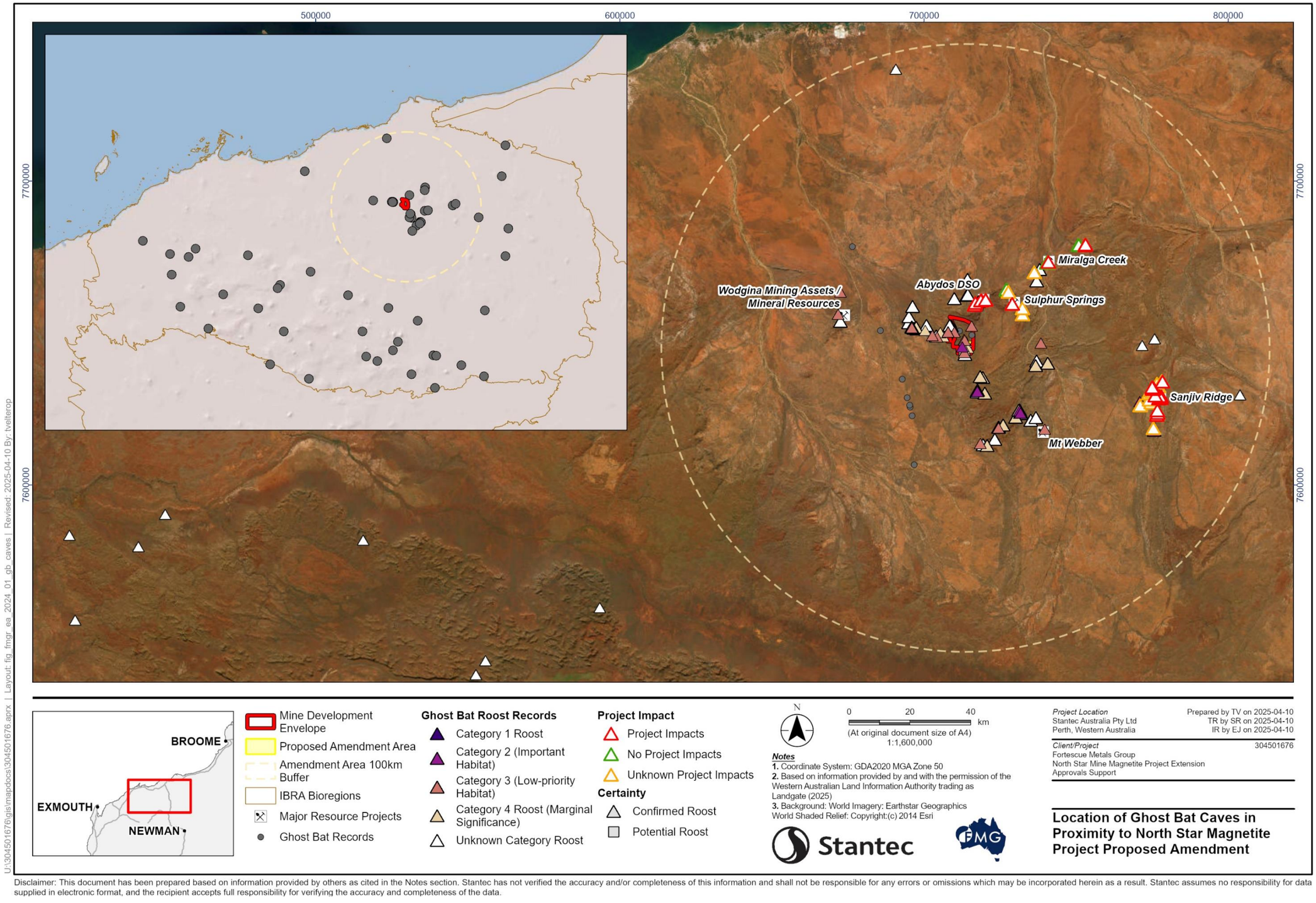


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Figure 3-1: Regional location of confirmed Ghost Bat roosts.

Table 3-7: Known Extent of Regional Ghost Bat Roost Caves

Roost Categories	Total Regional Roost Category Caves[1]	Roost Categories within 100km of Proposed Amendment	Extent within Approved Proposal	Extent within Proposed Amendment
Category 1 Roost	**2**	**2**		
Confirmed maternity roost cave	2	2		
Category 2 Roost	**10**	**9**		**1**
Permanent diurnal roost cave	2	2		
Possible maternity roost cave	2	2		
Diurnal roost with regular occupancy	6	5		1
Category 3 Roost	**18**	**15**	**2**	**1**
Transitory diurnal roost cave	2	2		
Occasional, isolated diurnal roost	16	13	2	1
Category 4 Roost	**23**	**17**		**6**
Nocturnal refuge	17	14		6
Unknown Category Roost	**135**	**99**		
Confirmed roost	100	64		
Possible roost	2	2		
Potential diurnal roost (unknown category)	26	26		
Unknown category roost	3	3		
Blank	4	4		
Total	**188**	**142**	**2**	**8**

[1] The total regional roost category cave dataset is compiled from extrapolated data points from publicly available regional data, third-party approval projects, and internal databases of Stantec and Fortescue.

The overall direct (2.7%) and indirect impacts (1.6%) for Ghost Bat roost caves impacted by the Proposed Amendment expressed as percentage of the known regional dataset is regarded as '**Low**':

- A total of five (2.7%) of the known Ghost Bat roost caves in the regional dataset directly impacted by the Proposed Amendment, comprising:
  - 0% (0) of known Cat. 1 roosts (2);
  - 0% (0) of known Cat. 2 roosts (10);
  - 5.5% (1) of known Cat. 3 roosts (18);
  - 17.4% (4) of known Cat. 4 roosts (23); and
  - 0% (0) of Unknown Cat. Roosts (135).
- A total of three (1.6%) of the known confirmed regional Ghost Bat roost caves in dataset indirectly impacted by the Proposed Amendment, comprising the following:
  - 0% (0) of known Cat. 1 roosts (2);
  - 10% (1) of known Cat. 2 roosts (10);

- 0% (0) of known Cat. 3 roosts (18);
- 8.7% (2) of known Cat. 4 roosts (23); and
- 0% (0) of Unknown Cat. roosts.

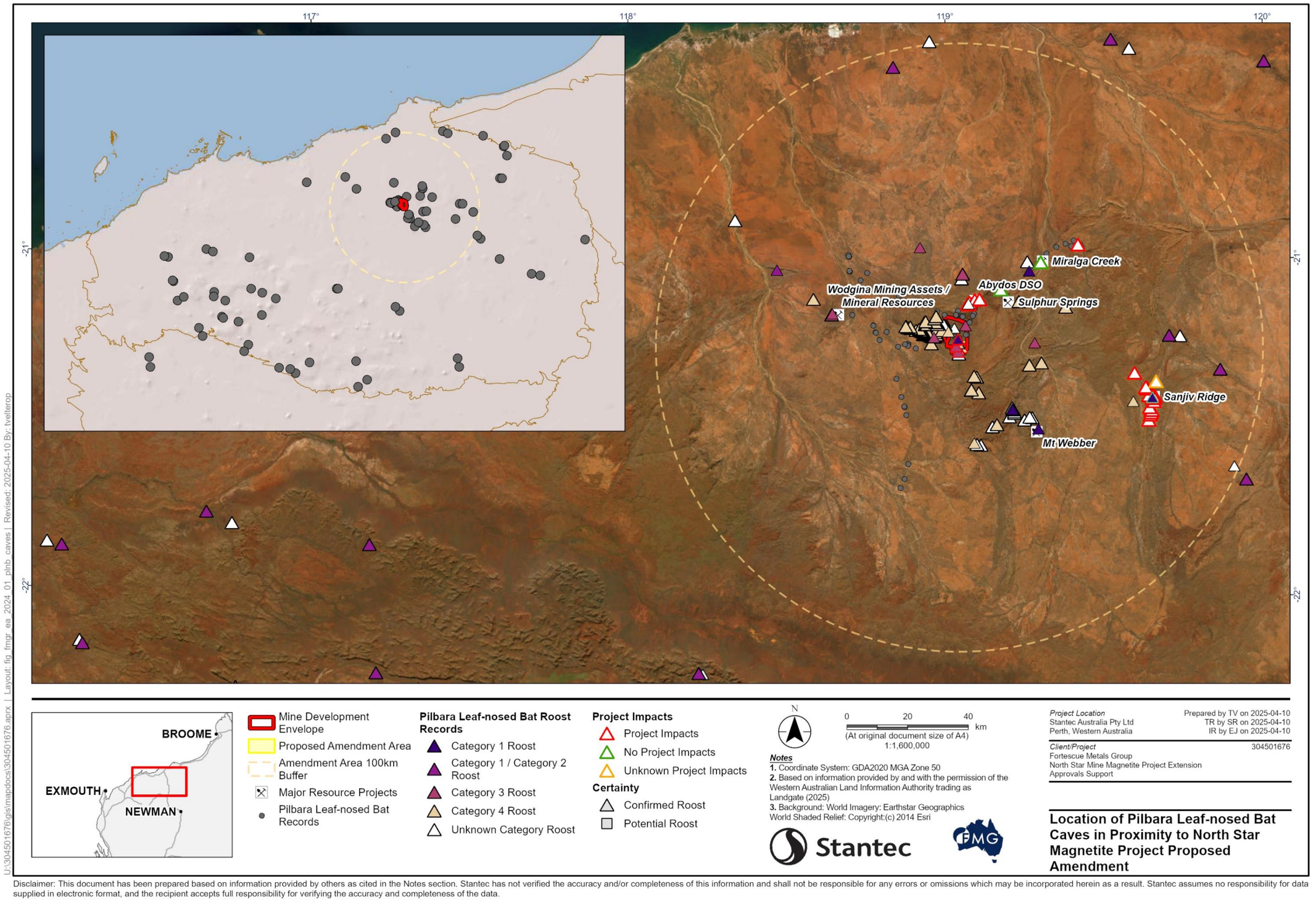

Figure 3-2: Regional location of confirmed Pilbara Leaf-nosed Bat roosts.

Table 3-8: Summary of Pilbara Leaf-nosed Bat Roost Caves in Regional Dataset according to Roost Category

Roost Categories	Total Known roosts in Regional Dataset[1]	Roost categories within 100km of Proposed Amendment	Extent within Approved Proposal	Extent within Proposed Amendment
Category 1 / Category 2 Roost	**37**	**3**		
Permanent diurnal roost or non-permanent breeding roost	37	3		
Category 1 Roost	**7**	**6**	**1**	
Permanent diurnal roost cave	7	6	1	
Category 3 Roost	**21**	**18**	**1**	**2**
Transitory diurnal roost cave	21	18	1	2
Category 4 Roost	**91**	**79**		**12**
Nocturnal refuge	91	79		12
Unknown Category Roost	**117**	**78**		
Confirmed roost	33	33		
Potential diurnal roost (unknown category)	31	31		
Unknown	28	8		
Blank	25	6		
Total	**273**	**184**	**2**	**14**

[1] The total regional roost category cave dataset is compiled from extrapolated data points from publicly available regional data, third-party approval projects, the regional assessment of Pilbara Leaf-nosed Bats (Bat Call WA, 2021b) and internal databases of Stantec and Fortescue.

The direct (3.3%) and indirect impacts (1.8%) to Pilbara Leaf-nosed Bat known roost caves regionally impacted by the Proposed Amendment is regarded as '**Low**':

- A total of nine (3.3%) of the total known Pilbara Leaf-nosed Bat roost caves in the regional dataset are directly impacted by the Proposed Amendment:
  - 0% (0) of known Cat. 1 roosts (7);
  - 0% (0) of known Cat. 1/2 roosts (37);
  - 4.8% (1) of known Cat. 3 roosts (21);
  - 8.8% (8) of known Cat. 4 roosts (91); and
  - 0% (0) of Unknown Cat. Roosts (117).
- A total of five (1.8%) total confirmed Pilbara Leaf-nosed Bat roost caves in the regional dataset indirectly impacted by the Proposed Amendment:
  - 0% (0) of known Cat. 1 roosts (7);
  - 0% (0) of known Cat. 2 roosts (37);
  - 4.8% (1) of known Cat. 3 roosts (21);
  - 4.4% (4) of known Cat. 4 roosts (91); and
  - 0% (0) of Unknown Cat. Roosts (117).

3.2.3.3 Cumulative Impacts

Roost categories for known Ghost Bat and Pilbara Leaf-nosed Bat roost caves are only defined for some of the known roosts within the regional dataset and the regional dataset does not assign whether roost caves are subject to direct or indirect impacts. As such, cumulative impacts have been assessed based on publicly available confirmed roost records obtained from third-party projects assessed within 100km of the Proposed Amendment:

Cumulative impacts to Ghost Bat and Pilbara Leaf-nosed Bat roost caves are assessed as the:

- Cumulative increase attributed to the Proposed Amendment of the number of caves at the landscape scale (<100 km of the Proposed Amendment) subject to direct disturbance through the removal of fauna habitat; and
- Cumulative increase attributed to the Proposed Amendment of the number of roost caves subject to indirect impacts (i.e. increased light sources, increased vibration and noise within the cave form natural levels).

The location of known Ghost Bat and Pilbara Leaf-nosed Bat roost caves within the Approved Proposal and the Proposed Amendment are shown in **Figure 3-11**. These records were used to inform the cumulative assessment and are presented alongside their cave name, roost category and habitat significance (where known), within **Table 3-9** and **Table 3-10.**

The location of confirmed Ghost Bat and Pilbara Leaf-nosed Bat roosts subject to known impacts within 100km of the Proposed Amendment are shown from **Figure 3-3** to **Figure 3-10**. A total of 15 (14.6%) of the 103 known Ghost Bat roost records and 22 (21.6%) of the 102 known Pilbara Leaf-nosed Bat roost records assessed within 100km of the Proposed Amendment will be subject to direct impacts, from the third-party assessed projects, the Approved Proposal and the Proposed Amendment. The percentage increase in cumulative impacts to confirmed roost caves for the Ghost Bat and Pilbara Leaf-nosed Bat attributed to the Proposed Amendment that are subject to direct and indirect impacts for assessed Projects within 100 km of the Proposed Amendment are shown in **Table 3-11** and are summarised as follows:

Ghost Bats:

- The percentage increase in cumulative direct impacts attributed to the Proposed Amendment, through clearing of five confirmed roost caves (comprising one Cat. 3, (Python Cave;), four Cat. 4 (Cave 1a; Cave 2; Cave 11; Heritage Cave) for the Ghost Bat, is 6.1% and is regarded as 'Low'.
- The percentage increase (cumulative impact) to three confirmed roost caves (comprising two Cat. 4 (Cave 32; Cave 33) and 1 Cat. 2 (Mundagoora Cave 3) subject to potential indirect impacts (noise, vibration) attributed to the Proposed Amendment, for the Ghost Bat, is 3.7% and is regarded as 'Low'.

Pilbara Leaf-nosed Bats:

- The percentage increase in cumulative direct impacts attributed to the Proposed Amendment, through clearing of nine confirmed roost caves (comprising one Cat. 3 (Python Cave), eight Cat. 4 (Heritage Cave; Caves 1a; 2; 3; 11; 14; 16; 21) of the Pilbara Leaf-nosed Bat, is 13% and is regarded as 'Moderate'.
- The percentage increase (cumulative impact) to five confirmed roost caves (comprising one Cat. 3 (Mundagoora Cave 3) and four Cat. 4 (Cave 32; Cave 33; Mundagoora Caves 1 and 2) subject to potential indirect impacts (noise and vibration) attributed to the Proposed Amendment, for the Pilbara Leaf-nosed Bat, is 7.3% and is regarded as 'Low'.

The above cumulative impact calculations may include roost caves that have both Pilbara Leaf-nosed Bat and Ghost Bat roosting within the cave (essentially where the same roost cave is accounted for in both the Ghost Bat and Pilbara Leaf-nosed Bat calculations listed above). Therefore, the 82 known Ghost Bat roost caves and 69 known Pilbara Leaf-nosed Bat roost caves assessed within 100km of the Proposed Amendment for cumulative impacts, equates to an actual total of 144 confirmed roost caves containing either or both the Ghost Bat or Pilbara Leaf-nosed Bat (**Table 3-11)**. Noting that for the Proposed Amendment of the 14 roost caves assessed, 8 caves contain both Pilbara Leaf-nosed Bat and Ghost Bat and for the Approved Proposal of the 2 caves assessed, 2 caves contain both Pilbara Leaf-nosed Bat and Ghost Bat.

Consideration is given to mitigation and management measures proposed by each third-party project within this Assessment. The implementation of mitigation measures can ensure that potential cumulative indirect impacts to roost caves are managed as such that cumulative impacts are acceptable within the bioregion. For example, ensuring that indirect impacts do not compromise the structural integrity and suitable microclimate of the caves has demonstrated that bats have returned to use caves post-mining. This has been demonstrated at a number of Category 2 and Category 3 Ghost Bat roost caves in reasonably close proximity to active large-scale open cut mining operations at distances ranging from 100 m to 500 m, some of which occur within proximity to the Proposed Amendment, including the Wodgina DSO Project and the Abydos Iron Ore Project. Ongoing monitoring has confirmed that these roost caves have remained viable as diurnal roosts for the species and as maternity roost candidates.

The Proposed Amendment will result in a Low (7.6%) cumulative increase to confirmed roost caves for the Ghost Bat or Pilbara Leaf-nosed Bat (one Cat. 3 (GB & PLNB) (Python Cave) and ten Cat. 4 (Cave 32 (GB & PLNB), Cave 33 (GB & PLNB), Cave 11 (GB & PLNB), Heritage cave (GB & PLNB), Cave 1a (GB & PLNB), Cave 2 (GB & PLNB), Cave 21 (PLNB), Cave 14 (PLNB), Cave 3 (PLNB), Cave 16 (PLNB))) subject to significant impacts following implementation of mitigation measures. For the third-party assessed projects with potential to have indirect impacts to caves, the proposed mitigation and management measures provided are summarised as follows:

- Implementation of buffer zones around identified potential roost caves, within which no works (e.g. clearing, blasting, operations) will be undertaken (Atlas, 2019, 2020, 2021; Coffey, 2012, 2013; FMG, 2013)

- Clearing in/of sensitive fauna habitats including scree slopes, ridges, outcrops, gullies and crevices will be kept to the minimum necessary for safe construction and operation of projects (Coffey, 2012, 2013; MBS Environmental, 2016)
- Corrective rehabilitation or measures should structural damage to roost caves be observed (Atlas, 2019; Coffey, 2012; Outback Ecology, 2013)
- Monitoring of sensitive bat roosts throughout the life of the projects to determine changes in bat behaviour or the physical condition of the caves (Coffey, 2012, 2013)
- Use of directional/screened lighting within the vicinity of bat roosts and minimisation of other secondary impacts (e.g. noise, vibration) (Atlas, 2020, 2021; Coffey, 2013; FMG, 2013)
- Implementation of appropriate management plans to monitor impacts and changes to the caves (Atlas, 2011, 2019, 2021)

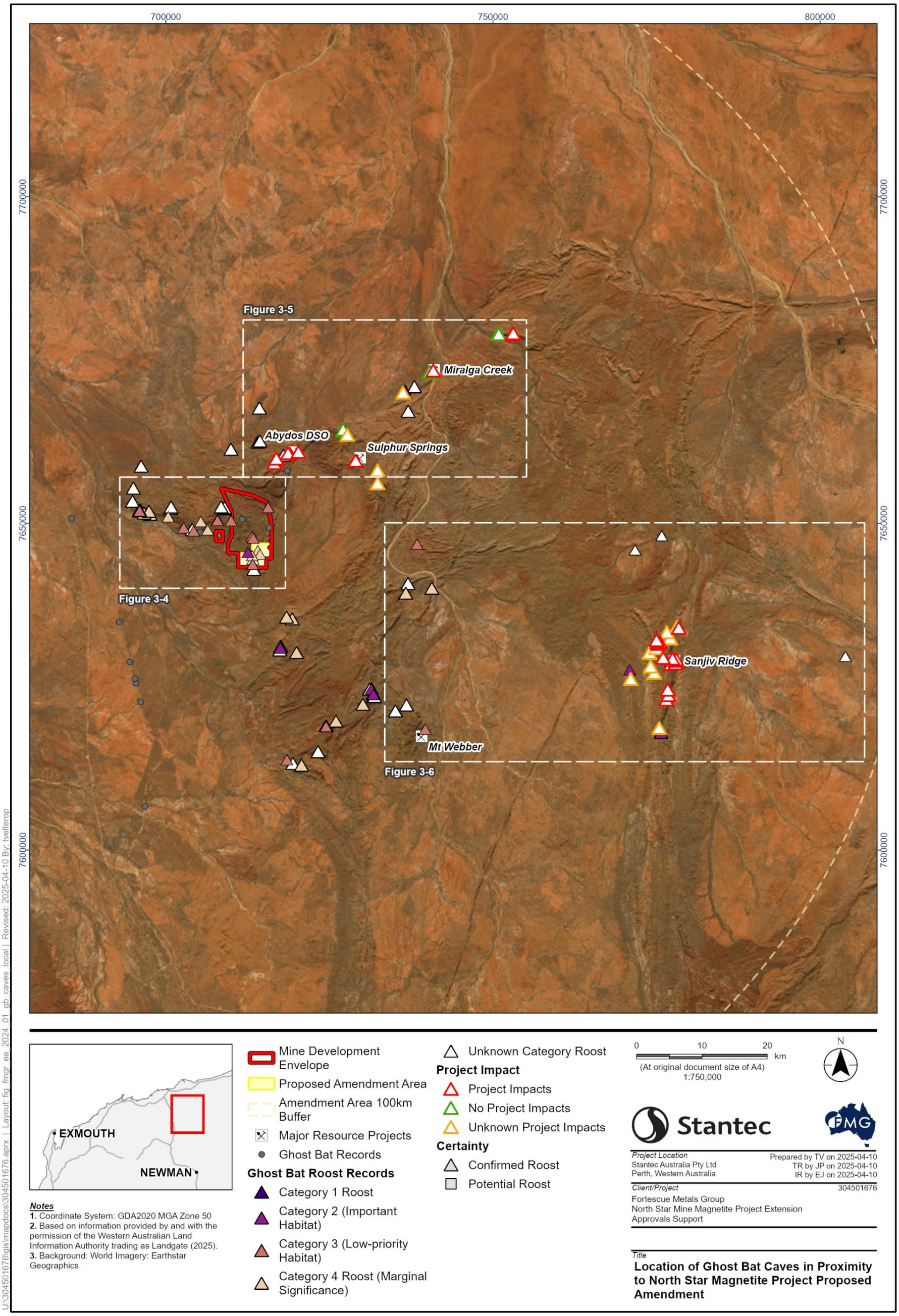

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Figure 3-3: Local context of confirmed Ghost Bat roosts in proximity to the Proposed Amendment.

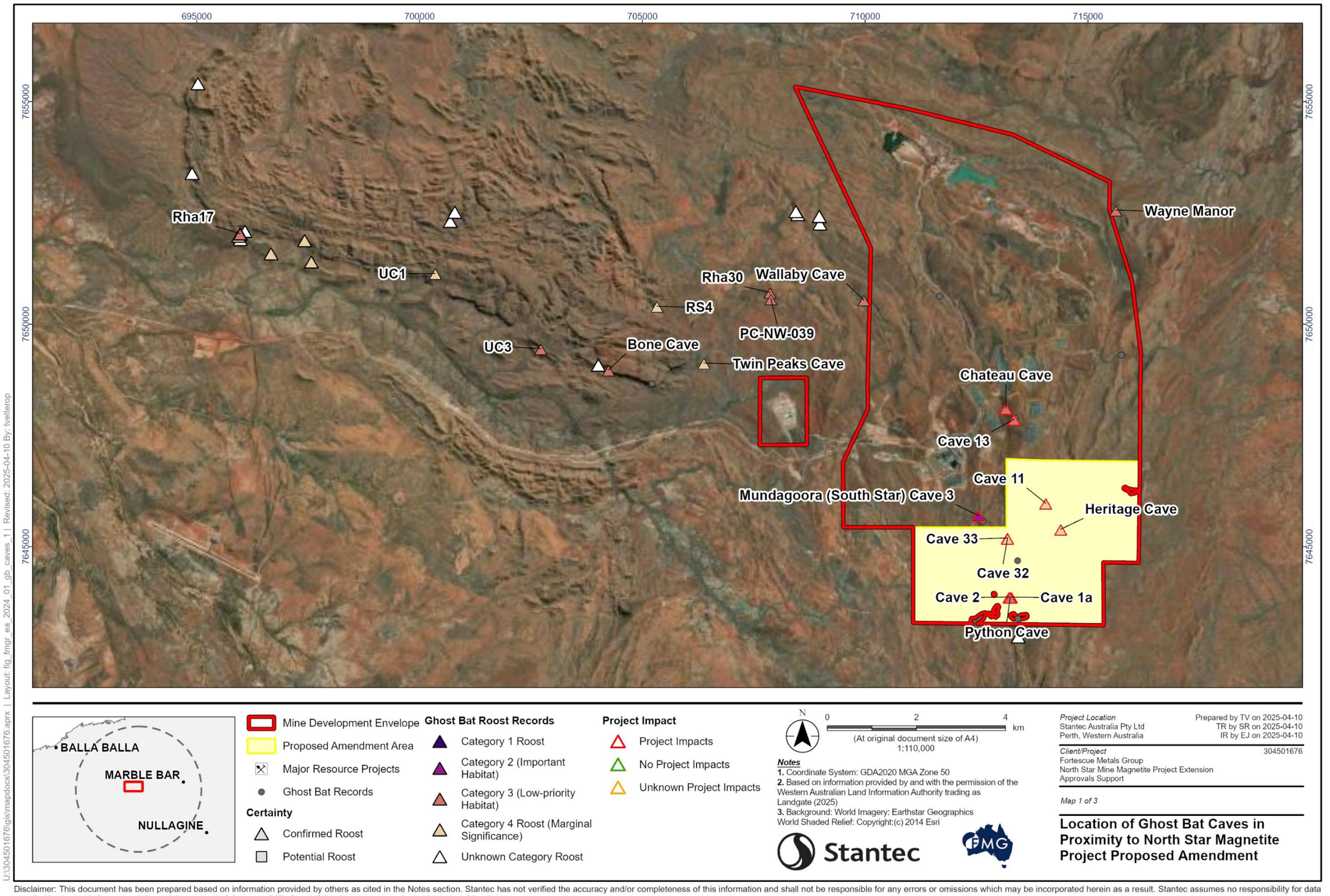

Figure 3-4: Local context of confirmed Ghost Bat roosts in proximity to the Proposed Amendment – western quadrant.

Figure 3-5: Local context of confirmed Ghost Bat roosts in proximity to the Proposed Amendment – north-eastern quadrant.

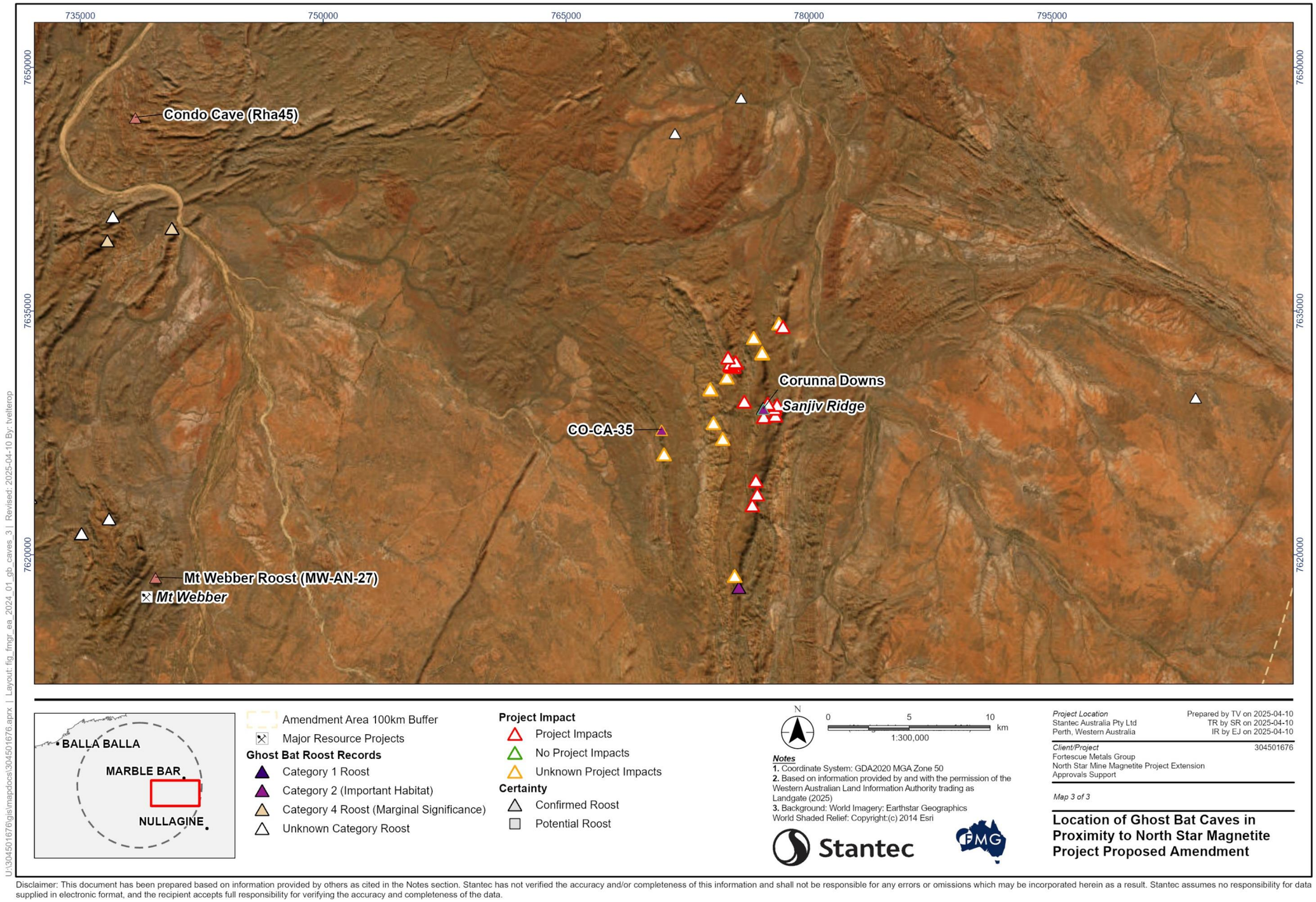

Figure 3-6: Local context of confirmed Ghost Bat roosts in proximity to the Proposed Amendment – southern quadrant.

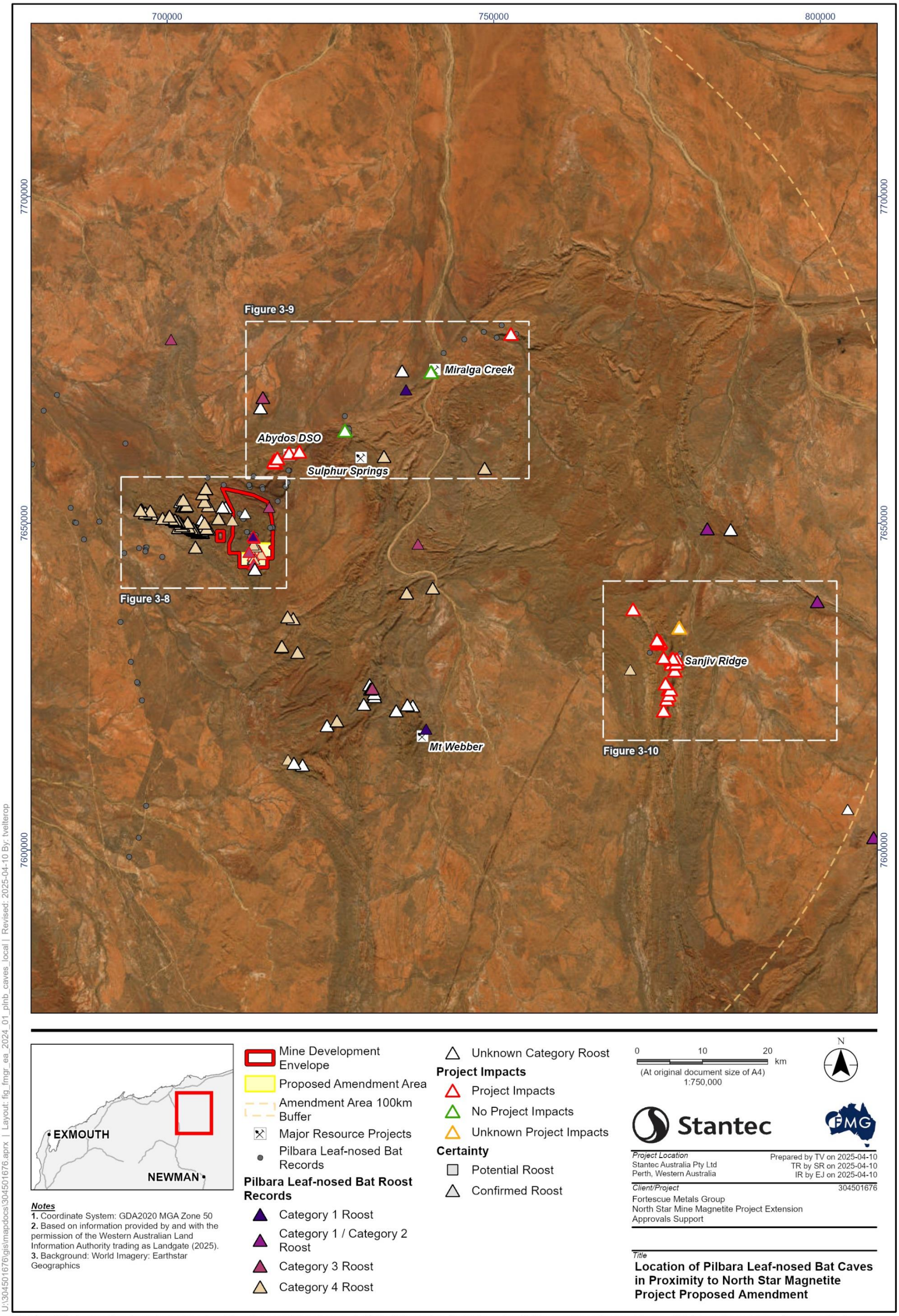

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Figure 3-7: Local context of confirmed Pilbara Leaf-nosed Bat roosts in proximity to the Proposed Amendment.

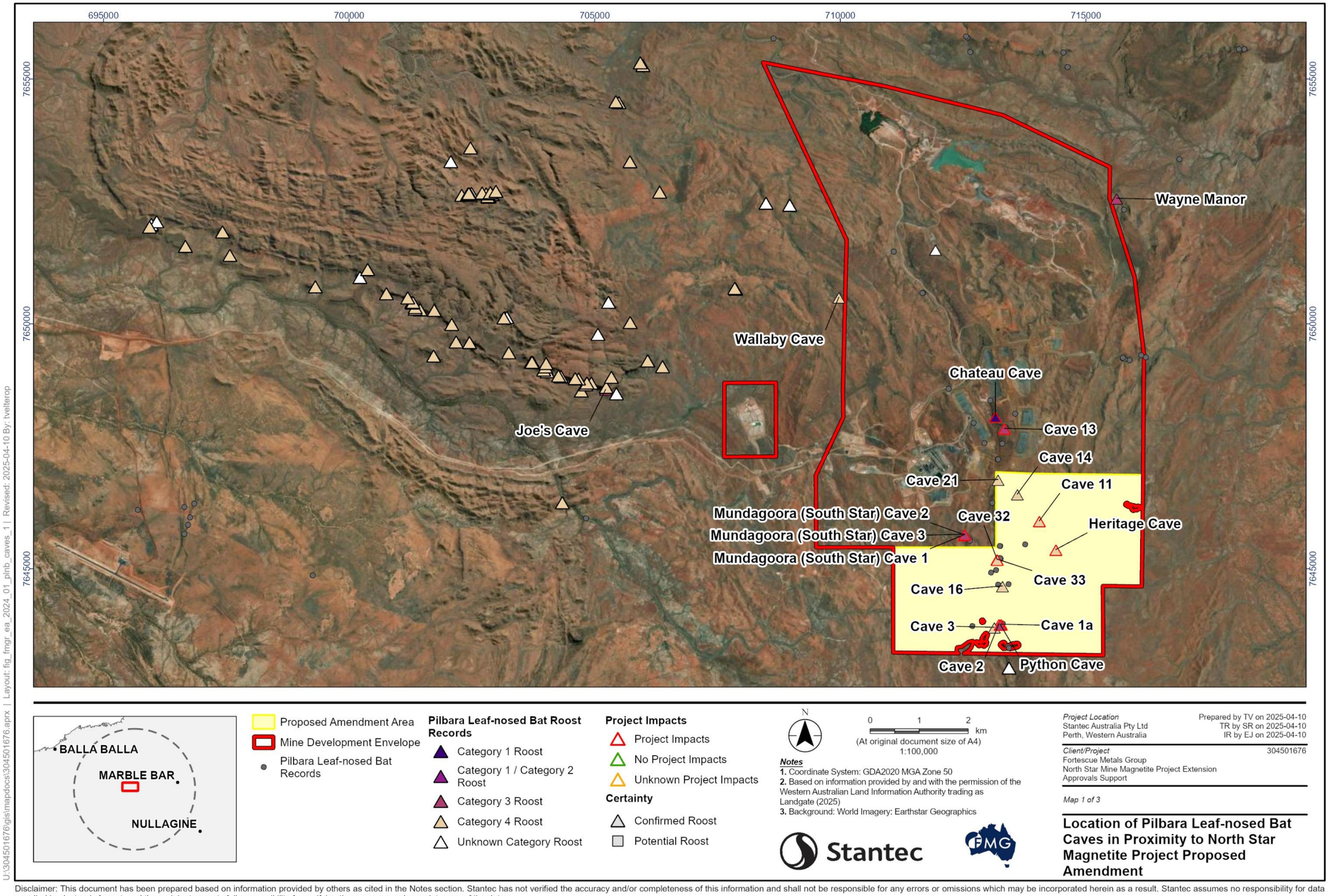

Figure 3-8: Local context of confirmed Pilbara Leaf-nosed Bat roosts in proximity to the Proposed Amendment – western quadrant.

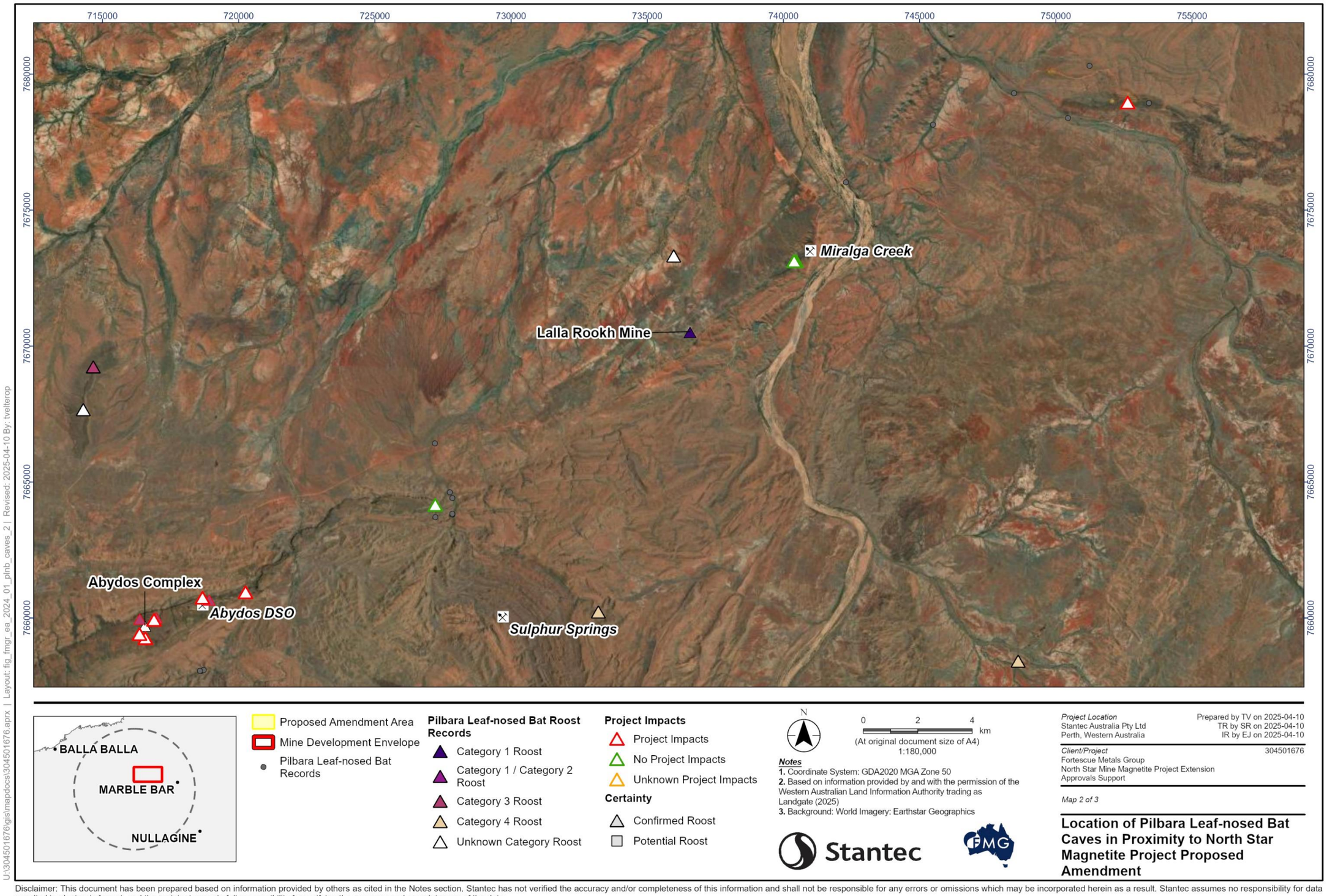

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Figure 3-9: Local context of confirmed Pilbara Leaf-nosed Bat roosts in proximity to the Proposed Amendment – north-eastern quadrant.

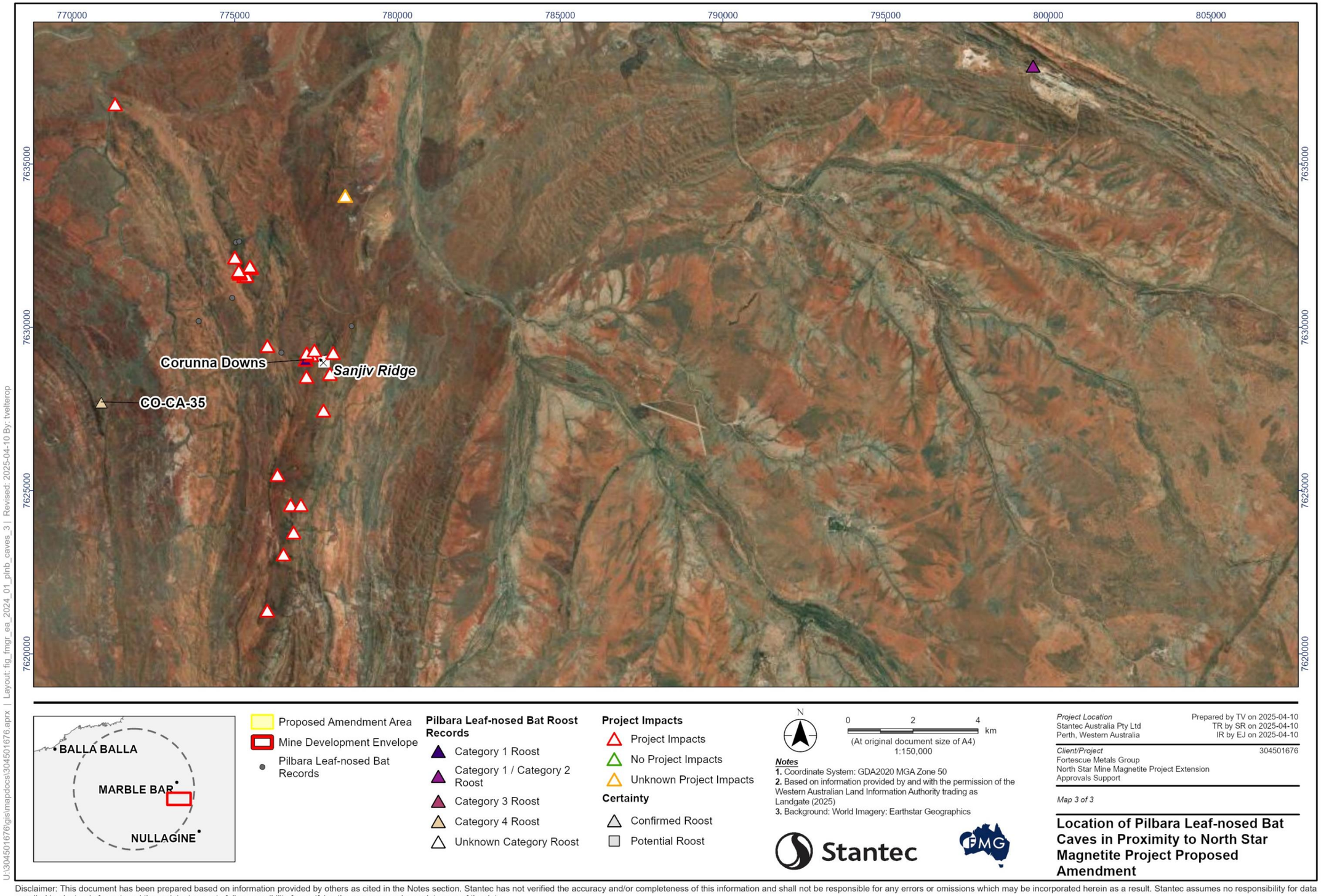

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Figure 3-10: Local context of confirmed Pilbara Leaf-nosed Bat roosts in proximity to the Proposed Amendment – southern quadrant.

Table 3-9: Confirmed Ghost Bat and Pilbara Leaf-nosed Bat roosts (including their associated roost category and habitat significance) subject to direct impacts attributed to the Approved Proposal.

Confirmed Roost Caves Directly Impacted by Approved Proposal	GB Roost Category	PLNB Roost Category	GB Habitat Significance as per (Bat Call WA, 2021a)	PLNB Habitat Significance as per (Bat Call WA, 2021b) and (TSSC, 2016a)
Cave 13	Category 3	Category 3	Critical Habitat	Critical Habitat
Chateau Cave	Category 3	Category 1	Critical Habitat	Critical Habitat
2 confirmed roost caves	**2 GB roost caves**	**2 PLNB roost caves**		

Table 3-10: Confirmed Ghost Bat and Pilbara Leaf-nosed Bat roosts (including their associated roost category and habitat significance) subject to direct and indirect impacts attributed to the Proposed Amendment, prior to the application of mitigation measures.

Confirmed Roost Caves Directly Impacted by Proposed Amendment	GB Roost Category	PLNB Roost Category	GB Habitat Significance as per (Specialised Zoological, 2025))	PLNB Habitat Significance as per (Bat Call WA, 2021b) and (TSSC, 2016a)
Python Cave	Category 3	Category 3	Low-priority Habitat	Low
Heritage Cave	Category 4	Category 4	Marginal Significance	Not significant
Cave 1a	Category 4	Category 4	Marginal Significance	Not significant
Cave 2	Category 4	Category 4	Marginal Significance	Not significant
Cave 3	Not a roost	Category 4	-	Not significant
Cave 11	Category 4	Category 4	Marginal Significance	Not significant
Cave 14	Not a roost	Category 4	-	Not significant
Cave 16	Not a roost	Category 4	-	Not significant
Cave 21	Not a roost	Category 4	-	Not significant
9 confirmed roost caves	**5 GB roost caves**	**9 PLNB roost caves**		
Confirmed Roost Caves Indirectly Impacted by Proposed Amendment	**GB Roost Category**	**PLNB Roost Category**	**GB Habitat Significance (as per (Specialised Zoological, 2025))**	**PLNB Habitat Significance (as per (Bat Call WA, 2021b) and (TSSC, 2016a))**
Mundgoora Cave 1[1]	-	Category 4	-	Not significant
Mundagoora Cave 2[1]	-	Category 4	-	Not significant
Mundagoora Cave 3[1]	Category 2	Category 3	Low-priority Habitat	Not significant
Cave 32	Category 4	Category 4	Marginal Significance	Not significant
Cave 33	Category 4	Category 4	Marginal Significance	Not significant
5 confirmed roost caves	**3 GB roost caves**	**5 PLNB roost caves**		

[1]Roost caves located outside of the Proposed Amendment area, however, are subject to indirect impacts by the Proposed Amendment.

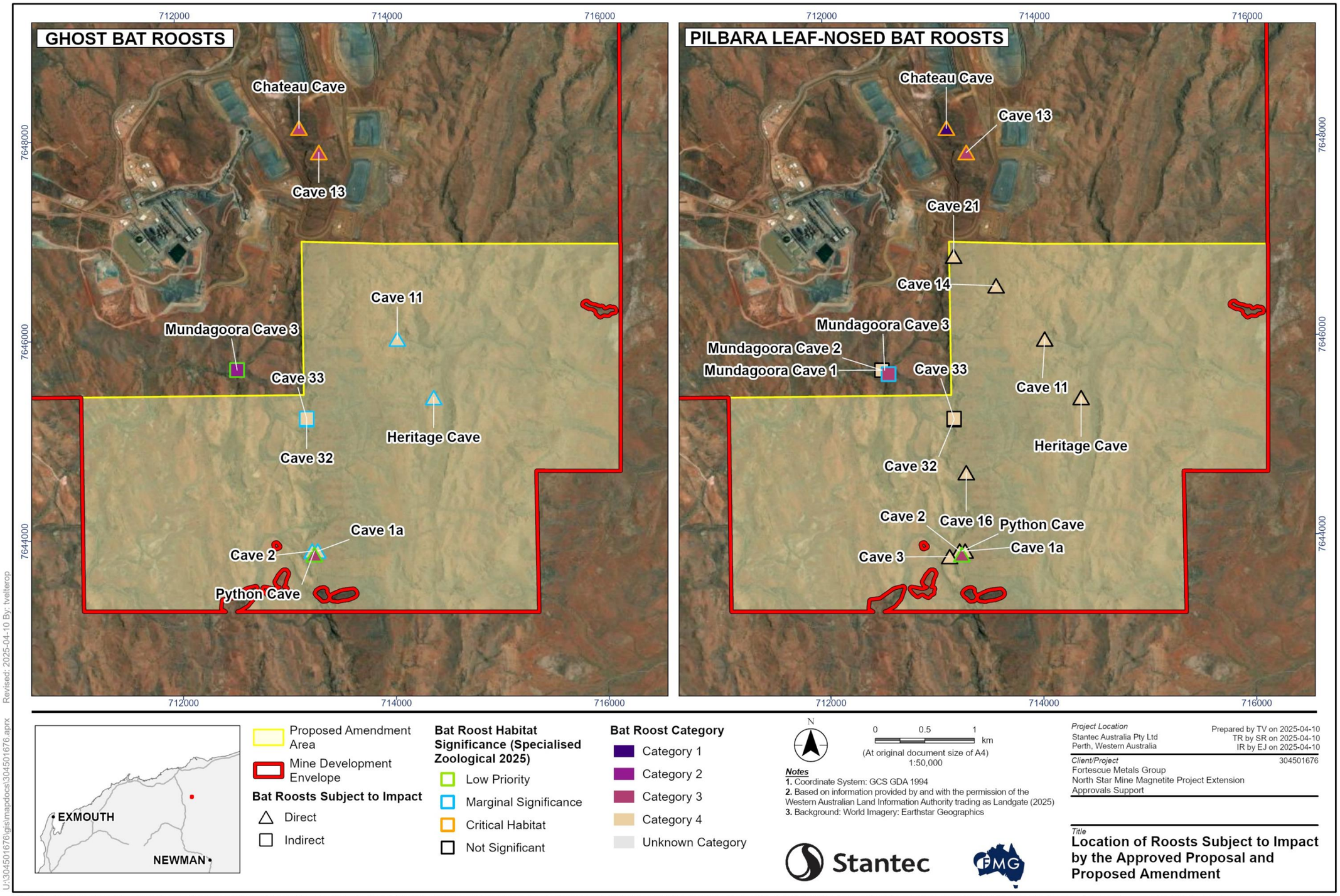

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Figure 3-11: Known Ghost Bat and Pilbara Leaf-nosed Bat roost caves within the Proposed Amendment and Approved Proposal.

Table 3-11: Cumulative impacts to caves from third-party projects within 100 km radius of the Proposed Amendment.

Cave Category	Proposed Amendment [1]	Approved Proposal [2]	Third-party Projects within 100 km radius of the Proposed Amendment								Cumulative Impact		
			Atlas Iron: Abydos Stage 1 [3]	Atlas Iron: Abydos DSO Stage 2 [4]	Venturex: Sulphur Springs Project [5]	Atlas Iron: Miralga Creek DSO Project (Extension of Abydos) [6]	Atlas Iron: Sanjiv Ridge (Stage 1 DE) [7]	Atlas Iron: Sanjiv Ridge (Stage 2 DE) [8]	Atlas Iron: Mt Webber DSO Project (Stage 1 / Stage 2 Study Area) [9]	Atlas Iron Wodgina DSO Project (Stage 1 and 2) [10]	Total number of confirmed roost caves assessed within 100km radius of Proposed Amendment		Cumulative % Increase[11] of Impacts Attributed to the Proposed Amendment within 100km Radius of Proposed Amendment (Cumulative Impacts Significance Rating)
											Total impact third-party projects and Approved Proposal (% of confirmed roost caves assessed within 100km radius of Proposed Amendment)	Total cumulative impact including Proposed Amendment (% of confirmed roost caves assessed within 100km radius of Proposed Amendment)	
• Number of caves recorded where Ghost Bat roost confirmed ○ Number of caves subject to potential direct or indirect impacts (Known GB roost cave category)	• 8 confirmed roost caves: ○ 5 roost caves (1 Cat. 3 (Python Cave) and 4 Cat. 4 (Cave 1a; Cave 2; Cave 11; Heritage Cave)) directly impacted. ○ 2 roost caves (2 Cat. 4 (Cave 32; Cave 33)) indirectly impacted. ○ 1 Cat. 2 (Mundagoora Cave 3) outside but to be indirectly impacted by Proposed Amendment.	• 2 confirmed roost caves: ○ 2 roost caves (2 Cat. 3 (Chateau Cave and Cave 13)) directly impacted. ○ No caves indirectly impacted.	• 3 confirmed roost caves, (including 1 maternity cave): ○ No caves directly impacted. ○ Number of caves subject to potential indirect impacts not clearly stated.	• 10 confirmed roost caves: ○ 1 directly impacted (Unknown Cat.). ○ 3 indirect impacts Unknown Cat.).	• 5 confirmed roost caves: ○ 1 directly impacted (Unknown Cat.) ○ Number of caves subject to potential indirect impacts not clearly stated.	• 17 confirmed roost caves: ○ 1 directly impacted (Unknown Cat.). ○ 3 indirectly impacted (Unknown Cat.).	• 6 confirmed roost caves: ○ 2 directly impacted (Unknown Cat.). ○ 3 indirectly impacted (Unknown Cat.).	• 31 confirmed roost caves (including 2 potential maternity roosts): ○ 1 directly impacted (Unknown Cat.) ○ 10 indirectly impacted (Unknown Cat.) ○ No maternity roosts impacted.	• Clearing permit decision reports state the Ghost Bat was recorded from caves within the application area; however, no further details were provided in relation to the number of caves or cave category ○ Number of caves impacted not stated.	• 0 confirmed GB roost caves.	• 82 confirmed Ghost Bat roost caves within 100km radius of Proposed Amendment ○ 8 roosts (2 Cat. 3 and 6 Unknown Cat.) directly impacted (**9.8%**). ○ 19 roosts (19 Unknown Cat.) indirectly impacted (**23.2%**).	• 82 confirmed Ghost Bat roost caves within 100km radius of Proposed Amendment ○ 13 roosts (3 Cat. 3, 4 Cat. 4 and 6 Unknown Cat.) directly impacted (**15.9%).** ○ 22 roosts (2 Cat. 4, 1 Cat. 2 and 19 Unknown Cat.) indirectly impacted (**26.8%**).	○ **6.1%** cumulative increase to confirmed GB roost caves directly impacted **(Low).** ○ **3.7%** cumulative increase to confirmed GB roost caves indirectly impacted **(Low).**
• Number of caves recorded where Pilbara Leaf-nosed Bat roost confirmed ○ Number of caves subject to potential direct or indirect impacts (Known PLNB roost cave category)	• 14 confirmed roost caves: ○ 9 roost caves (1 Cat. 3 (Python Cave), 8 Cat. 4 (Heritage Cave; Caves 1a; 2; 3; 11; 14; 16; 21) directly impacted. ○ 2 roost caves (2 Cat. 4 (Cave 32; Cave 33)) indirectly impacted. ○ 3 roost caves (1 Cat. 3 (Mundagoora Cave 3) and 2 Cat. 4 (Mundagoora Caves 1 and 2)) outside but to be indirectly impacted by Proposed Amendment.	• 2 confirmed roost caves: ○ 2 roost caves (1 Cat. 3 (Cave 13) and 1 Cat. 1 (Chateau Cave)) directly impacted. ○ No caves indirectly impacted.	• 3 confirmed roost caves: ○ No caves directly impacted. ○ 3 caves indirectly impacted (Unknown Cat.).	• 8 confirmed roost caves: ○ 1 directly impacted (Unknown Cat.). ○ Number of caves subject to potential indirect impacts not clearly stated.	• 0 confirmed PLNB roost caves.	• 4 confirmed roost caves: ○ 1 directly impacted (Unknown Cat.). ○ 1 indirectly impacted (Unknown Cat.)	• 16 confirmed roost caves: ○ 2 directly impacted (Unknown Cat.). ○ 13 indirectly impacted (Unknown Cat.).	• 14 confirmed roost caves: ○ 1 directly impacted (Unknown Cat.) ○ 10 indirectly impacted (Unknown Cat.)	• 8 confirmed roost caves: ○ 5 directly impacted (Unknown Cat.) ○ Number of caves subject to potential indirect impacts not clearly stated	• 0 confirmed PLNB roost caves.	• 69 confirmed Pilbara Leaf-nosed Bat roost caves within 100km radius of Proposed Amendment ○ 12 roosts (1 Cat. 1, 1 Cat 3 and 10 Unknown Cat.) directly impacted (**17.4%**). ○ 27 roosts (27Unknown Cat.) indirectly impacted (**39.1%**).	• 69 confirmed Pilbara Leaf-nosed Bat roost caves within 100km radius of Proposed Amendment ○ 21 roosts (1 Cat. 1, 2 Cat. 3, 8 Cat. 4 and 10 Unknown Cat.) directly impacted (**30.4%**). ○ 32 roosts (1 Cat. 3, 4 Cat. 4 and 27 Unknown Cat.) indirectly impacted (**46.4%**).	○ **13%** cumulative increase to confirmed PLNB roost caves directly impacted **(Moderate).** ○ **7.3%** cumulative increase to confirmed PLNB roost caves indirectly impacted **(Low).**

Cave Category	Proposed Amendment [1]	Approved Proposal [2]	Third-party Projects within 100 km radius of the Proposed Amendment								Cumulative Impact		
			Atlas Iron: Abydos Stage 1 [3]	Atlas Iron: Abydos DSO Stage 2 [4]	Venturex: Sulphur Springs Project [5]	Atlas Iron: Miralga Creek DSO Project (Extension of Abydos) [6]	Atlas Iron: Sanjiv Ridge (Stage 1 DE) [7]	Atlas Iron: Sanjiv Ridge (Stage 2 DE) [8]	Atlas Iron: Mt Webber DSO Project (Stage 1 / Stage 2 Study Area) [9]	Atlas Iron Wodgina DSO Project (Stage 1 and 2) [10]	Total number of confirmed roost caves assessed within 100km radius of Proposed Amendment		Cumulative % Increase[11] of Impacts Attributed to the Proposed Amendment within 100km Radius of Proposed Amendment (Cumulative Impacts Significance Rating)
											Total impact third-party projects and Approved Proposal (% of confirmed roost caves assessed within 100km radius of Proposed Amendment)	Total cumulative impact including Proposed Amendment (% of confirmed roost caves assessed within 100km radius of Proposed Amendment)	
Total number of confirmed roost caves containing either or both GB or PLNB within the 100km radius of the Proposed Amendment area	14 (8 caves contain both PLNB and GB)	2 (2 caves contain both PLNB and GB)	3	10	5	17	18	31	14	30	144 confirmed roost caves containing either or both GB or PLNB assessed within 100km radius of Proposed Amendment.		
Mitigation measures proposed/ or implemented (Yes/No).	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	
Number of roost caves (known roost category) subject to significant impacts following implementation of mitigation measures (% of confirmed roost caves assessed).	Both GB and PLNB roost caves: 1 Cat. 3 roost cave (Python Cave) 6 Cat. 4 (Cave 32; Cave 33, Cave 11, Heritage cave, Cave 1a, Cave 2)	Both GB and PLNB roost caves: 1 Cat. 3 roost cave (Cave 13)	0 roost caves	1 roost cave (Unknown Cat.)	1 roost cave (Unknown Cat.)	1 roost cave (Unknown Cat.)	2 roost caves (Unknown Cat.)	1 roost cave (Unknown Cat.)	5 roost caves (Unknown Cat.)	0 roost caves	13 confirmed roost caves (Cave 13, Chateau cave) and 11 Unknown Cat.) subject to significant impacts **(9%**)	24 confirmed roost caves **(**2 Cat. 3 (Python Cave; Cave 13); 2 Cat. 4 (Cave 32; Cave 33) and 11 Unknown Cat.) subject to significant impacts **(16.7%)**	**7.6%** cumulative increase to confirmed roost caves significantly impacted **(Low).**
	GB roost caves: 1 Cat. 3 roost cave (Python Cave) 6 Cat. 4 (Cave 32; Cave 33, Cave 11, Heritage cave, Cave 1a, Cave 2)	GB roost caves: 1 Cat. 3 (Chateau cave) 1 Cat. 3 (Cave 13)											
	PLNB roost caves: 1 Cat. 3 roost cave (Python Cave) 10 Cat. 4 (Cave 32; Cave 33, Cave 11, Heritage cave, Cave 1a, Cave 2, Cave 21, Cave 14, Cave 3, Cave 16)	PLNB roost caves: 1 Cat. 1 (Chateau cave) 1 Cat. 3 roost cave (Cave 13)											

[1](FMG, 2022);[2](FMG, 2013);[3](Coffey, 2012);[4](Coffey, 2013);[5](MBS Environmental, 2016);[6](Atlas, 2020);[7](Atlas, 2019);[8](Atlas, 2021);[9](Outback Ecology, 2013);[10](Atlas, 2011)

[11] Cumulative % increase refers to the change in percentage (%) of confirmed roost caves subject to impacts which are attributed to the Proposed Amendment.

3.2.4 Surface Water Pools

There are numerous significant fauna species that rely on permanent surface water pools ("pools") to persist, with the Pilbara Olive Python, Northern Quoll, Ghost Bat and Pilbara Leaf-nosed Bat of relevance to the Proposed Amendment. Permanent pools are considered important foraging resources for the Pilbara Leaf-nosed Bat, Ghost Bat and Northern Quoll, and provide critical habitat for the Pilbara Olive Python. Currently, factors affecting the usage of water sources by the Ghost Bat adjacent to or nearby their roosts are not well documented. This species is known to forage in productive areas including around waterholes and riparian zones but direct evidence of visits for drinking are rare. Current best practice is to consider semi- and permanent water sources within 5 km of a Category 1 or 2 roost to be important but not critical habitat for the species.

Water pools can be classified as either permanent, semi-permanent and are directly impacted through clearing or indirectly impacted as a result of runoff, erosion, sedimentation, and change in hydrological regime. A publicly available regional data set of 453 pools was used to provide regional context for this Assessment. This regional data set comprised 401 registered named pools in the Pilbara bioregion included within the Landgate regional dataset (Landgate, 2023) and an additional 52 pools (not identified within the Landgate dataset) occur in the third- party assessed project areas. The location of pools in proximity to the Proposed Amendment are shown in **Figure 3-12**.

The total cumulative impact to pools associated with third-party projects within 100 km of the Proposed Amendment is summarised in **Table 3-12**. A total of 70 pools (15.5 % of known pools within the Pilbara bioregion dataset) were recorded in association with third-party projects, the Approved Proposal, and the Proposed Amendment. Of these, 16 (23%) are subject to potential impacts (direct and indirect) inclusive of the following:

- A total of 25 of Semi-Permanent pools recorded of which, 7 (28%) subject to potential impacts.
- A total of 11 of Permanent Water Pools recorded of which, 4 (36.4%) subject to potential impacts.
- A total of 34 of uncategorised pools recorded of which, 5 (14.7%) subject to potential impacts.

The percentage increase in cumulative impacts attributed to the Proposed Amendment to each category of pools is as follows:

- A 5% (Low) increase attributed to the Proposed Amendment, to the cumulative total of semi-permanent pools subject to potential impacts.
- No percentage increase attributed to the Proposed Amendment to the cumulative total of permanent pools subject to potential impacts.
- A 2.6% (Low) increase attributed to the Proposed Amendment to the cumulative total of uncategorised pools subject to potential impacts.

For the third-party assessed projects with the potential to have indirect impacts to water pools, the proposed mitigation and management measures considered in this Assessment are summarised as follows:

- Clear delineation on the ground of areas to be cleared (FMG, 2013)
- Clearing of vegetation associated with significant fauna and habitat (e.g., gorges, caves, waterholes and mature spinifex grassland) will be avoided or minimised as far as reasonably practicable (Coffey, 2012)
- Access to pools will be restricted to authorised personnel only (FMG, 2013)
- Dust and erosion management measures put in place to limit the potential indirect impact of clearing activities (Atlas, 2019)
- Installation of culverts along haul roads and intersections of drainage features, to minimise impacts to surface water quality and quantity in pools and maintain flow during operations (Atlas, 2019; Coffey, 2012, 2013)
- Implementation of a Site Water Operating Plan (SWOP) to monitor groundwater, surface water quality, clearing and waste management procedures (Atlas, 2021)

With consideration of proposed management and mitigation measures, the increase in cumulative percentage to all pools subject to significant impacts, attributed to the Proposed Amendment, is considered Low (1.4%).

Table 3-12: Cumulative impacts to water pools.

Pool Category	Proposed Amendment[3]	Approved Proposal[4]	Third-party Projects occurring within comparable land systems (100km radius of the Proposed Amendment)								Cumulative Impact		
			Atlas Iron: Abydos DSO Stage 1 [5]	Atlas Iron: Abydos DSO Stage 2 [6]	Venturex: Sulphur Springs Project [7]	Atlas Iron : Miralaga Creek DSO Project [8]	Atlas Iron: Sanjiv Ridge (Stage 1 DE) [9]	Atlas Iron: Sanjiv Ridge (Stage 2 DE)[10]	Atlas Iron: Mt Webber DSO Project (Stage 1 / Stage 2 Study Area)[11]	Atlas Iron Wodgina DSO Project (Stage 1 and 2)[12]	Total Cumulative Impact (Third-party Projects)	Total Cumulative Impact (including Proposed Amendment)	% Increase Cumulative Impacts Attributed To The Proposed Amendment (Cumulative Impacts Significance Rating)
Number of Semi-Permanent pools Recorded (number, % subject to potential impacts[1])	4 (2;50%)	Unknown	0 (0)	Unknown[2]	0	12 (0)	5 (1; 20%)	4 (4; 100%)	0 (0)	0 (0)	21 (5; 23%)	25 (7; 28%)	• 5% (Low)
Number of Permanent Water Pools Recorded (number, % subject to potential impacts[1])	0 (0%)	1 (0)	0 (0)	Unknown	1 (0)	2 (0)	6 (3; 50%)	1 (1; 100%)	0 (0)	0 (0)	11 (4;36.4%)	11 (4, 36.4%)	• No cumulative increase
Number of uncategorised pools recorded and (number, % subject to potential impacts[1])	1 (1; 100%)	10 (2; 20%)	18 (2: 11%)	Unknown	1 (0)	0 (0)	0 (0)	4 (0)	0 (0)	0 (0)	33 (4; 12.1%)	34 (5; 14.7%)	• 2.6% (Low)
Management and mitigation measures proposed (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No impacts to water pools	No impacts to water pools	Yes	Yes	
Total Pools recorded (number, % subject to significant residual impact following consideration of mitigation measures	5 (1;20%)	11 (0;0%)	18 (0; 0%)	Direct impacts to pools mentioned however, significance of impact not stated.	2 (0; 0%)	14 (0; 0%)	11 (0;0%)	9 (0; 0%)	0 (0)		65 (0; 0%)	70 (1; 1.4%)	• 1.4% (Low)

[1] *Project has the potential to impact the pool (directly or indirectly).*

[2] *Details of pools not specified within publicly available approvals documents.*

[3](FMG, 2022);[4](FMG, 2013);[5](Coffey, 2012);[6](Coffey, 2013);[7](MBS Environmental, 2016);[8](Atlas, 2020);[9](Atlas, 2019);[10](Atlas, 2021);[11](Outback Ecology, 2013);[12](Atlas, 2011)

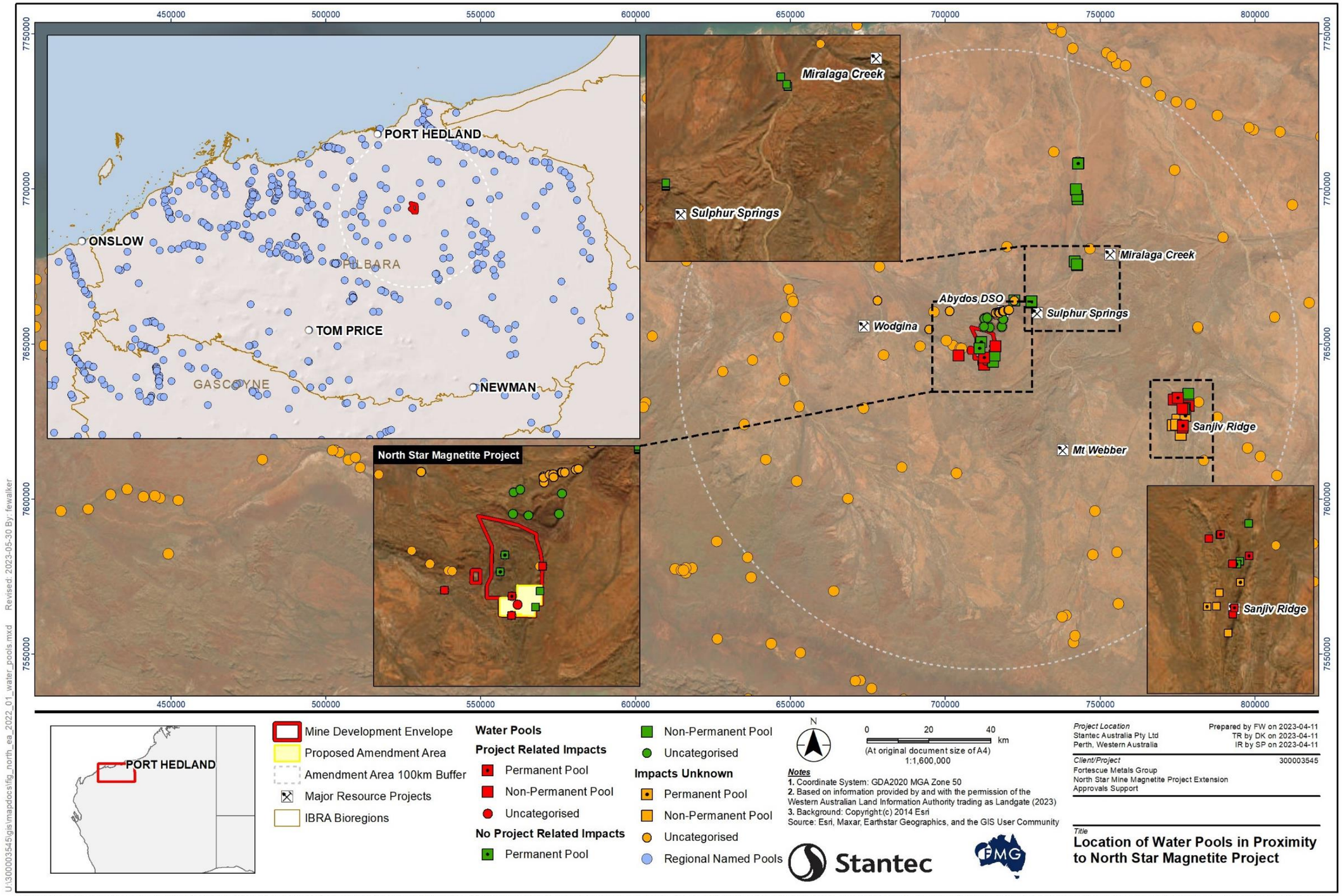

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Figure 3-12: Location of water pools in proximity to the Proposed Amendment.

4 Conclusion

The Proposed Amendment has the potential to contribute to cumulative impacts to terrestrial fauna values in combination with approved third-party projects at a landscape scale within the bioregion. The Assessment identified six significant species (Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat, Western Pebble-mound Mouse, Pilbara Olive Python, Peregrine Falcon) recorded across all approved third-party projects within 100 km of the Proposed Amendment, all of which have specific habitat requirements which increases the likelihood of exposure to cumulative impacts. Based on the results of the Assessment, significant cumulative impacts to broad fauna habitats, caves and water pools are not expected to occur at a bioregional scale.

Land Systems

The proposed clearing will result in a 50% reduction of the local area extent of the Capricorn land system, which will result in localised impacts to significant fauna species utilising habitats within this land system (Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python). The Proposed Amendment contributes a 9% increase to the total extent of cumulative impact to the Capricorn land system at a bioregional scale. Considering the above, and that all land systems will maintain an extent greater than 30% of their pre-European extent, it is unlikely that clearing will result in a significant cumulative impact to the associated land system and fauna habitat at a bioregional scale.

The proposed clearing will result in a reduction of 0.6% of its local area extent of the Rocklea land system; therefore, it is unlikely to have a significant impact to fauna species utilising habitats within this land system given the remaining extent available within the Proposed Amendment area and surrounds. A 0.3% (Negligible) increase in cumulative impacts to clearing within the Rocklea land system is attributed to the Proposed Amendment. There is no cumulative increase as a result of the Proposed Amendment to the Talga land system.

Fauna Habitat

The cumulative impact assessment indicates that the Proposed Amendment will not lead to a significant increase in cumulative impacts to terrestrial fauna habitat within the Pilbara bioregion, with a Low (<10%) increase in cumulative impacts on any one broad fauna habitat type attributed to the Proposed Amendment. Where Rocky Escarpment (considered critical habitat for significant fauna) has been consolidated within the Gorges and Gullies habitat, the cumulative increase attributed to the Proposed Amendment is considered 'Low' at 8.5%, and furthermore is likely an overrepresentation due to the consolidation of habitat undertaken in this assessment.

Caves

The regional data set for Ghost Bat roost caves included a total of 188 confirmed and potential roost caves, of which five (2.7%) will be subject to direct impacts and three (1.6%) will be subject to indirect impacts attributed to the Proposed Amendment. The increase in impacts to regional Ghost Bat roost caves attributed to the Proposed Amendment is considered 'Low'.

The regional data set for Pilbara Leaf-nosed Bat roost caves included a total of 273 confirmed and potential roost caves, of which nine (3.3%) will be subject to direct impacts and five (1.8%) will be subject to indirect impacts attributed to the Proposed Amendment. The increase in impacts to regional Pilbara Leaf-nosed Bat roost caves attributed to the Proposed Amendment is considered 'Low'.

The percentage increase in cumulative impacts to confirmed roost caves for the Ghost Bat and Pilbara Leaf-nosed Bat attributed to the Proposed Amendment that are subject to direct and indirect impacts for assessed Projects within 100 km of the Proposed Amendment are summarised as follows:

Ghost Bat:

- The percentage increase in cumulative direct impacts attributed to the Proposed Amendment, through clearing of five confirmed roost caves (comprising one Cat. 3, (Python Cave;), four Cat. 4 (Cave 1a; Cave 2; Cave 11; Heritage Cave) for the Ghost Bat, is 6.1% and is regarded as 'Low'.
- The percentage increase (cumulative impact) to three confirmed roost caves (comprising two Cat. 4 (Cave 32; Cave 33) and 1 Cat. 2 (Mundagoora Cave 3) subject to potential indirect impacts (noise, vibration) attributed to the Proposed Amendment, for the Ghost Bat, is 3.7% and is regarded as 'Low'.

Pilbara Leaf-nosed Bats:

- The percentage increase in cumulative direct impacts attributed to the Proposed Amendment, through clearing of nine confirmed roost caves (comprising one Cat. 3 (Python Cave), eight Cat. 4 (Heritage Cave; Caves 1a; 2; 3; 11; 14; 16; 21) of the Pilbara Leaf-nosed Bat, is 13% and is regarded as 'Moderate'.
- The percentage increase (cumulative impact) to five confirmed roost caves (comprising one Cat. 3 (Mundagoora Cave 3) and four Cat. 4 (Cave 32; Cave 33; Mundagoora Caves and 2) subject to potential indirect impacts (noise and vibration) attributed to the Proposed Amendment, for the Pilbara Leaf-nosed Bat, is 7.3% and is regarded as 'Low

The following mitigation and management measures considered by each third-party project subject to this Assessment, include:

- Implementation of buffer zones around identified potential roost caves, within which no works (e.g. clearing, blasting, operations) will be undertaken.
- Clearing in/of sensitive fauna habitats including scree slopes, ridges, outcrops, gullies and crevices will be kept to the minimum necessary for safe construction and operation of projects.
- Corrective rehabilitation or measures should structural damage to roost caves be observed.
- Monitoring of sensitive bat roosts throughout the life of the projects to determine changes in bat behaviour or the physical condition of the caves.
- Use of directional/screened lighting within the vicinity of bat roosts and minimisation of other secondary impacts (e.g. noise, vibration), and
- Implementation of appropriate management plans to monitor impacts and changes to the caves.

The Proposed Amendment will result in a Low (7.6%) cumulative increase to confirmed roost caves for the Ghost Bat or Pilbara Leaf-nosed Bat (Python Cave – Category 3 (GB & PLNB); Cave 32 – Category 4 (GB & PLNB); Cave 33 – Category 4 (GB & PLNB); Cave 11 – Category 4 (GB & PLNB); Heritage cave – Category 4 (GB & PLNB); Cave 1a – Category 4 (GB & PLNB); Cave 2 – Category 4 (GB & PLNB); Cave 21 – Category 4 (PLNB), Cave 14 – Category 4 (PLNB), Cave 3 – Category 4 (PLNB), Cave 16- Category 4 (PLNB) subject to significant impacts following implementation of the mitigation measures outlined above. All these caves are considered to be of low-priority, marginal or insignificant habitat for Ghost Bats or Pilbara Leaf-nosed Bats (GHD, 2025), which equate to 3.7% of the total known Ghost Bat and 4% of the total known Pilbara Leaf-nosed Bat regional roost datasets.

Surface Water Pools

The percentage increase in cumulative impacts attributed to the Proposed Amendment to each category of pools is as follows:

- A 5% (Low) increase attributed to the Proposed Amendment, to the cumulative total of semi-permanent pools subject to potential impacts.
- No percentage increase attributed to the Proposed Amendment to the cumulative total of permanent pools subject to potential impacts.
- A 2.6% (Low) increase attributed to the Proposed Amendment to the cumulative total of uncategorised pools subject to potential impacts.

For the third-party projects assessed within 100km of the Proposed Amendment the proposed mitigation and management measures for water pools were considered in this Assessment. Mitigation measures are summarised as follows:

- Clear delineation on the ground of areas to be cleared.
- Clearing of vegetation associated with significant fauna and habitat (e.g., gorges, caves, waterholes and mature spinifex grassland) will be avoided or minimised as far as reasonably practicable.
- Access to pools will be restricted to authorised personnel only.
- Dust and erosion management measures put in place to limit the potential indirect impact of clearing activities.
- Installation of culverts along haul roads and intersections of drainage features, to minimise impacts to surface water quality and quantity in pools and maintain flow during operations.
- Implementation of a Site Water Operating Plan (SWOP) to monitor groundwater, surface water quality, clearing and waste management procedures.

The increase in cumulative impacts (significant impacts following implementation of mitigation measures) to known water pools (semi-permanent, permanent, uncategorised) as a result of the Proposed Amendment is expected to be Low (1.4%). Permanent surface water pools are considered important foraging resources for the Pilbara Leaf-nosed Bat, Ghost Bat and Northern Quoll, and provide critical habitat for the Pilbara Olive Python. There will be no cumulative increase in impacts to permanent water pools attributed to the Proposed Amendment, which is therefore unlikely to adversely impact, reduce the area of occupancy of, or alter the conservation status of significant fauna that rely on permanent surface water pools within the bioregion.

With consideration of the above, significant terrestrial fauna are unlikely to be significantly impacted by the cumulative clearing of fauna habitat, attributed to the Proposed Amendment, within the bioregion and no change to the conservation status or bioregional distribution of significant fauna species is expected to occur as a result of cumulative impacts attributed to the Proposed Amendment.

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Appendix A Detailed Bat Habitat Assessment - North Star Extension

Detailed Bat Habitat Assessment

North Star Extension

Fortescue Metals Group Iron Bridge

4 March 2025

→ **The Power of Commitment**

Project name	Detailed Bat Habitat Assessment					
Document title	Detailed Bat Habitat Assessment | North Star Extension					
Project number	12637028					
File name	12637028_REP-1_NSE Detailed Habitat Assessment.docx					
Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
S3	A	H. North	D. Farrar		D. Farrar		20/01/2024
S4	0	H. North	D. Farrar		D. Farrar		17/02/2025
S4	1	H. North	D. Farrar		D. Farrar		04/03/2025

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Acknowledgement of Country

GHD acknowledges Aboriginal and Torres Strait Islander peoples as the Traditional Custodians of the land, water and sky throughout Australia. We recognise their strength, diversity, resilience and deep connections to Country.

Iron Bridge is located within the Traditional lands of the Nyamal people, and we acknowledge the ongoing connection to country of the various cultural and family groups.

We pay our respects to Elders of the past, present and emerging, as they hold the memories, knowledges and spirit of Australia. GHD is committed to learning from Aboriginal and Torres Strait Islander peoples in the work we do.

Executive summary

The North Star Extension (NSE) is a proposed southern extension of the North Star (Iron Bridge) iron ore mine. The NSE was referred by FMG Iron Bridge (Aust) Pty Ltd (FMGIB) under the *Environment Protection and Biodiversity Conservation Act 1999* and was decided by the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to be a controlled action, to be assessed by Public Environmental Report. The NSE was also referred under the WA *Environmental Protection Act 1986* and was determined by the EPA to be assessed by Referral Information.

GHD Pty Ltd was engaged by FMGIB to assess habitat and/or bat occupancy at twenty-six caves for the Ghost bat (GB) and Pilbara Leaf-nosed bat (PLNB) within the NSE Development Envelope (DE). The assessment included review of previous habitat assessment data, occupancy surveys, collection of acoustic and thermal imagery data and subsequent analysis by Specialised Zoological. The purpose of this report is to provide the results of a comprehensive habitat assessment for GB and PLNB to ultimately inform the Public Environmental Report process for the North Star Extension Project.

This report discusses the limitations and ambiguities associated with the current roost characterisation schemes for the GB. The caves assessed in this study were unable to be matched to one category using these schemes. Therefore, this report utilises a new and improved scheme for GB roost classification developed by Dr Kyle Armstrong (Specialised Zoological), which retains the same categories but assigns them with the use of a scoring system underpinned by occupancy rate, colony size and breeding evidence criteria.

The habitat assessment results presented in this report demonstrates Python Cave is occasionally used as a diurnal roost by the GB and the PLNB. The GB was observed to have a 40% diurnal occupancy rate at Python Cave for between 1-3 individuals. This level of occupancy categorises Python Cave as a Category 3 "Occasional Diurnal Roost," which can be considered low-priority habitat. The PLNB exhibited primarily nocturnal visitation patterns at all assessed caves, except for Python Cave, where PLNB were found to roost diurnally on limited occasion. Diurnal roosting by both species was not observed at any other cave across this habitat assessment. Historical observations have recorded GB diurnal roosting at Mundagoora Cave 3.

Assigning a level of risk associated with the removal of Python Cave is possible in the amended GB roost categorisation scheme, which suggests that removal of a C3-12 roost has a ‘moderate’ level of risk to the GB utilising Python Cave, as well as the population more broadly and its genetic connectivity. However, the removal of caves within the NSE is considered insignificant to both bat species, given the limited use of these caves by a small number of individuals and their demonstrated ability to move to and use alternative roosts within the region. Further, there is a high level of local roost redundancy, with several known Category 1, 2 and 3 roosts within nightly flight ranges of both species. This demonstrates that the loss of Python Cave would likely have minimal impact on population connectivity and gene flow because other diurnal roosts are available nearby.

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Appendices

1. Introduction

FMG Iron Bridge (Aust) Pty Ltd (FMGIB) operates the North Star (Iron Bridge) iron ore mine located approximately 110 kilometres (km) south of Port Hedland in the Pilbara region of Western Australia (WA). FMGIB is a majority-owned subsidiary company of Fortescue Metals Group Ltd (Fortescue), which owns and operates several mining and infrastructure projects in the Pilbara. Iron Bridge is a world-class magnetite operation that commenced operations in 2023 and is expected to run for a mine life of over 25 years.

The North Star Extension (NSE, previously referred to as 'Glacier Valley') is a proposed southern extension of the North Star operations comprising of new mine pits, extension of the waste dump and ancillary infrastructure. NSE was referred by FMGIB under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and was decided by the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to be a controlled action, to be assessed by Public Environmental Report (PER). The NSE was also referred under the WA *Environmental Protection Act 1986* and was determined by the EPA to be assessed by Referral Information.

Draft PER Guidelines issued to FMGIB in January 2024 outlined a detailed assessment and classification of suitable Ghost bat (GB) and Pilbara Leaf-nosed bat (PLNB) roosts are required, to inform buffer or exclusion zones for Category 1, 2 and 3 roosts to be implemented.

FMGIB considered the proposed guidelines may be overstating the importance of the roosts within the Development Envelope (DE), which may be a result of a lack of consolidated and contextual information on these roosts.

1.1 Scope of works

GHD Pty Ltd (GHD) were engaged by FMGIB to assess and characterise several caves within the NSE DE with respect to PLNB and GB roosting habitat and occupancy. The scope of this Detailed Habitat Assessment, included:

1. Mapping of GB and PLNB field observational data collected from monthly surveys undertaken by GHD since 2021 within the North Star study area
2. Reviewing previous data and habitat characterisation for bat roosts identified within the DE
3. Conducting a Detailed Habitat Assessment of bat roosts identified within the NSE DE
4. Conducting occupancy surveys and/or acoustic data collection for GB and PLNB where roosts are assessed as having diurnal usage
5. Undertaking a targeted utilisation survey of Python Cave by GB and PLNB, including counts of GB within Python Cave using thermal video recording
6. Analysing acoustic data collected from potential diurnal roosts at the Python Cave and Mundagoora Pool Cave Complex sites to determine presence and activity at these locations.

1.1.1 Contributing and supplementary scope

FMGIB engaged Specialised Zoological separately to supplement the scope being delivered by GHD. Specialised Zoological installed thermal video cameras at Python Cave and Heritage Cave to target GB and PLNB, which supplements scope item 4 above. Specialised Zoological also analysed bat detector and thermal video recordings from survey work undertaken to discover and characterise the use of caves by the target bat species, which adds to scope item 6 above.

1.2 Purpose of this report

This report details the methods and results of the Detailed Habitat Assessment for GB and PLNB within the NSE DE. The purpose of this report is to prepare a comprehensive and consolidated bat habitat assessment report, which can be used to inform the PER assessment process for the NSE Project.

1.3 Limitations

This report has been prepared by GHD for FMGIB and may only be used and relied on by FMGIB for the purpose agreed between GHD and FMGIB as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than FMGIB arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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

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

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.2 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

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.

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

2. Methods

2.1 Study area

The study area is consistent with the NSE DE, an approximately 1,426 ha area located immediately to the south of the existing North Star (Iron Bridge) operations (Figure 1). Twenty-six caves with the potential to provide PLNB and/or GB roosting habitat were assessed (with varying degrees of detail) during this study and are shown in Figure 2. The method used to assess these caves is provided in Table 5.

2.2 Desktop review

As part of the long-term PLNB monitoring at North Star, GHD has recorded bat observations during monthly field surveys, since April 2021. This data, where relevant to the NSE project area, was reviewed for GB and PLNB observations, regarding presence and frequency.

Previous reports were reviewed (Spectrum Ecology, 2023 and GHD, 2021) to consolidate existing descriptions of the bat roosts identified within the NSE DE and to determine the location of any new roosts for either species before the field surveys.

2.3 Roost categorisation

2.3.1 Ghost bat

There are currently two primary sources used to define GB roost categories:

– *Research priorities for the ghost bat (*Macroderma gigas*) in the Pilbara region of Western Australia* (Cramer et al., 2022)
– *A review of Ghost bat ecology, threats and survey requirements* (Bat Call WA, 2021b).

Nomenclature and definition of these categories are provided in Table 1. These two schemes are commonly accepted for use on project assessments in the Pilbara, but there is no prescriptive standard that requires their application, and no comprehensive guidelines for their application.

Table 1 Ghost bat roost category definitions (Cramer et al., 2022; Bat Call WA, 2021)

Roost category	Definition	Habitat significance
Category 1: Maternity/diurnal roost sites with permanent occupancy	These diurnal roost sites are permanently occupied by the GB, but the number of individuals present might fluctuate over time. Caves with proven permanent presence must all be assumed to be maternity caves and therefore considered critical habitat for the ongoing presence of GBs in the area. Category 1 and 2 caves are most often deep, dark and have at least one roosting chamber deep within, behind a reasonably narrow entrance or in-cave constriction. The roosting chamber is normally elevated above the entrance to trap warm moist air. The ceiling of the chamber is often domed or flat and has cracks and a roughed natural rock surface that allows the bats to grip. Some chambers have hollows in the ceiling where the bats back into completely for roosting or refuge. The ceiling heights are usually over 1.5 m and usually higher than 2 m, thereby providing some protection from terrestrial predators. The depth of the caves is variable ranging from shallow 20 m depth to 250 m (authors unpublished WA data) to over 500 m in the NT (L. Rhykus pers. comm.). Often, ongoing studies or monitoring may be required before Category 1 and 2 roosts can be confirmed.	'Critical' habitat

Roost category	Definition	Habitat significance
Category 2: Maternity/diurnal roost caves with regular occupancy	Caves and adits where GBs have regular, but not continuous, presence over long periods. i.e. most have roosting recorded for >25% of days but they may be abandoned for periods. These may have similar features as Category 1 caves with deep and complex structures. These caves typically have several other caves, shelters and overhangs within a few hundred meters. Together they make up an 'apartment block' grouping (TSSC 2016, Bullen 2017) that supports the ongoing presence of the bats. Any cave that has regular occupancy must be assumed to be capable of supporting one or more reproducing females and their offspring and are therefore critical habitat.	'Critical' habitat
Category 3: Diurnal roost caves with occasional occupancy	These sites have internal characteristics that can support roosting, with roosting recorded <25% of days and the site abandoned for long periods. These sites are important for the local, long-term persistence of Ghost bats in an area when located as part of an 'apartment block' roosting complex that contains category 1 or 2 sites and should be considered as critical habitat. In contrast, isolated Category 3 caves are not considered critical habitat essential to the long-term viability of a local population. However, these caves may enable the long-distance movement of individuals across a landscape and therefore contribute to genetic exchange between neighbouring colonies. Category 3 diurnal caves are usually shallower or not have a stable microclimate in an elevated roosting chamber but usually have a roosting chamber with a ceiling over 1.5 m high and usually, but not always, have significant scats and food middens.	'Critical' habitat where they occur within an 'apartment block' 'key' habitat when they occur in isolation
Category 4: Nocturnal roost	The majority of shallow caves, overhangs and shelters (e.g. adits and culverts) in the Pilbara may be used by GBs but usually are not structurally suited to maintaining stable temperatures and humidity. These may be used for resting and/or consuming prey during short night-time stays. Scats and/or prey remains are sometimes found. These are not considered critical habitat.	'Key' habitat

2.3.1.1 An improved Ghost bat roost classification scheme

This study has adopted a new scheme for GB roost classification and approach to interpreting roost habitat significance, which was developed by Dr Kyle Armstrong (Specialised Zoological, 2025; Appendix A). The improved scheme retains four categories used in Bat Call WA (2021b) and Cramer *et al.* (2022) but assigns potential roosts to them based on a scoring system to allocate criteria including diurnal occupancy, colony size and breeding activity. The scores are allocated to a roost category to indicate their level of significance. This is then applied to a risk matrix to inform impact assessment of a proposed project. While the scheme will benefit from some further development, it allows for a more informed assessment and response than could be made based on the information in Bat Call WA (2021b) and Cramer et al. (2022).

The scheme also distinguishes between two types of categorisation, depending on the confirmation of diurnal roosting (as opposed to nocturnal visitation). These are defined as:

– **Provisional categorisation** is based on ultrasonic recordings and other casual observations; and where there has been no determination of diurnal roosting behaviour using a method that allows unambiguous interpretation. Instead, the categorisation is made based on a variable 'detection of presence'.
– **Substantiated categorisation** is based on a determination of diurnal roosting behaviour using a method that allows unambiguous interpretation. Other observations can be used to support the categorisation to provide further confidence in the designation.

Roost categorisations can still be made when 'detection of presence' has been the only means of assessment, but the 'provisional' status should be considered in the context of adequacy of assessment, and whether further data is likely to change the categorisation (for example, if the roost structure is unlikely to support permanent roosting).

Interpretations of habitat significance

Category 1, category 2 and (isolated) category 3 roost sites are defined as 'critical' habitat by both Bat Call WA (2021b) and Cramer et al. (2022). Under these schemes, only category 4 nocturnal roosts are considered non-critical habitat. Bat Call WA (2021b) uses the 'apartment bock' concept where the relative importance of a category 3 roost increases (and is considered 'critical habitat') if proximate to other diurnal roosts. However, Cramer et al. (2022) recognises that maintaining colonies at the local scale likely requires a more nuanced consideration of the arrangement and number of roost sites, their physical characteristics (e.g. roost architecture and microclimate), and how they function as a roosting complex.

This consideration is further developed within the improved GB roost classification scheme adopted for this study (Dr Kyle Armstrong, 2025; Appendix A), which presents the view that not all diurnal roosts can and should be considered 'critical' habitat (Table 2). Rather, this scheme places a framework (based on measurable variables) around the interpretations and terms that indicate the importance of a structure to the GB, and how assessments should consider them in the context of development proposals. The framework also suggests a contrasting (opposite) approach to the 'apartment block' theory, by using a roost redundancy assessment. This assessment suggests the relative significance of a Category 3 roost that is part of a complex of several other diurnal roosts would be lower than an isolated category 3 roost. For example, if there are several roosts used by small colonies of GB in a local area that comprises several ridge lines, then the loss of one of these might not cause a local extirpation or reduce opportunities for intra-population connectivity - because of roost redundancy. Thus, local persistence is likely to be promoted by having several options for roosting, so the relative value of a Category 3 roost would be lower than a roost that is further away from others.

Table 2 Interpretation of habitat importance, Dr Kyle Armstrong (Specialised Zoological 2025; Appendix A, table A1.2)

Category	Usage type	Habitat significance
Category 1	Permanent diurnal roost	Critical habitat
Category 2	Regular diurnal roost	Important habitat
Category 3	Occasional diurnal roost	Low-priority habitat
Category 4	Nocturnal refuge	Marginal significance

The amended scheme (and framework for defining habitat significance) developed by Dr Armstrong (Specialised Zoological, 2025) has been applied to characterise caves utilised by GB within the NSE DE. The full and detailed methodology and rationale for this scheme, including how it has been applied in this study, is provided Appendix A.

2.3.2 Pilbara Leaf-nosed bat

The following sources were referenced to define PLNB roost categories:

– *TSSC Conservation Advice* (TSSC, 2016)
– *A review of Pilbara leaf-nosed bat ecology, threats and survey requirements* (Bat Call WA, 2021a)

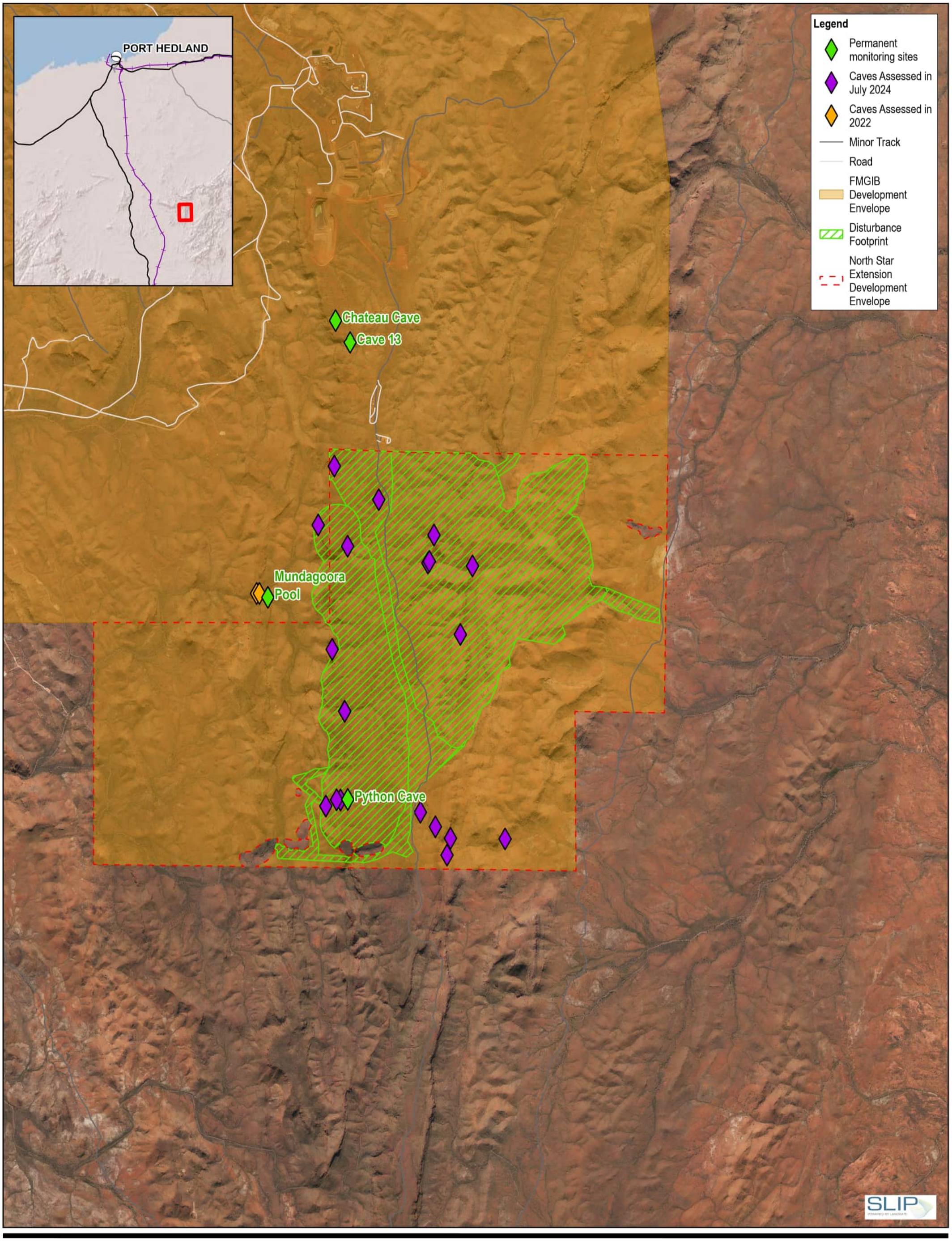
Nomenclature and definition of these categories are provided below in Table 3.

Table 3 PLNB roost category definitions

Roost category	Definition
Permanent diurnal roosts (Category 1)	Category 1 permanent diurnal roosts are maternity roosts where seasonal presence of young is proven. These often have large colonies present.
Permanent diurnal roosts (Category 2)	Category 2 permanent diurnal roosts are occupied year-round but without the proven presence of young. Based on wet season presence, these must also be classed as maternal sites, and these often have smaller colonies present. Both categories are considered as critical habitat that is essential for the daily and long-term survival of the PLNB.

Roost category	Definition
Transitory/semi-permanent diurnal roosts (Category 3)	These are used diurnally during some part of the year, but not occupied year-round. They may be used during the breeding cycle and also may facilitate long distance dispersal in the region, particularly in autumn. They are often associated with a nearby Category 1 or 2 permanent roost as a 'satellite' roost, that together make up a colony. Category 3 roosts are considered critical habitat that is essential for the long-term survival of the PLNB.
Nocturnal refuges (Category 4)	These are occupied or entered at night for resting, feeding or other purposes, with perching not a requirement. These are not considered critical habitat but are important for persistence in a local area. Excludes shallow overhangs, however moderately deep caves and shallow abandoned mines fall into this category.

This study uses the above roost categorisation scheme, however PLNB roost utilisation is likely more nuanced and variable than is defined within these four categories and may change throughout years depending on various environmental and other factors. Roost categorisation (and interpretations of roost habitat significance) would likely benefit from a similarly refined approach applied by Dr Kyle Amstrong (Specialised Zoological, 2025) to the GB roost categorisation scheme, however this was not available during this study.



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

GHD

Fortescue Metals Group Ltd
North Star Expansion - Detailed Habitat Assessment

Project No. **12637028**
Revision No. **0**
Date **04/03/2025**

Study Area and Survey Effort

FIGURE 1

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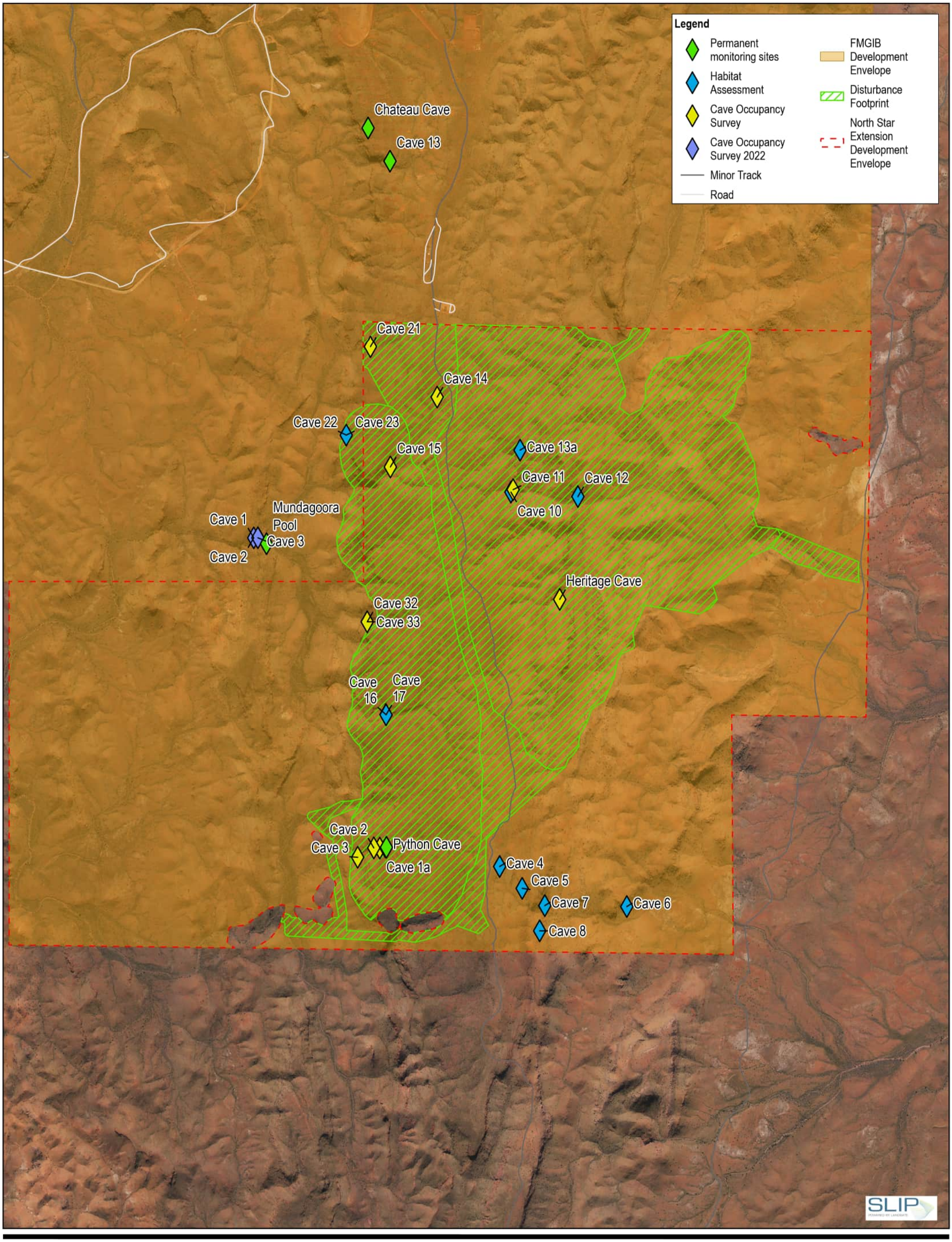
OpenStreetMap: Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri



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Grid: GDA 1994 MGA Zone 50

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Fortescue Metals Group Ltd
North Star Expansion - Detailed Habitat Assessment

Survey Effort

Project No. **12637028**
Revision No. **0**
Date **04/03/2025**

FIGURE 2

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OpenStreetMap: Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri

2.4 Field survey

Where relevant and applicable, field survey approach and methodologies were conducted in accordance with the following guidelines:

– Minimum survey requirements discussed in Bat Call WA (2021a) and Bat Call WA (2021b)
– Guidelines for detecting bats listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999 (DEWHA, 2010)
– Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment (WA Environmental Protection Authority, 2020).

2.4.1 Habitat assessment

Of the 26 caves identified within the NSE as requiring assessment, 20 required visitation during July 2024 by two GHD senior ecologists to assess the suitability of roosting habitat (Figure 2; Table 5). For caves where previous assessments had been conducted, the field team verified the earlier findings and provided an updated assessment as necessary, incorporating any new data or environmental variables identified.

Assessments were conducted from the front (outside) or just inside the cave entrances, where safe to do so. Where possible, a visual assessment was undertaken using a red filtered light or handheld thermal camera from the entrance to locate presence of roosting bats. The following data was collected and used to assist with determining the category of roosts as described above in Section 2.3:

– Location (GPS coordinates) and topographical position
– Elevation and aspect
– Size and shape of cave entrance
– Internal characteristics and dimensions of passages and chambers
– Notes on internal cave microclimate, including airflow, internal temperature and humidity (compared to outside ambient conditions)
– Photographs of the cave entrance and outlook
– Presence / absence of bats (seen and/or heard), guano, middens or other evidence.

2.4.2 Cave occupancy survey

Among the 20 caves where habitat assessments were conducted, those identified as having features suitable for potential bat roosting (such as internal chambers with possible humidity and/or where the presence of bats and/or guano) were investigated further for bat occupancy using the methods outlined below. The following data on bat utilisation and occupancy were collected.

2.4.2.1 Scat collection

Any suspected GB guano at the entrance of the cave was collected and submitted to the Australian Genome Research Facility (AGRF), to confirm GB presence, and allow identification of individual bats based on a panel of genotypes from custom-designed genetic markers. The results are pending as of 20 January 2025.

2.4.2.2 Ultrasonic recording

Bat calls were recorded using in situ (stationary) full spectrum ultrasonic detectors (either Wildlife Acoustics Song Meter SM4 bat or Titley Scientific Anabat Swifts) fitted with omni-directional microphones at each location. These were set to record for a minimum of three consecutive nights from 30 minutes pre-sunset to 30 minutes post-sunrise, at a 500khz sampling rate. The microphones were directed toward the likely bat flyway at the front or just inside of caves with habitat characteristics potentially suitable for diurnal roosting for GB and PLNB.

The timing of calls recorded at a given site was used to indicate the potential for the cave to be a diurnal roost, or the potential for a diurnal roost to be nearby.

The ultrasonic recorder system at Python Cave is described in Section 2.5 (below).

2.4.2.3 Thermal video recording

The GB can be readily identified in thermal video recordings by the presence of diagnostic features including long ears, broad wing shape, flight pattern and relatively large body size compared to other species such as the Common Sheath-tailed bat (*Taphozous georgianus*).

Thermal video recordings allow confirmation of diurnal roosting, if the first observation of the species is an egress from the cave. In addition, it is possible to estimate colony size by counting the number of individuals that emerge within the first three hours after sunset (and taking into account those that fly back into the cave).

Caves assessed as having the potential to contain GBs were monitored using thermal video recorders to confirm the presence or absence of the species, document emergence after diurnal roosting, and estimate the size of any GB colony (if present). The thermal video recording set-up used at the non-permanent caves was a FLIR Tau 360 x 240 30 fps video camera core connected to a TEC digital video recorder saving to an SD memory card. Units were programmed to record between sunset and sunrise. Analysis of the thermal video recordings was conducted by manual inspection in MPV software by Specialised Zoological.

The thermal camera system at Python Cave is described in Section 2.5.

2.5 Python Cave utilisation

Python Cave has been the focus of long-term monitoring with ultrasonic recorders (Songmeter SM4) for several years (GHD 2024a) as a requirement of Ministerial Statement 993. In August 2024, the monitoring system was upgraded to a 'SatBat' system (data made available by Supersensory Technologies Pty Ltd). Acoustic data from the latter of these two methods were collected by the automated system with a Pettersson Elektronik D500-384 bat detector connected to an automated recording and data analysis system with a Raspberry Pi 5 single board computer at its core.

The thermal camera at Python Cave was a FLIR Boson 640x512 60 fps video camera core connected to an automated recording system run by the Raspberry Pi 5 single board computer. This system runs nightly with analysis limited to the first three hours after sunset on selected nights. For the purposes of this study, Specialised Zoological analysed call activity data from both systems using methods summarised in Section 2.6.

Thermal video recordings at Python Cave were analysed with a custom Python (https://www.python.org/) script (Dr R.C. Morgans, Supersensory Technologies Pty Ltd unpublished) applied to a background subtraction algorithm from the *opencv* framework to the recordings and constructed a concatenated short video containing only portions of the recording with moving objects above a certain size. These concatenated videos were watched at <50% speed in the MPV MEDIA PLAYER, which allows fine control of frame advancement.

GB presence and activity was recorded to document emergence after diurnal roosting and estimate the size of GB colonies present by calculating the number of GB access/egress 'passes'.

Full and detailed methodology is provided in Appendix A.

2.6 Data analysis

Analysis of data collected by GHD as part of this study in July – September 2024 was conducted by Specialised Zoological (Dr Kyle Armstrong). A summary of both acoustic and thermal data analysis methods is listed below, and more detailed methodology is provided in Appendix A.

Ultrasonic recordings

A multi-step acoustic analysis procedure was applied to the recordings. The WAV files (sound files compressed from W4V to WAV) were scanned for echolocation calls of the two target species, GB and PLNB, using two separate parameters set in the software SCAN'R version 1.8.3 (Binary Acoustic Technology). After confirmation of WAV files that had signals consistent with GB and PLNB, a list of positive detections was summarised for each night.

Thermal video recordings

Analysis of the thermal video recordings (at sites other than Python Cave) was conducted by manual inspection in MPV software in order to confirm the presence of species. GB presence and activity was recorded to document emergence after diurnal roosting and estimate the size of GB colonies present by calculating the number of GB access/egress 'passes'.

2.7 Limitations

2.7.1 Detectability of bats

The calls of the GB are of low intensity and the bat must be close to the microphone (< 5-7m) for detection (Pettigrew et al. 1986). GB may hang within the entrance of a roost cave before nightly foraging, during which they will utilise other caves to rest and feed. Activity based on the detection of echolocation and social calls may not always be useful for predictions about diurnal usage (Specialised Zoological 2018). However, continuous presence over many nights can indicate the importance of a particular structure for a local group of GB.

This assessment has overcome this limitation for GB detectability by using thermal video recordings at caves where GB activity was considered possible, based on the roost habitat assessments.

PLNB also need to be in close proximity to the bat detector to be recorded. 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). Predictions about whether the PLNB roosts within a particular surveyed cave (where a bat detector was placed at the entrance), or somewhere nearby, based on the time of first detection should be considered indicative only. If unambiguous information of diurnal roosting of this species is required, diurnal roosting should be confirmed using the entrance sheeting method that is described in DEWHA (2010).

2.7.2 EPA limitations

Several potential fauna survey limitations are outlined by WA EPA (2016). These aspects are assessed and discussed in Table 4. No major limitations or constraints were identified for the current survey.

Table 4 Potential constraints and limitations

Potential limitation or constraint	Limitation to current survey	Relevance to this survey
Experience/ Competency	Nil	The field personnel involved in the study have in excess of 5 years' experience undertaking PLNB research in the Pilbara. Data analysis and interpretation was conducted by Dr Kyle Armstrong from Specialised Zoological who has over 30 years' experience in PLNB research.
Scope (faunal groups sampled and whether any constraints affect this)	Nil	The scope of the survey was a targeted habitat assessment and cave occupancy assessment survey focused on PLNB and GB. The survey was conducted in accordance with relevant guidelines and recommendations. All sampling methods implemented were able to be undertaken as expected. The survey was undertaken using standardised and established techniques.
Completeness	Nil	The results obtained within this study are adequate to address the purpose of the assessment as outlined in section 1.2.
Sources of information (recent or historic) and availability of contextual information	Nil	All contextual resources required to complete the scope were available (previous surveys, database searches, environmental information). This included information from previous fauna surveys and monitoring surveys previously conducted within the NSE.
Timing / weather / season / cycle	Nil	The study was conducted during the dry season when PLNB activity has been historically relatively high at known permanent diurnal roost in the region. Therefore, the timing of this survey is considered suitable for identifying priority habitat for the species in the study area.

Potential limitation or constraint	Limitation to current survey	Relevance to this survey
Disturbances (e.g. fire or flood	Nil	No disturbance occurred during or immediately prior to the surveys that is likely to have significantly impacted survey outcomes.
Proportion of fauna identified, recorded or collected	Minor	This study was conducted over a relatively short time period. Bat activity sampled at very low density over the course of 1-3 months provides a snapshot of roosting activity at a particular time of year. **Pilbara Leaf-nosed Bat:** While the acoustic survey effort applied in this study was not directly comparable to the DEWHA survey guidelines (2010), it does not limit the confidence or validity of the assessment outcomes. This is because the acoustic survey was supplemented by and balanced with the researchers' knowledge of roosting habitat and species movement ecology in the area within and surrounding the NSE DE; roost structural characteristic observations (i.e. ruling out unsuitable roosting habitat); and through the implementation of contemporary survey methods including thermal imagery and PIT tagging data. **Ghost bat:** While acoustic survey was not conducted across multiple seasons for some of the potential roost sites, the survey effort was balanced by roost structural characteristic observations (i.e. ruling out unsuitable roosting habitat); the methods in this study are considered sufficient and do not limit the confidence of validity of the assessment outcomes.
Proportion of the task achieved	Nil	The primary objective of the survey, to categorise caves located in previous surveys has been achieved.
Intensity of the survey	Nil	The area has been previously surveyed for potential PPLNB and GB roosting habitat. These caves were targeted during this survey.
Data analysis / sampling biases	Minor	The detectability of bats is discussed above in section 2.7.1. The absence of detections of bats at a given location does not confirm the absence of bats in the area.
Remoteness or access issues	Minor	Most of the NSE was accessible either by helicopter, vehicle or on foot. The current survey was largely unconstrained by accessibility or remoteness, however there were two caves that were inaccessible due to steep terrain. This is discussed in further detail in section 3.2.

3. Results

3.1 Desktop review

GHD (2021) details survey effort and observations within the NSE area for both species to the end of 2020. The report also provides broad context of the occurrence of the two bat species across the NSE area compared to the larger regional survey area (30 km buffer surrounding Chateau Cave). Since that report, GHD together with Specialised Zoological have implemented the PLNB Habitat Survey and Research Plan (as required by Ministerial Statement 993) and several other supporting studies on PLNB, within the study area. These studies are incorporated into the survey effort and results sections below, where relevant.

3.2 Survey effort

Habitat assessments were conducted at 20 caves through on-foot inspection (not including Python Cave or Mundagoora Caves 1-3). Of these, 11 were assessed as being suitable for GB and PLNB roosting habitat and selected for further occupancy survey. The remaining nine caves were assessed as being not suitable for bat roosting habitat due to lacking cave complexity (chambers) and/or depth of the cave (i.e. small overhang only). Habitat assessment forms for all caves are provided Appendix B.

The occupancy survey dataset collected and submitted for analysis during the initial July 2024 survey period consisted of 81,200 full spectrum bat detector sound files, from 11 recording sites (excluding Python Cave and Mundagoora Caves 1-3) over six recording nights (total 34 recording nights). A thermal video recording from one night at Heritage Cave was also submitted for analysis. Following analysis of this data two of these sites were selected for further cave occupancy survey (Heritage Cave and Cave 11), due to a high number of calls of GB and PLNB (higher relative to the rest of the dataset, but not necessarily high in terms of other known roosts). A further 30 nights of ultrasonic data was collected at Cave 11 and 38 nights of ultrasonic and 12 nights of thermal video data was collected at Heritage Cave during August to October 2024.

Cave 21 was not accessible due to steep and unsafe terrain. The few caves surrounding it were shallow overhangs unsuitable for GB or PLNB diurnal roosting. However, a detector was positioned as close as possible to capture activity in the vicinity. Cave 15 had similar access issues, so a detector was positioned nearby to capture activity in the area. Cave 17 could not be located.

A detailed list of survey effort for all sites is provided in Table 5.

Python Cave utilization survey

Survey effort at Python Cave during the Glacier Valley bat surveys (GHD, 2021) included ultrasonic recordings collected in May and September 2020, results from which were included in this assessment. Data analysed during this detailed assessment included 610 nights of ultrasonic recordings from between August 2021 and November 2024, and 92 nights of thermal video recordings from July – August 2024. These timeframes have allowed for the assessment of GB and PLNB activity across both breeding and non-breeding periods of the species.

Mundagoora (South Star Pool Complex)

Three caves near Mundagoora Pool (Cave 1, 2, & 3; Figure 2) were assessed for their potential to function as either diurnal roosts or nocturnal refuges for the GB. Emergence surveys in 2019 (GHD, 2021), and subsequent ultrasonic recordings were made over 99 nights with bat detectors between January 2022 and June 2022. This spans both the breeding and non-breeding periods of this species.

Table 5 Summary of survey effort and datasets analysed

Site name	Latitude	Longitude	Habitat assessment	Ultrasonic detector	Thermal video	Scat Collection for Genetics Analysis^
Python Cave	-21.2945	119.05568	GHD (2021)	Pettersson Elektronik D500-384: 3 Aug – 12 Nov 2024 (102 nights) Songmeter SM4Bat: 4 Aug 2021 - 17 May 2023 (508 nights)	SatBat: 20 Jul–16 Nov 2024 (92 nights)	-
Cave 1a (up gully from Python Cave)	-21.294575	119.05582	23 July 2024	Anabat Swift 23-26 July (3 nights)	-	-
Cave 2 (down gully from Python Cave)	-21.294567	119.055438	23 July 2024	Anabat Swift 23-26 July (3 nights)	Thermal Boson 1: 23-24 July 2024 (1 night)*	-
Cave 3 (down gully from Python Cave)	-21.29508	119.05453	23 July 2024	Anabat Swift 23-26 July (3 nights)	-	23 July^
Mundagoora (South Star Pool Complex) Cave 1	-21.27811546	119.0483659	GHD (2021)	14 Jan – 3 Feb 2022 (48 nights) 25 May – 24 Jun 2022 (24 nights)	-	-
Mundagoora (South Star Pool Complex) Cave 2	-21.27811546	119.0483659	GHD (2021)	21 Feb – 22 Mar 2022 (26 nights)	-	-
Mundagoora (South Star Pool Complex) Cave 3	-21.27810632	119.0486019	GHD (2021)	13 Jan 2022 (1 night)	-	-
Caves 4, 5, 6, 7	Coordinates provided in Appendix B		23 July 2024	-	-	-
Caves 8, 10, 12, 13a	Coordinates provided in Appendix B		24 July 2024	-	-	-
Cave 11	-21.27535	119.06310	24 July 2024	Anabat Swift 24-27 Jul (3 nights); 27 Aug – 25 Sep (30 nights)	-	24 July^
Cave 14	-21.27047	119.05871	26 July 2024	Songmeter SM4Bat: 26 – 29 Jul (3 nights)	-	26 July^
Cave 15 (area)	-21.275519	119.055394	25 July 2024	Songmeter SM4Bat: 25 – 29 (4 nights)	-	-
Cave 16	-21.28743	119.05603	25 July 2024	Anabat Swift: 25 - 29 Jul (4 nights)	-	25 July^
Cave 17	Cave could not be found. No caves in area, suspected erroneous data point.		-	-	-	-
Cave 21 (area)	-21.267715	119.055149	Cave entrance could not be	Songmeter SM4Bat: 26 – 29 Jul (3 nights).	-	-

Site name	Latitude	Longitude	Habitat assessment	Ultrasonic detector	Thermal video	Scat Collection for Genetics Analysis^
			accessed due terrain.			
Caves 22 and 23	Coordinates provided in Appendix B		25 July 2024	-	-	-
Cave 32	-21.28257	119.05492	25 July 2024	Anabat Swift: 25-28 Jul (3 nights)	-	-
Cave 33	-21.28250	119.05489	25 July 2024	Songmeter SM4Bat; 25-28 Jul (3 nights)	-	-
Heritage Cave	-21.28062	119.06638	24 July 2024	Anabat Swift; 24-27 Jul (3 nights); 27 Aug – 3 Oct (38 nights)	TAU 1: 24 Jul, 27 Aug– 7 Sep (13 nights)	-

***** *No data recorded due to technical error*

^ *Results pending. Results will supplement knowledge of GB genetic connectivity in the Pilbara, but will not change roost categorisation assessment outcomes of caves assessed in this study.*

3.3 Python Cave

This section presents the results of the occupancy survey for both species at Python Cave. Section 3.4 provides similar results for the other caves assessed. Further discussion around how these results can be interpreted to assign roost categories and define the significance of roosting habitat are provided in detail in Section 4 and Appendix A.

3.3.1 Ghost bat

3.3.1.1 Ultrasonic recordings

September – October 2020

Analysis of calls recorded from 15 nights of monitoring during September to October 2020 (GHD 2021) only detected GB on one night.

April 2021 – May 2023

Bat detector recordings between 8 April 2021 and 17 May 2023 were not continuous but spanned several months per year that included both breeding (April to July) and non-breeding (August to March) periods. Based on the detection of echolocation calls, the GB had a relatively low rate of visitation (Figure 3). There were GB calls detected 23% of the time during the non-breeding period and 11% of the time during the breeding period, which is an overall occupancy rate of 15%.

These detections do not necessarily represent diurnal roosting, as calls can also be attributed to nocturnal visitation. The rates of diurnal occupancy can be delineated from thermal video recordings (where video allows distinction from other bat species). This method is explained in Section 2.4.2.3). These rates of detection can be used as criteria to match the cave to a roost category (Section 2.3.1.1; Appendix A).

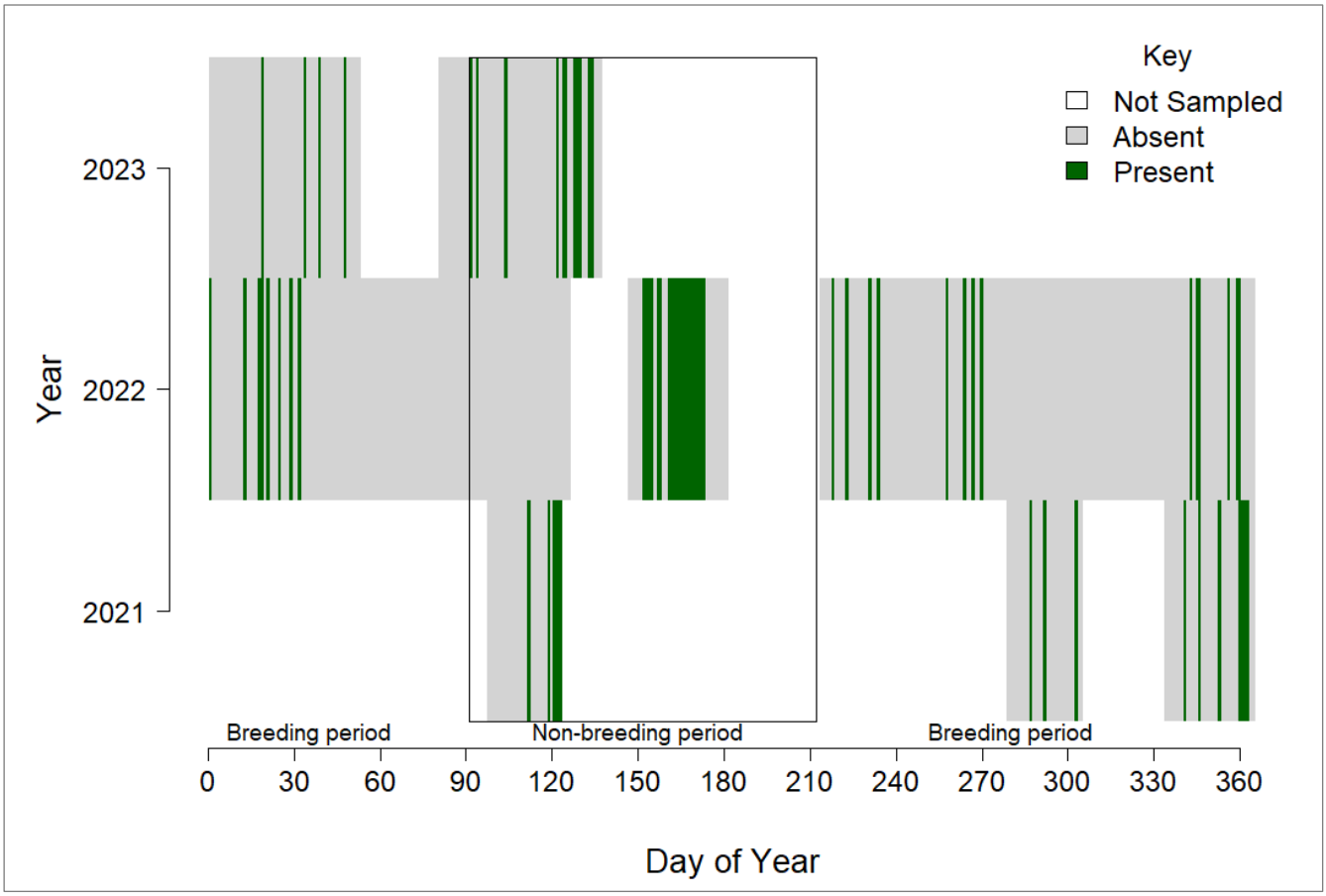


Figure 3 ***Summary of GB detections at Python Cave between April 2021 and May 2023 (rectangular box delineates the non-breeding months of April to July) (Specialised Zoological, 2025; Appendix A)***

GBs was also detected at Caves 1a and 2, which are situated in the same gully as Python Cave, less than 100 meters away (Figure 2). Full results are provided below in Section 3.4.1, the number of calls detected were low, and not within 30 minutes of civil sunrise/sunset.

3.3.1.2 Thermal video recordings

Thermal video recordings made between 20 July 2024 and 16 November 2024 were not continuous but included 92 nights in this period. Most of this period can be defined as being within the breeding months, though 12 nights in July were within the non-breeding period.

Based on the observation of individuals, the GB had a moderate rate of visitation, with three nights where there was no diurnal roosting but nocturnal visitation; and 37 days with diurnal roosting of at least one and up to three individuals (Figure 4). The overall rate of diurnal occupancy was therefore 40% (37 out of 92 days sampled). This included 32 of 81 days sampled (35%) during the breeding season, and eight of 11 days sampled (73%) during the non-breeding season. It is a slightly higher occupancy rate than is suggested by encounter rates from the much longer-term bat detector survey undertaken between April 2021 and May 2023 (Figure 3).

Figure 4 illustrates the number of individuals that were diurnally roosting inside Python Cave (net count excluding re-entries and re-emergence) (green bars). The long blue bars represent the number of individuals entering the cave during the post-sunset emergence period (i.e., no diurnal roosting). The short blue bars indicate nights where monitoring occurred, but no GB were observed.

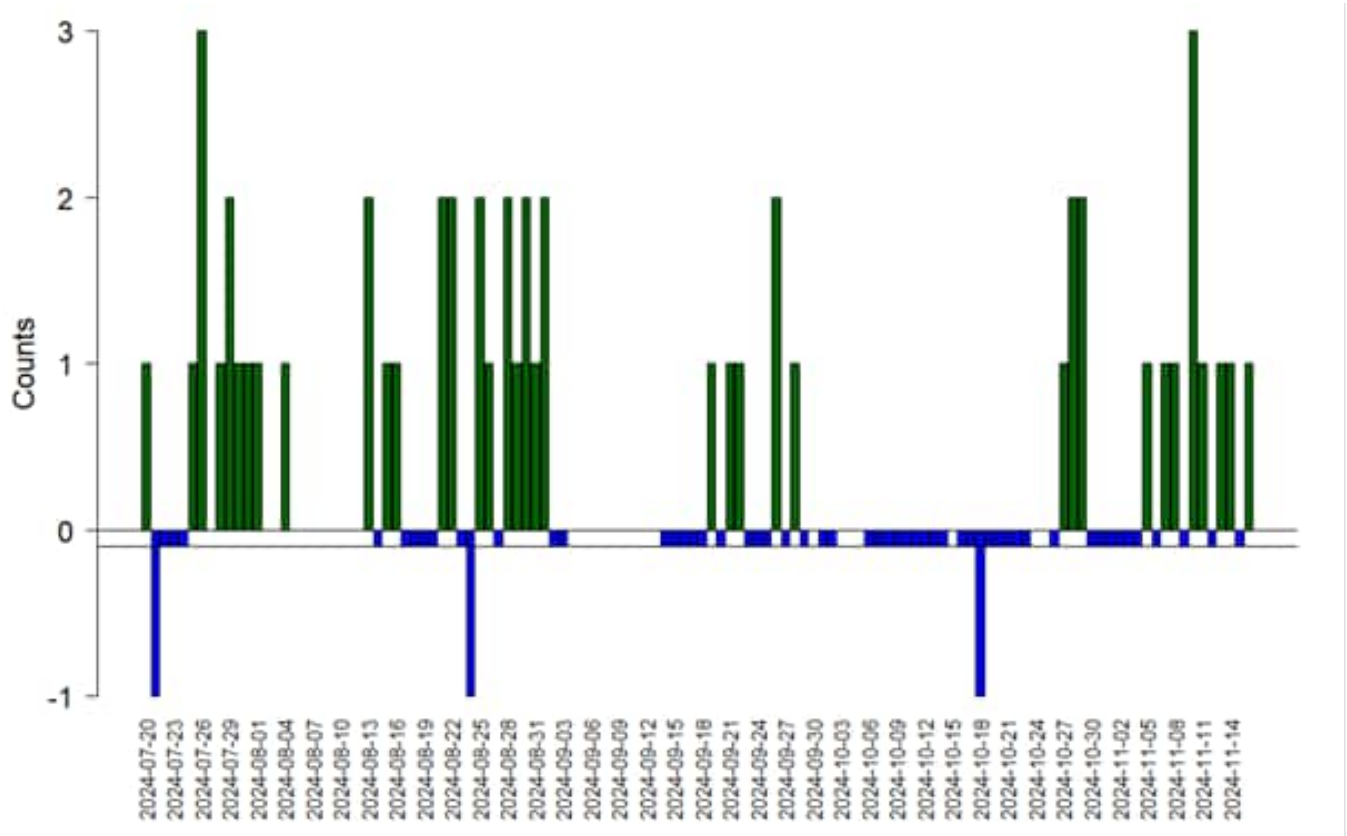


Figure 4 ***Summary of Ghost bat colony counts at Python Cave between July 2024 and November 2024 (Specialised Zoological, 2025; Appendix A)***

3.3.2 Pilbara Leaf-nosed bat

3.3.2.1 Ultrasonic recordings

Call data was collected between September 2020 and January 2024 and analysed by GHD (GHD 2024a). Ultrasonic call data collected as part of this long term PLNB monitoring program included an analysis method for defining call activity that differs to that of Specialised Zoological, and is detailed in section 2.4.2.2 and Appendix A.

GHD defined a call (pass) as a sequence of three or more consecutive pulses of similar frequency and shape over a period of one second, except for the PLNB where at least one clear pulse was acceptable.

September - October 2020

Analysis of calls recorded from 15 nights of monitoring during September to October 2020 (GHD 2021), shows low PLNB activity (e.g. <50 calls per night) for all nights, with calls within 20 minutes of civil twilight recorded on two consecutive nights. The detector was placed just inside the roost entrance, so these detections may indicate diurnal roosting, but cannot definitively be ruled out as individuals roosting at Chateau Cave (~4km north) travelling to Python Cave following emergence. There was also three PLNB observed roosting during the day inside Python Cave on 10 September 2020 (GHD 2021).

April 2021 - January 2024

Analysis of calls recorded between April 2021 to January 2024 conducted by GHD (GHD 2024a) has identified 86,592 PLNB calls. Average nightly call activity was low but occasionally calls exceeded 1,000 per night (Figure 5). Activity tended to be highest between 9pm and 2am (Figure 6), which contrasts with permanent diurnal roosts including Chateau Cave, that have highest activity in the first few hours after sunset and just before sunrise (GHD 2024a). Patterns in activity were strongly associated with time of year, with the highest activity occurring in the winter months (non-breeding period). The seasonal pattern of activity is similar to Chateau Cave (Category 1, 2 roost ~4km north; GHD 2024a). Activity also appeared to be lower overall in the third year of monitoring.

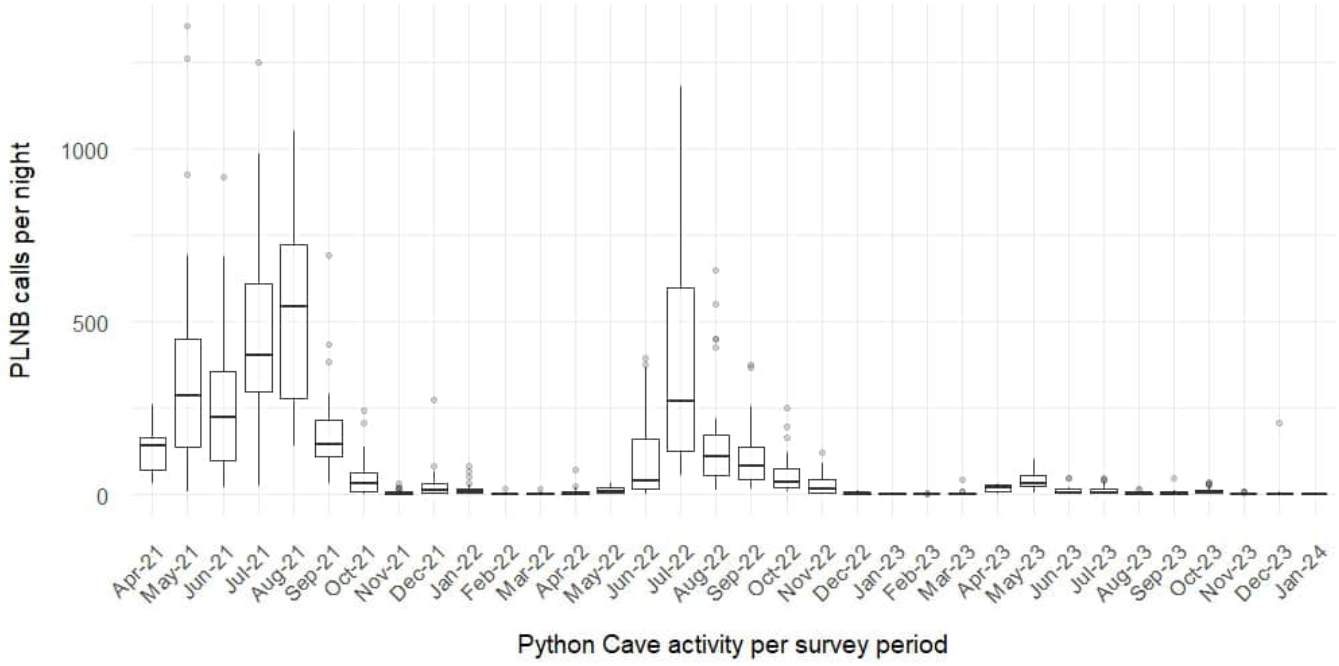


Figure 5 *Boxplot of Python Cave PLNB calls per night from April 2021 – January 2024 (GHD 2024a)*

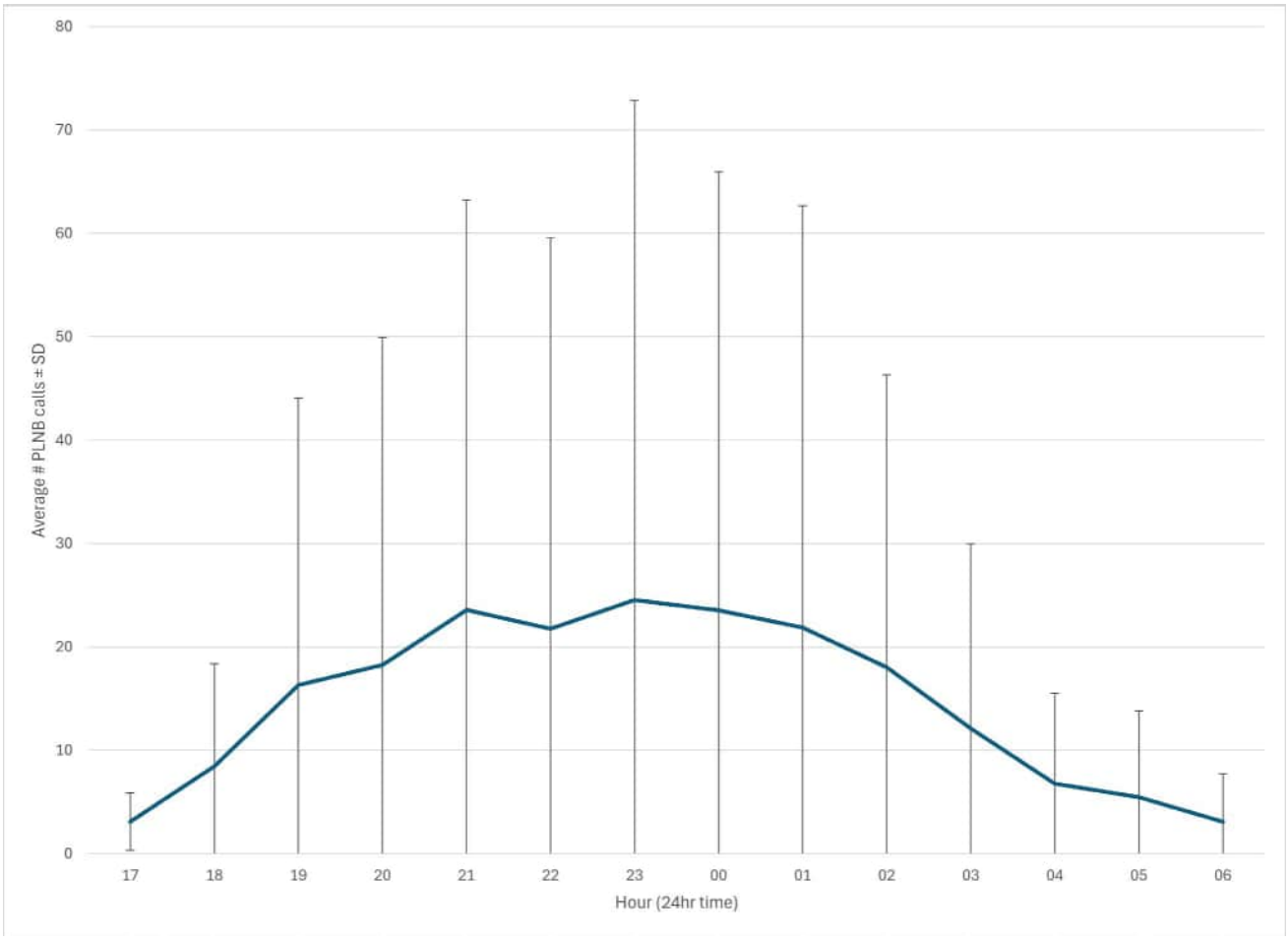


Figure 6 *Average hourly PLNB activity for all nights surveyed between April 2021 - Jan 2024*

August – November 2024

Bat detector recordings between 3 August 2024 and 12 November 2024 were made over 102 nights with the SatBat installation. This period falls within the breeding months for the PLNB.

Based on August to November 2024 data, the PLNB is found to have nocturnal visitation on a nightly basis, but activity is highly variable. There is no clear pattern to visitation between months/seasons during this period, with the highest number of pulses per night in late September 2024 (Appendix A). The distance between Python Cave the known permanent diurnal roost at Chateau Cave is4.2 km (north), meaning the times of first and last detection are not reliable indications of diurnal roosting within Python Cave. This is because individuals that roost during the day in Chateau Cave can be present at Python Cave very soon after their emergence.

The methodology for call analysis for this period of data (Specialised Zoological, 2025) does not allow it to be directly comparable to data collected and analysed by GHD as described for September 2020 through January 2024 (i.e. number of echolocation pulses as opposed to number of nightly ‘passes’, which is 3 or more pulses in a sequence). However, the overall patterns, longer term trends in the nightly total detections, and times of first and last detection are interpretable from both data types.

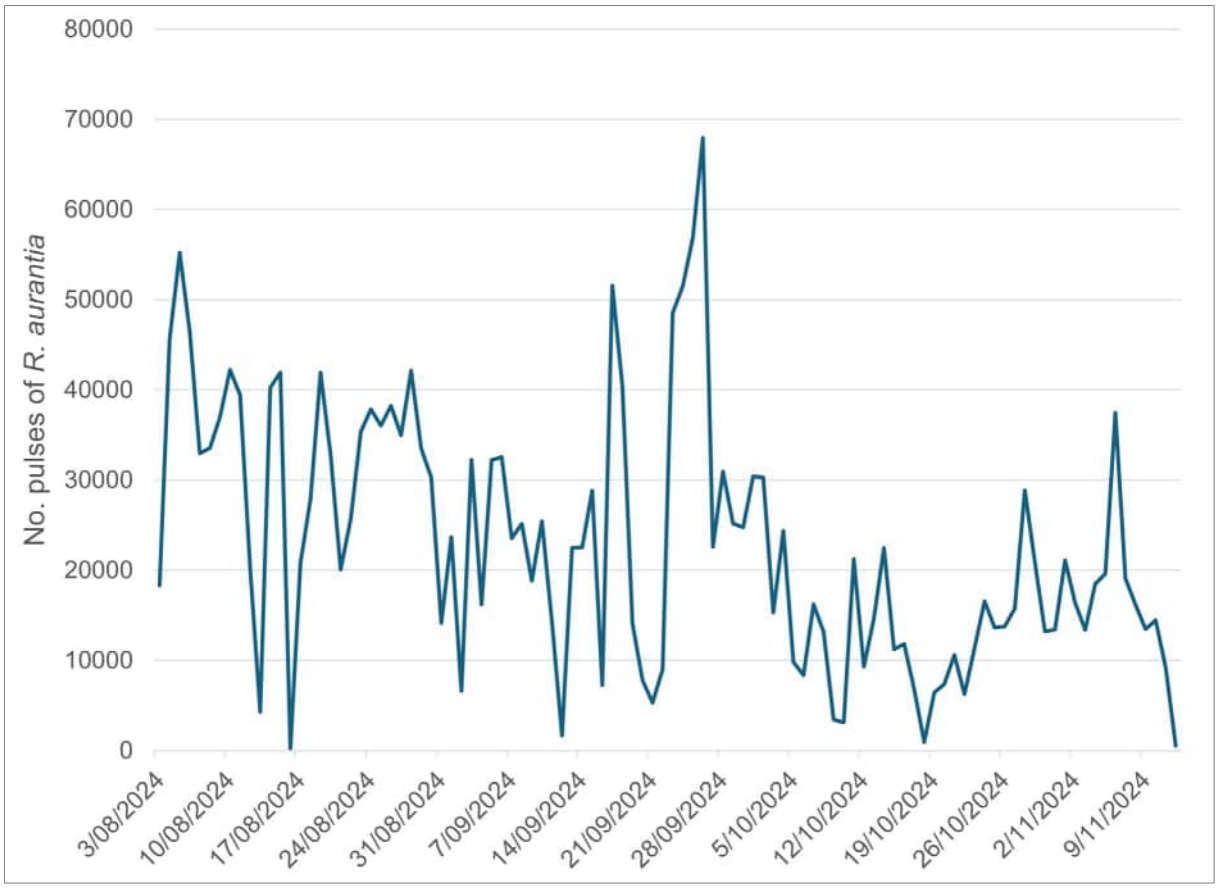


Figure 7 ***Levels of activity of the Pilbara Leaf-nosed bat at Python Cave in the latter half of 2024. (Specialised Zoological, 2024; Appendix A)***

3.3.2.2 Passive Integrated Transponder (PIT) data

GHD PIT tagged 152 PLNB during September 2023 and July 2024 and together with SuperSensory Technologies have since been monitoring the activity of tagged bats at six roost locations in the region. The Python Cave PIT reader has been operational from 25 July 2024 to the present day. Between the day of installation and 15 January 2025 (174 days), 32 tagged PLNB have been detected flying through the Python Cave entrance antenna at least once, which represents 21% of all 152 tagged individuals. All 32 of these individual PLNB were originally tagged at Chateau Cave (approximately 4km north of Python Cave) and consists of 21 males and 11 females (SuperSensory Technologies, unpublished data).

Similar to ultrasonic recordings, the patterns of detections from a PIT reader at a cave entrance may provide evidence for diurnal roosting during twilight periods. The pattern at Python Cave is indicative of mostly night visitation of individuals that have originated from a diurnal roost elsewhere (likely from Chateau Cave as is indicated in visitation by PIT tagged individuals). The few detections close to periods of twilight could be indicative of occasional diurnal roosting. A full and detailed analysis of patterns of detection is provided by Specialised Zoological (2025) in Appendix A.

3.4 Other caves within the NSE DE

3.4.1 Ghost bat

3.4.1.1 Acoustic data and thermal video analysis

The GB was detected at five caves (total nine recording nights; 19 echolocation sequences). At ‘Heritage Cave’ the detections of echolocation calls were corroborated with observations of GB in flight at the same time in a recording from a thermal video camera on one night (24 Jul 2024).

However, the thermal video resolution on subsequent nights was too low to allow separation of GB from the many Common Sheath-tailed bats present, diurnal presence could not be confirmed, nor could colony size be estimated. A summary of GB detections from assessed caves is provided in Table 6, and full data provided in Appendix B.

Table 6 Summary of GB echolocation call (acoustic) detections from assessed caves

Cave	Number of recording nights	Number of detections	Earliest time of first detection	Time since sunset (H:MM)	Latest time of last detection	Time until sunrise (H:MM)
Cave 1a	3	7	18:56	1:15	5:56	0:38
Cave 2	3	3	18:55	1:16	5:35	0:59
Cave 11	33	1	20:43	3:03	20:43	9:51
Cave 33	3	1	5:03	11:22	5:03	1:30
Heritage Cave	41	131	18:52	0:47	5:39	0:37

3.4.1.2 Mundagoora Cave 3 observations

Mundagoora Cave 3 was observed to have between 26-30 GB emerging and diurnal roosting was confirmed through screening of the entrance at the beginning of the evening on the 21 January 2019. There were also several GB calls detected during the emergence period on this night (GHD, 2021).

The only survey effort conducted following the 2019 emergence survey included GHD collecting ultrasonic call data over 99 recording nights between all three Mundagoora Caves in 2022 (spanning both breeding and non-breeding periods; Table 5). This data was analysed for the purposes of this study, and there were no GB calls identified within this data (Specialised Zoological, 2024).

3.4.2 Pilbara Leaf-nosed bat

3.4.2.1 Acoustic data and thermal video analysis

The PLNB was detected at all 11 caves where occupancy surveys were conducted (total 103 recording nights). A summary of PLNB detections at all caves is provided in Table 7, and full data provided in Appendix B

The highest number of nightly passes, both in a single night, and overall was at Cave 11 (approximately 2.3 km from Chateau Cave; Figure 2) the highest number of nightly passes of PLNB was 355 on 26 July 2024, and the lowest was a single pass on the 12 September 2024. These detections were all during the night, with no calls close to civil twilight.

The closest calls to civil twilight were from Caves 1a, 2 and 3, which are located within the same gully as Python Cave.

Table 7 Summary of PLNB detections from assessed caves

Cave	Number of recording nights	Highest # nightly passes	Avg nightly passes	Earliest time of first detection	Time since sunset (H:MM)	Latest time of last detection	Time until sunrise (H:MM)
Cave 1a	3	89	67	18:25	0:43	4:40	1:60
Cave 2	3	52	34	18:39	0:57	3:39	3:00
Cave 3	3	33	22	18:59	1:16	3:10	3:30
Cave 11	33	355	46	20:07	2:23	3:26	3:13
Cave 14	3	4	10	19:34	1:50	2:30	4:08
Cave 15 (area*)	4	1	2	20:51	3:07	20:53	9:46
Cave 16	4	1	2	23:01	5:17	23:21	7:17
Cave 21 (area*)	3	7	20	19:22	1:38	4:30	2:09

Cave	Number of recording nights	Highest # nightly passes	Avg nightly passes	Earliest time of first detection	Time since sunset (H:MM)	Latest time of last detection	Time until sunrise (H:MM)
Cave 32	3	1	1	3:17	9:34	3:17	3:22
Cave 33	3	6	11	21:24	3:41	1:39	4:60
Heritage Cave	41	22	27	20:12	2:29	1:06	5:33

**Indicates detectors were placed in the general area of a cave rather than pointing into or across the entrance of a cave. For Cave 21, this was done due to inaccessibility of the cave by foot. For Cave 15 this was done due to Cave 15 itself being assessed at unsuitable roosting habitat, but there were other nearby caves that had the potential to be roosting habitat but were inaccessible by foot.*

4. Discussion

4.1 Roost categorisation

With the exception of Python Cave, there was no strong indication any of the caves were being used as a diurnal roost by either species. A summary of interpretations of roost categorisation for GB and PLNB in the NSE DE is provided in Table 8. The criteria and methodology associated with roost categorisation (and roost habitat significance) are detailed in Section 2.3.

Ghost bats were detected at 5 out of 14 sites where acoustic call data was available. Further analysis and interpretation of these results, particularly regarding the improbability of diurnal roost use, are discussed in the following sections.

For PLNB, the time of first detection from which diurnal roosting can be inferred, is expected to be within 30 minutes before/after civil twilight, and given all caves assessed within the NSE DE are between 0-5 km of a known diurnal roost (Chateau Cave; Figure 1), and their tendency to around cave entrances and repeatedly re-enter caves (Bat Call WA 2021b), this time could be reduced to within 5 minutes to reduce likelihood of detecting individuals from that roost. These early/late detections were not observed at any of the caves surveyed. The quantity of PLNB call activity at all caves was also observed to be relatively low (Table 7), compared with a proximate, known Priority 1 Permanent diurnal maternity roost, Chateau Cave (Figure 1), which had on average 8,598 nightly passes between April 2021 and May 2023.

Table 8 Roost category interpretations

Ghost bat	**Category**				
	Category 1: Maternity/ diurnal roost sites with permanent occupancy	**Category 2: Maternity/ diurnal roost caves with regular occupancy**	**Category 3: Diurnal roost caves with occasional occupancy**	**Category 4: Nocturnal roost caves with opportunistic usage**	**Habitat significance^**
Python Cave	-	-	Applies (see section 4.1.1)	Applies	Low priority habitat
Heritage Cave	-	-	Might apply (see section 4.1.2.1)	Applies	Marginal significance
Mundagoora Cave 3	-	-	Might apply (see section 4.1.2.1)	Applies	Low priority habitat
Caves 1a, 2, 11, 33	-	-	-	Applies	Marginal significance
Mundagoora Caves 1 and 2; Caves 3, 4, 5, 6, 7, 8, 10, 12, 13a, 14, 15, 16, 17, 21, 22, 23 and 32	-	-	-	Might apply*	Marginal significance
Pilbara Leaf-nosed bat	**Category**				
	Priority 1: Permanent diurnal roost	**Priority 2: Non-permanent breeding roost**	**Priority 3: Transitory diurnal roost**	**Priority 4: Nocturnal refuge**	**Habitat Significance^**
Python cave	-	-	Applies (see section 4.1.1)	Applies	Low
Cave 11	-	-	-	Applies	Insignificant
Heritage Cave	-	-	-	Applies	Insignificant
Caves 1a, 2 and 3	-	-	-	Applies	Insignificant

Ghost bat	Category				
	Category 1: Maternity/ diurnal roost sites with permanent occupancy	Category 2: Maternity/ diurnal roost caves with regular occupancy	Category 3: Diurnal roost caves with occasional occupancy	Category 4: Nocturnal roost caves with opportunistic usage	Habitat significance^
Mundagoora Caves 1, 2 and 3; Caves 4, 5, 6, 7, 8, 10, 12, 13a, 14, 15, 16, 17, 21, 22, 23, 32 and 33	-	-	-	Might apply*	Insignificant

**Limited ultrasonic recording data collected as part of this survey and previous surveys (GHD 2021) cannot be used to confirm absence at the cave.*

^ *Using interpretations presented in Specialised Zoological 2025; Appendix A*

4.1.1 Python Cave

The most detailed assessment was conducted on Python Cave as it has several years of data and therefore the interpretation of usage for both bat species can be considered as a 'substantiated categorisation' (i.e. data collected across seasons and GB diurnal roosting confirmed through thermal video; details provided in Appendix A). The remainder of sites can be considered as 'provisional categorisation', however these are unlikely to require the collection of further data for substantiated categorisation, due to the nature of the call activity (i.e. low quantity and not close to civil twilight) and cave structure (i.e. lacking depth and structural complexity). Further discussion is provided in subsequent sections.

4.1.1.1 Ghost bat

As discussed in Section 2.3.1, GB roosts are typically categorised (and significance of roost habitat is interpreted) using schemes described in Bat Call WA (2021b) and Cramer et al. (2022). These schemes are challenging because they are insufficiently structured and detailed for empirical assessment. Matching Python Cave to a single category was not possible using these schemes, thus this report uses an improved classification scheme as presented above in Section 2.3.1 and provided in full detail in Appendix A (Specialised Zoological, 2025).

The GB occupancy rate at Python Cave was 40%, with diurnal roosting observed on 37 out of 92 nights by one- to three individuals (considered a 'substantiated categorisation' using thermal data). Using acoustic data only ('provisional categorisation') resulted in 23% of recording nights during the non-breeding period and 11% during the breeding period. These levels of occupancy do not meet the criteria for a Category 1 or 2 roost, which require higher and more consistent occupancy rates, as well as a larger colony size.

Using this scheme, the final substantiated classification outcome for Python Cave is Category 3 "Occasional Diurnal Roost" (Low-priority Habitat) as summarised in Table 9 and Appendix A. A redundancy assessment has also been conducted on Python Cave to allow further consideration of the relative significance of the roost in the context of the proximity and number of other diurnal roosts in the area (see below section 4.2.1).

Table 9 Assessment of GB roost category for Python Cave

Criteria	Python Cave scores	
	Ultrasonic recordings	**Thermal imagery data**
A. Diurnal occupancy rate Season 1 survey August – March (pregnancy, parturition, lactation)		
Greater than 90%		
Between 25% and 90%		4 (results Section 3.3.1.2)
Less than 25%	3 (results Section 3.3.1.1)	
Never, night visitation only, >50% encounter rate per survey period		
Never, night visitation only, <50% encounter rate per survey period		
B. Diurnal occupancy rate Season 2 survey April – July (independent young, mating)		
Greater than 90%		
Between 25% and 90%		4 (results Section 3.3.1.2)
Less than 25%	3 (results Section 3.3.1.1)	
Never, night visitation only, >50% encounter rate per survey period		
Never, night visitation only, <50% encounter rate per survey period		
C. Colony size (maximum over surveyed period)		
21-100s		
4-20		
1-3		4 (results Section 3.3.1.2)
No diurnal occupancy		
Total score (A+B+C)	**10**	**12**
Category allocated	**C3**	**C3**
Usage type (see table Appendix A, Table A1.2)	**Occasional diurnal roost**	**Occasional diurnal roost**
Categorisation type	**Provisional**	**Substantiated**
Habitat significance (see table Appendix A, Table A1.2)	**Low-priority Habitat**	**Low-priority Habitat**

Caves 1a, 2 & 3 are in close proximity (i.e. approx. 40-120 m) and within the same gully as Python Cave (Figure 8) and are 'provisional classification' Category 4 "Nocturnal roost caves with opportunistic usage" (see further details in section 4.1.2.1). Attributing the 'apartment block' concept (Table 1) to Python Cave and Caves 1a, 2 & 3 is not warranted given that Python Cave is a category 3 cave rather than a Category 1-2 cave as required by Bat Call WA (2021), and caves 1a, 2 and 3 have very little activity and do not have the structural characteristics required for significant roosting habitat. It is not justifiable to elevate the level of importance of Python Cave because the individuals that occupy it during the day may also visit nearby underground structures of relatively shallow depth after sunset (results provided section 3.4.1.1).

4.1.1.2 Pilbara Leaf-nosed bat

Observations made over several years have demonstrated Python Cave is used as an occasional PLNB diurnal roost, by one or more individuals (Priority 3 roost). However, the gully Python Cave is situated in is regularly utilised nocturnally by PLNB. Nightly call activity patterns (Figure 6) did not align with those of permanent diurnal roosts, which typically show a bimodal pattern of peaks in activity immediately after sunset and again before sunrise. This was supported by the PIT detection patterns), with Python Cave only showing a few detections close to periods of twilight that could be indicative of diurnal roosting (Specialised Zoological, 2025; Appendix A).

Given the definitions and categorisations of roost types in the Conservation Advice for the PLNB (Threatened Species Scientific Committee, 2016), the observations provided in section 3.3.2 support the assessment that Python Cave is used primarily as a Priority 4 nocturnal refuge, and occasionally as a Priority 3 transitory diurnal roost.

4.1.2 Other caves within the NSE DE

4.1.2.1 Ghost bat

Applying the improved scheme (Specialised Zoological, 2025; Appendix A) to the five other caves found to have GB activity in the NSE DE, the final 'provisional classification' outcome for all five is Category 4 "Nocturnal roost caves with opportunistic usage" (Table 10). Upgrade to category 3 roosts through the collection and analysis of further data is not considered possible for any of these five roosts, due to being unlikely to support regular occupancy of GB throughout the seasons, as they lack size and structural complexity (Appendix B). Additionally, there was no evidence of scat piles or middens to suggest regular GB occupancy within the cave (Appendix B). These five roosts are not considered priority habitat for the species, and the loss of these five caves can be considered insignificant.

The data collected at Heritage Cave did not suggest diurnal roosting, however the thermal data could not rule out GB emerging/entering the cave apart from the many Common Sheath-tailed bats (*Taphozous georgianus*) that occupy the cave. Heritage Cave may occasionally serve as a diurnal roost for GB. The 'provisional classification' of a category 4 roost could be substantiated and potentially meet the criteria for a Category 3 at best, with further data collection and analysis (Specialised Zoological, 2025). However, the cave's internal structure is unlikely to support regular occupancy of GB throughout the seasons, as it lacks structural complexity, and the rear chamber is exposed to ambient weather conditions through a small opening to the top/side of the ridge (Appendix B). Additionally, there was no evidence of scat piles or middens to suggest regular GB occupancy within the cave (Appendix B).

Based on the available GB data for Mundagoora Cave 3 (Figure 8), which includes zero calls within the 99 nights of acoustic data, and the historic observations of 26-30 GB emerging through entrance screening in 2019, it is not possible to determine the extent of diurnal roosting. While GHD (2021) stated this cave is likely to be a category 1 or 2 roost, based on the fact diurnal roosting was confirmed on one day during the breeding season, there remains insufficient data to substantiate this categorisation using the current scheme detailed in Appendix A (Specialised Zoological, 2025). Under this improved scheme, it is likely to be a Category 3 occasional diurnal roost at the least, and its categorisation may be elevated to a provisional Category 2 with the analysis of further occupancy data. However, for the purposes of this assessment Mundagoora Cave 3 has been categorised as a provisional Category 2 GB roost. Mundagoora Cave 3 has not been included in Table 10 given the paucity of data.

Table 10 Assessment of GB roost category for other caves within the NSE

Criteria	Heritage Cave	Caves 1a, 2, 11, 33
A. Diurnal occupancy rate Season 1 survey August – March (pregnancy, parturition, lactation)		
Greater than 90%		
Between 25% and 90%		
Less than 25%		
Never, night visitation only, >50% encounter rate per survey period	2 (see results in Section 3.4.1)	
Never, night visitation only, <50% encounter rate per survey period		1 (see results in Section 3.4.1)
B. Diurnal occupancy rate Season 2 survey April – July (independent young, mating)		
Greater than 90%		
Between 25% and 90%		
Less than 25%		
Never, night visitation only, >50% encounter rate per survey period	2 (see results in Section 3.4.1)	
Never, night visitation only, <50% encounter rate per survey period		1 (see results in Section 3.4.1)
C. Colony size (maximum over surveyed period)		
21-100s		
4-20		
1-3		
No diurnal occupancy	1 (see results in Section 3.4.1)	1 (see results in Section 3.4.1)
Total classification score (A+B+C)	**5**	**3**
Category allocated	**C4**	**C4**
Usage type (see table Appendix A, Table A1.2)	**Nocturnal refuge**	**Nocturnal refuge**
Categorisation type	**Provisional**	**Provisional**
Habitat significance (see table Appendix A, Table A1.2)	**Marginal**	**Marginal**

4.1.2.2 Pilbara Leaf-nosed bat

Patterns of PLNB call activity indicated that all caves assessed for occupancy during this survey (or the areas surrounding their entrances) are visited during the night by PLNB. The quantity of nocturnal activity associated with these caves and surrounding areas is considered low, and there is no evidence to suggest diurnal roosting at any of the caves.

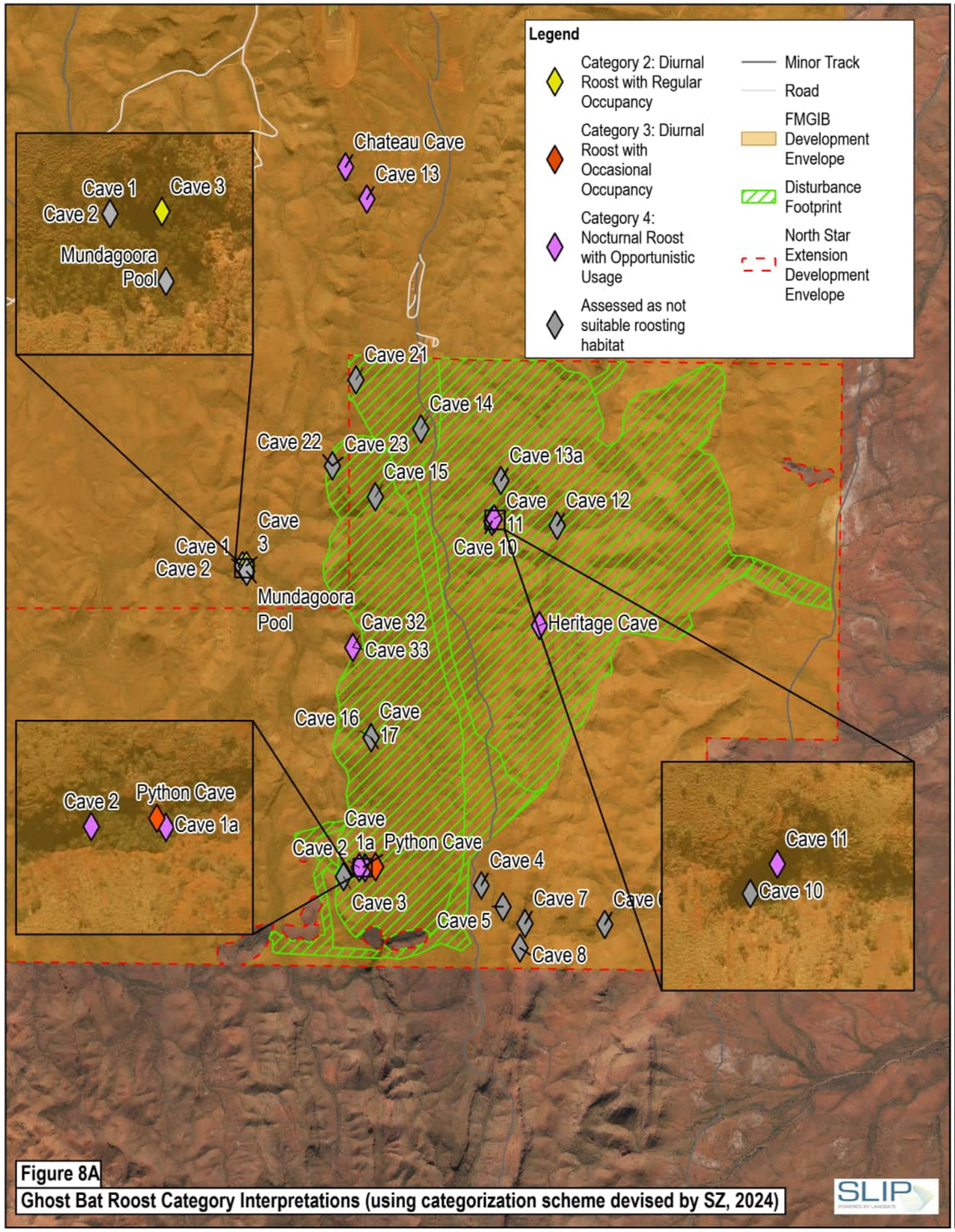


Figure 8A
Ghost Bat Roost Category Interpretations (using categorization scheme devised by SZ, 2024)

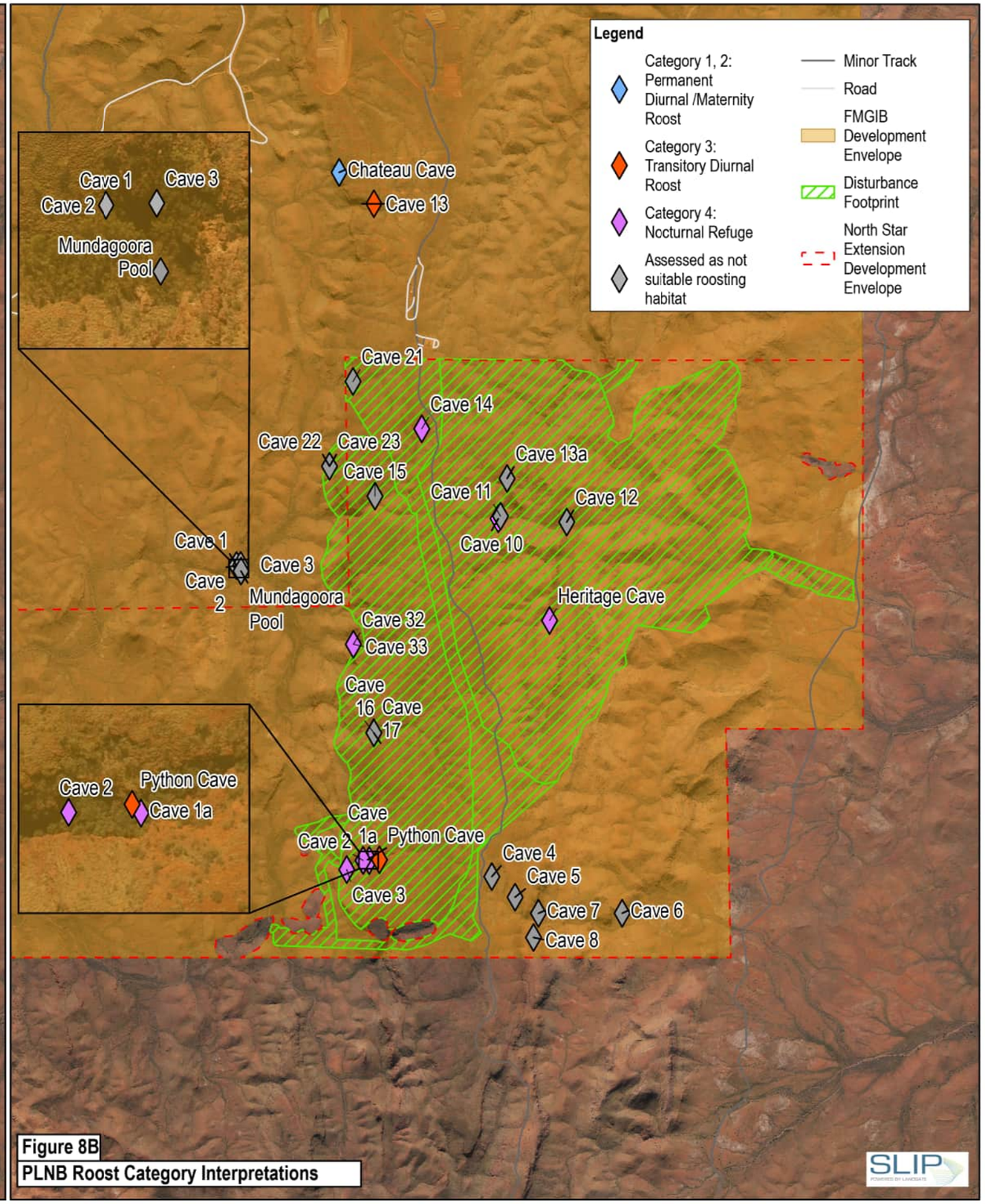


Figure 8B
PLNB Roost Category Interpretations

Paper Size ISO A3
0 300 600 900 1,200
Meters
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

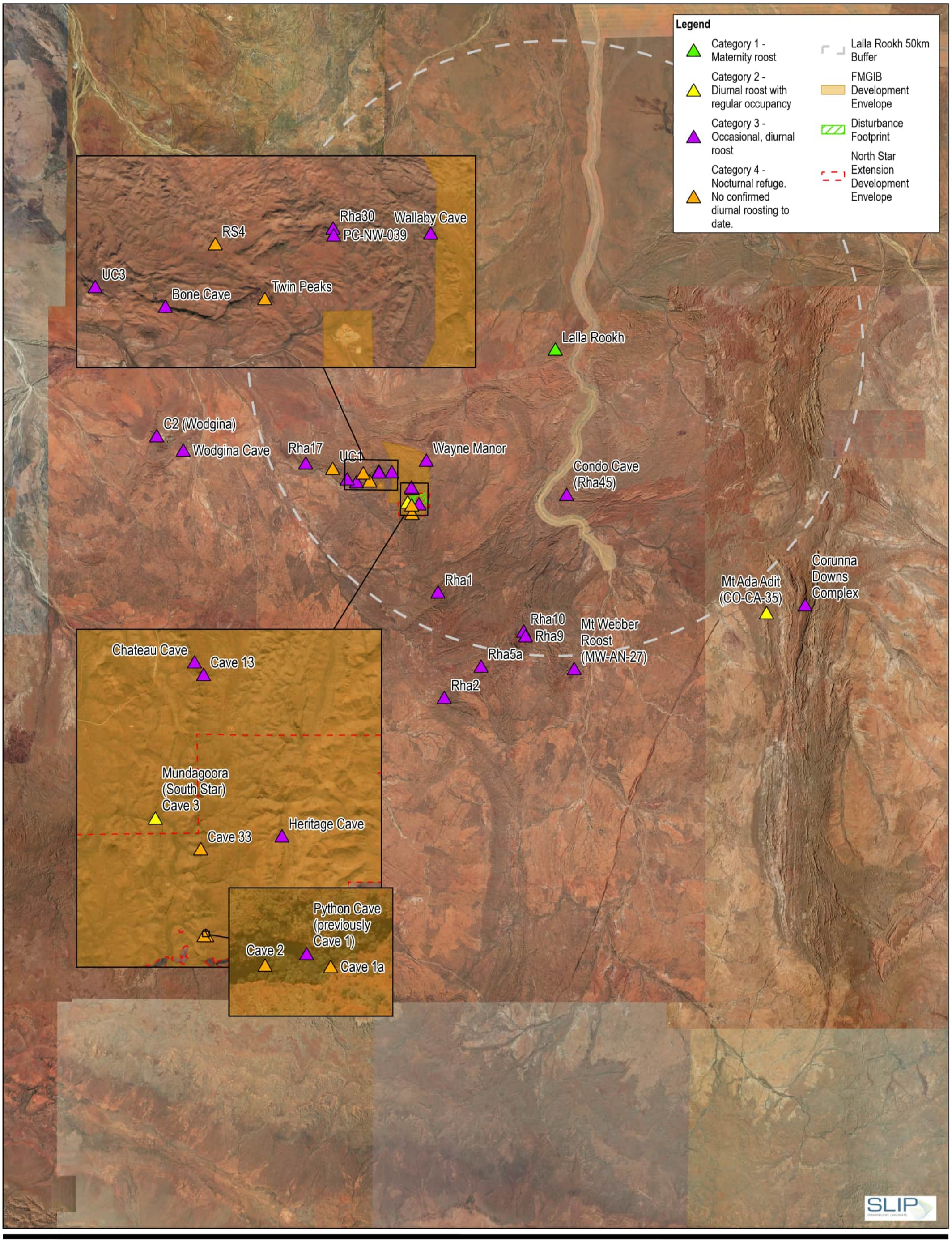
Fortescue Metals Group Ltd
North Star Expansion - Detailed Habitat Assessment

Project No. 12637028
Revision No. 0
Date 04/03/2025

FIGURE 8

\\ghdnetghd\AU\Darwin\Projects\61\12637028\GIS\Maps\Working\12637028 - North Star Envelope Bat Assessment.aprx - 12637028_008_RoostCategory_Rev0
Print date: 04 Mar 2025 - 10:46

Data source: Landgate_Subscription_Imagery\WANow World_Shaded_Relief. Copyright (c) 2014 Esri. Created by: kmacaspac



Paper Size ISO A3

0 5 10 15 20

Kilometers

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

N

GHD

Fortescue Metals Group Ltd
North Star Expansion - Detailed Habitat Assessment

Project No. **12637028**
Revision No. **0**
Date **04/03/2025**

Ghost Bat Roosts Identified to Date

FIGURE 9

\\ghdnet\ghd\AU\Darwin\Projects\61\12637028\GIS\Maps\Working\12637028 - North Star Envelope Bat Assessment.aprx - 12637028_009_GhostBatRoostsIdentifiedToDate_Rev0
Print date: 04 Mar 2025 - 07:59

4.2 Implication of roost removal

This section provides a discussion of the results and roost categorisations in the context of the potential removal of Python Cave, and other caves found within the NSE DE, and the associated potential implications to both the GB and PLNB within the NSE. This discussion is limited to the removal of caves assessed within this report and does not consider other habitat (i.e. foraging) in a broader context.

4.2.1 Ghost bat

The substantiated roost categorisation for the GB at Python Cave of C3-12 “Occasional Diurnal Roost” and the subsequent interpretation of the importance of this habitat in the context of development approvals can be considered low-priority habitat (Table A1.2 in Appendix A; further discussion for habitat significance is provided in Section 2.3.1).

Assigning a risk level to a development is possible using the Specialised Zoological GB roost categorisation scheme (Table A14 and A15 in Appendix A). The method adopts a risk matrix that considers the roost categorisation with expected effects from development activities. The matrix suggests removal of a C3-12 roost (risk score 10) has a ‘moderate’ level of risk to the GB utilising Python Cave, as well as the population more broadly and its genetic connectivity. This matrix suggests that “action may be needed over time or for specific events, minor assessment to support management or a proposal”. The following provides a small assessment of potential implications of the removal of Python Cave.

It is not determined if the one to three individual GB that occupy Python Cave approximately 40% of the time are the same individuals, or multiple individuals over time. However, it can be said that three individuals represent approximately 0.25% of the Pilbara population if using the (likely conservative) Pilbara population estimate by Armstrong and Anstee (2000) of 1,200 individuals. Subsequent studies (McKenzie and Bullen 2009; Bat Call WA 2021b) have suggested slighter larger estimates of up to 1,850.

Interpretation of roost habitat significance - Redundancy assessment

Python Cave may provide GB with opportunities for gene flow and/or normal dispersal and movement in the area. However, not enough is known about the movement of GB between Python Cave and other roosts in the broader area to determine what impact the loss of Python Cave and the other nocturnal refuges within the NSE might be in this context. It is possible, however, to assess the level of local redundancy for roosting opportunities and connectivity (and thus infer habitat significance) based on the number, proximity and category of other known roosts in the area (Specialised Zoological, 2025).

The redundancy assessment model (Figure 10 in Appendix A) demonstrates Python Cave was relatively redundant because of the proximity of Mundagoora Cave 3 (1.9 km to the north; Figure 9; FMG, 2025), which is a Provisional Category 2 roost. This suggests that its loss would have minimal impact on population connectivity and gene flow because other diurnal roosts are available nearby. The nightly flight range of the GB has been found to be 10's km per night (Bullen et al 2023; Harahan, unpublished data 2022). It can be assumed that nightly flight range could be up to 36 km which places Python Cave within the nightly flight range of another known major Category 1,2 diurnal roost, Lalla Rookh (Figure 9). This assumption also places Python Cave within nightly flight range of 10 other potential (Category 3 or higher classification) roosts with known occasional occupancy. For this reason, potential impacts associated with cave closure may be considered low, assuming the small number of individuals occupying Python Cave are capable of moving to an alternative roost within a night.

For this redundancy assessment to remain applicable it is assumed that Lalla Rookh remains a Category 1 roost and that Mundagoora Cave 3 continues to be protected.

4.2.2 Pilbara Leaf-nosed bat

Patterns of PLNB call activity indicate the caves assessed for occupancy during this survey (or the areas surrounding their entrances) are visited during the night by PLNB. The activity associated with these caves and surrounding areas is considered low, and there is no evidence to suggest diurnal roosting at any of the caves, except for Python Cave. Python Cave ultrasonic recordings coupled with PIT data demonstrate it is utilised primarily during the night; however, a small number of individuals do occasionally use the cave diurnally.

The individuals are likely to be individuals that primarily use Chateau Cave (Category 1, 2 diurnal roost, located approx. 4 km north).

PLNB nightly flight range has been demonstrated by a movement study implemented by GHD in 2023-current utilising both radio-tracking (GHD 2024b) and PIT tagging (GHD 2024c; SuperSensory Technologies unpublished data 2025). This study found PLNB regularly make nightly movements of around 60 km between roosts in a single night, and in some cases an individual will do this over multiple nights in a row (SuperSensory Technologies unpublished data 2025). Movements of PIT tagged individuals of even greater distances between roosts have also been detected, including approximately 170 km (12 months between detections) (Bullen & Reiffer 2020).

Python Cave (Priority 3, 4) and Chateau Cave (Priority 1, 2) are within PLNB nightly flight range of at least eight known category 3 roosts, the furthest approximately 41 km west; and four Category 1, 2 permanent diurnal roosts, the furthest 67 km east of the NSE (Figure 9; FMG 2025). It appears possible that following cave closure, PLNB utilising Python Cave would have the capability to move to several alternative roosts within a night.

5. Conclusion

This assessment considered extensive data collection from 2019 to 2024, which has allowed for a detailed assessment of GB and PLNB activity and habitat usage within the NSE DE and has provided an adequate understanding of bat activity in the area, which may be used to inform an assessment of impacts for these two bat species.

GB were detected at six of 12 caves and PLNB were detected at all 12 caves through either or both ultrasonic and thermal video recordings. The analysis of this data revealed that none of the caves where individuals were detected are considered to be significant diurnal roosts. Python Cave was the only cave found to have evidence of diurnal roosting during this study, with one to three GBs occupying it approximately 40% of the time, and a small number of PLNB only roosting occasionally. There is also historic evidence of the GB roosting diurnally within Mundagoora Cave 3, which is outside of the NSE DE and will not be disturbed as part of the NSE. The absence of significant diurnal roosts for the GB and PLNB suggests the proposed closure of caves within the NSE DE is unlikely to pose potential significant impact to these species.

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Appendices

Appendix A

Bat activity data analysis report: Specialised Zoological, 2025

SuperSensory Technologies Pty Ltd
Systems for continuous environmental monitoring ABN 54 665 618 351

Bat roost characterisation for North Star Extension, Western Australia

Prepared for **GHD Pty Ltd | Fortescue Ltd**
Prepared by **Supersensory Technologies Pty Ltd**
Project reference **ST027**
Version **2025-02-12**

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Version history

Version	Note
2024-08-15	Separate report: Specialised Zoological (2024)
2025-01-21	Final corrected version from Specialised Zoological
2025-02-11	Updated and transferred to Supersensory Technologies Pty Ltd
2025-02-12	Minor amendments

This report should be included as an appendix in any larger submission to Government, and cited as:

Supersensory Technologies (2025). Bat roost characterisation for North Star Extension, Western Australia. Unpublished report by Supersensory Technologies Pty Ltd for GHD Pty Ltd and Fortescue Ltd, version 2025-02-12, project reference ST027.

Contents

1.0 Summary

1.1 Background and scope of work

This report documents the analysis of bat detector and thermal video recordings from survey work undertaken to discover and characterise the use of caves by the Ghost Bat *Macroderma gigas* (Megadermatidae) and Pilbara Leaf-nosed Bat *Rhinonicteris aurantia* (= Pilbara Diamond-faced Bat; Rhinonycteridae; Foley et al. 2015 and Armstrong et al. 2016) in the North Star Extension (NSE) Development Envelope ('study area'), near the Iron Bridge Mine, in the Pilbara region of Western Australia. A total of 12 separate datasets was analysed (**Table 1**).

Categorisations of caves where these two species were detected have been made according to two schemes:

- **Ghost Bat**—A revised scheme of categorisation that extends the usefulness of those presented in Bat Call WA (2021) and Cramer et al. (2022)—detailed in **Appendix 1**.
- **Pilbara Leaf-nosed Bat**—Matching to definitions and specific terminology of roost types in the Conservation Advice for the species (Threatened Species Scientific Committee 2016).

A revised version of the Ghost Bat roost categorisation scheme was necessary because of the difficulty in matching observations to the brief definitions of just one category (**Table 7**).

1.2 Results

Data were collected over 916 nights at 15 cave sites between April 2021 and November 2024 using a combination of commercial bat detectors (Wildlife Acoustics Song Meters and Titley Scientific Anabat Swifts), custom thermal video recording setups that record for several nights, and the automated remote recording 'SatBat' system installed by Supersensory Technologies Pty Ltd at Python Cave (contains a Pettersson Elektronik M500-384 ultrasonic microphone and FLIR Boson thermal cameras). Analysis was undertaken using several semi-automated methods, with outputs from these validated by manual inspection.

The Ghost Bat was detected at six caves. Using the refined roost categorisation scheme, Python Cave was matched to Category 3 Occasional Diurnal Roost (Roost Score 10 or 12); the remainder were matched to Category 4 Nocturnal Refuge (Roost Score 3), though Heritage Cave might be used occasionally as a diurnal roost (Roost Score 5). Use of Python Cave had the best match to the descriptions of Category 3 in both Bat Call WA (2021) and Cramer et al. (2022), but some observations also matched descriptions in Category 2 in both those schemes.

The Pilbara Leaf-nosed Bat was detected at 12 caves. Python Cave was matched to Priority 3 Transitory Diurnal Roost (mainly on the basis of PIT tag data that did not indicate regular diurnal roosting); and the remainder to Priority 4 Nocturnal Refuge.

Most attention was given to the assessment of Python Cave because it has a history of study over several years, and therefore the interpretation of usage for both bat species can be considered as a Substantiated Categorisation. The remainder of sites can be considered as Preliminary Categorisation; these are unlikely to be elevated based on the collection of further data (no further data collection recommended), with the possible exception of Heritage Cave.

Table 1. Summary of the datasets analysed for the NSE study (total 916 sampling nights; season: b: breeding period defined here as August to March, n: non-breeding period April to July; Mg: Ghost Bat, Ra: Pilbara Leaf-nosed Bat; bd: commercial bat detector, PIT: Passive Infrared Transponder PIT tag data; sbu: 'SatBat' ultrasonic sensor, sbt: 'SatBat' thermal video; tv: thermal video).

Survey period	Location	Date range	Total nights	Season	Focus	Method	Results
2021 April – 2023 May	Python Cave	2021-04-08 – 2023-05-17	508	b, n	Mg	bd	Section 3.1.1; Table 2; Figure 1
2024 July – November	Python Cave	2024-07-20 – 2024-11-16	92	b, n	Mg	sbt	Section 3.1.2; Figures 2 – 4
2024 August – November	Python Cave	2024-08-03 – 2024-11-12	102	b	Ra	sbu	Section 3.1.3; Figure 5
2024 July – 2025 January	Python Cave	2024-07-26 – 2025-01-10	168	b	Ra	PIT	Section 3.1.4; Figures 6 and 7
2022 January – February	Mundagoora Cave 1	2022-01-14 – 2022-03-02	48	b	Mg	bd	Section 3.2.1
2022 June	Mundagoora Cave 1	2022-05-25 – 2022-06-24	24	n	Mg	bd	Section 3.2.1
2022 February – March	Mundagoora Cave 2	2022-02-21 – 2022-03-22	26	b	Mg	bd	Section 3.2.1
2022 January – February	Mundagoora Cave 3	2022-01-13	1	b	Mg	bd	Section 3.2.1
2024 July	11 caves	2024-07-23 – 2024-07-28	34 (3 – 4 each)	n	Mg, Ra	bd	Section 3.3.1; Tables 3 and 4; Appendix 3
2024 July	Heritage Cave	2024-07-24	1	n	Mg	tv	Section 3.3.1; Tables 3 and 4; Figure 8
2024 August – September	Cave 11	2024-08-27 – 2024-09-25	30	b	Mg, Ra	bd	Section 3.3.2; Appendices 4 and 6
2024 August – September	Heritage Cave	2024-08-27 – 2024-10-03	38	b	Mg, Ra	bd	Section 3.3.2; Appendix 5
2024 August – September	Heritage Cave	2024-08-27 – 2024-09-07	12	b	Mg	tv	Section 3.3.2

2.0 Methods

2.1 Ultrasonic recordings

Both the Ghost Bat and Pilbara Leaf-nosed Bat can be identified unambiguously from their echolocation and social calls (**Appendix 2**). However, diurnal roosting cannot be confirmed simply from the detection of calls on bat detector recordings—other methods need to be used, such as recording thermal video. However, deployment of bat detectors is an extremely efficient way to discover the potential for caves to contain roosts of these species.

Ultrasonic recordings were made in full spectrum WAV format with Titley Scientific Anabat Swift bat detectors and Wildlife Acoustics SM4BAT bat detectors (sampling rate 500 kHz, set to turn on automatically at sunset and off at sunrise).

A multi-step acoustic analysis procedure developed to process large full spectrum echolocation recording datasets from insectivorous bats (Armstrong et al. 2021a,b) was applied to the recordings. The WAV files were scanned for bat echolocation calls of the two target species using two separate parameter sets in the software SCAN'R version 1.8.3 (Binary Acoustic Technology). Scripts in the [R] statistical computing language were then used to produce:

1. A copy of any WAV files that had signals consistent with the Ghost Bat and Pilbara Leaf-nosed Bat.
2. A summary list of positive detections for each night, based on a manual check of spectrograms in Adobe Photoshop version 23.1 software to confirm that these WAV file copies contained echolocation pulses of these two species.
3. The times of first detection after sunset and the last detection before sunrise were calculated, as well as the time difference between these times and the times of sunset, end of civil twilight at night, beginning of civil twilight in the morning and sunrise.

Ultrasonic recordings were made at Python Cave with a ‘SatBat’ automated recording and data analysis system installed by Supersensory Technologies Pty Ltd. This comprises a Pettersson Elektronik D500-384 bat detector connected to a Raspberry Pi 5 single board computer (SBC), with recorded signals being processed and identified onboard the SBC, and results sent to a cloud computing environment via a SpaceX Starlink communication system.

Recordings were made in minute blocks and echolocation calls (pulses rather than sequences) were classified using a custom deep learning neural network model trained on calls from the local area. The number of pulses was summarised with custom R scripts, and the output is a summary of the number of pulses detected rather than the number of 1-second sound files containing pulses. This index of activity provides a general indication of the frequency of visitation over successive nights and the longer term, and the basis for a prediction of how important the cave might be for the species. The index is not useful for predicting diurnal roosting in this particular case because Python Cave is relatively close (4.2 km) to a known Priority 1 Permanent Diurnal Roost (‘Chateau Cave’). The times of first and last detection are therefore likely to be similar to what would be expected for a diurnal roost even if it was not being used as such.

2.2 Cave occupancy assessments with thermal video recordings

The Ghost Bat can be identified unambiguously in long-wave infrared thermal video recordings. Key diagnostic features include long ears (longer than those of the Common Sheath-tailed Bat *Taphozous georgianus*), its relatively large body size (as determined in comparison to the many observed examples of *T. georgianus* in the same recordings), broad wing shape, and 'an impression' of its flight pattern. While these are all qualitative characters, they allow an experienced observer to make an unambiguous identification. A screenshot was taken of every individual (or rather, from every individual flight track) to support an independent verification of the identifications if required. An example is illustrated (**Figure 3**), and the remainder are available upon request (given the size of this raw dataset).

Thermal video recordings also allow confirmation of diurnal roosting, if the first observation of the species is of an egress. In addition, it is possible to estimate colony size by counting the number of individuals that emerge within the first three hours after sunset (and taking into account those that fly back into the cave). However, if the cave entrance is large and complex, this can be difficult.

Two types of thermal video camera set-ups were deployed (based on component availability):

- At Heritage Cave, the equipment comprised a FLIR Tau 360x240 30 fps video camera core connected to a TEC digital video recorder saving to an SD memory card; this was programmed to record between sunset and sunrise.

- At Python Cave, the equipment comprised a FLIR Boson 640x512 60 fps video camera core connected to an automated recording system run by a Raspberry Pi 5 single board computer (installed as a long-term monitoring system by Supersensory Technologies Pty Ltd). This system runs each night, and analysis was limited to the first three hours after sunset (the emergence period of the Ghost Bat) on all nights with available recordings.

All videos were processed with an expeditious and robust analysis method. A custom Python (https://www.python.org/) script applied a background subtraction algorithm from the *opencv* framework (https://opencv.org/) to the recordings and constructed a concatenated short video containing only portions of the recording with moving objects above a certain size. These concatenated videos were watched at <50% speed in the MPV Media Player software (https://mpv.io/), which allows fine control of frame advancement.

2.3 Limitations

The identifications presented in this report have been made within the following context:

1. The identifications made herein were based partly on the ultrasonic acoustic data recorded and provided by a 'third party' (GHD Pty Ltd).
2. The scope of this report extended to providing information on the identification of two target bat species in ultrasonic and thermal video recordings, and providing an interpretation of how caves might be used. Further extensive comment on these species and the possible impacts of a planned project on bat species were not part of the scope.
3. Supersensory Technologies has had minimal input into the overall design of the sampling design (in terms of timing, recording site placement, and the degree of recording site replication).
4. Identifications have been made to the best of our ability given the available materials, and we reserve the right to re-examine the data and revise any identification or interpretation following a query. Supersensory Technologies bears no liability for any follow-up work that may be required to support an identification based initially on the analysis of acoustic recordings undertaken and reported on here.
5. There are a variety of factors that affect the 'detectability' of each bat species, given the frequency, power and shape characteristics of their calls. Further information on the analysis and the various factors that can impinge on the reliability of identifications can be provided upon request.
6. The echolocation calls of the Ghost Bat are of low amplitude, so reliable methods of detection include video recordings and the placement of bat detectors at cave entrances with the microphone facing into a potential cave roosting site.
7. Predictions about whether the Pilbara Leaf-nosed Bat roosts within a particular surveyed cave (where a bat detector was placed at the entrance), or somewhere nearby, based on the time of first detection should be considered indicative only (a 'provisional categorisation' rather than a 'substantiated categorisation'; see **Appendix A1.2** for further details; the same considerations around confirmation of diurnal roosting for the Ghost Bat are applicable). If unambiguous information of diurnal roosting of this species is required, diurnal roosting should be confirmed using the entrance sheeting method that is described in DEWHA (2010).
8. This version of the document supersedes all previous versions. Previous drafts and versions are not authorised by us for submission to the regulator or the public domain.

3.0 Results

3.1 Python Cave

3.1.1 Python Cave long-term bat detector recordings

Bat detector recordings made between 8 April 2021 and 17 May 2023 were not continuous, but spanned several months per year that included representation in times of both breeding and non-breeding.

Based on the detection of echolocation calls, the Ghost Bat had a relatively low rate of visitation (**Table 2**; **Figure 1**). The key values are percent detections below 25% (15% overall; 23% in the non-breeding period; 11% in the breeding period).

These detections do not necessarily represent diurnal roosting—rates of diurnal occupancy are available from thermal video recordings. These rates of detection can be used as criteria to match the cave to a roost category (**Appendix 1**; **Table 5**).

Table 2. Summary of the rate of detection of the Ghost Bat at Python Cave between April 2021 and May 2023, based on bat detector recordings.

	2021	2022	2023		Total
Survey effort per period					
nights surveyed non-breeding April-July	26	71	47		144
nights surveyed breeding August-May	59	242	63		364
nights surveyed total all seasons	85	313	110		508
Numbers of detections per period					
nights detected non-breeding April-July	5	19	11		35
nights detected breeding August-May	10	22	4		36
nights detected total all seasons	15	41	15		71
Final percent detection rates					
percent detection non-breeding April-July	19	27	23		23%
percent detection breeding August-May	17	9	6		11%
percent detection total all seasons	**18**	**13**	**14**		**15%**

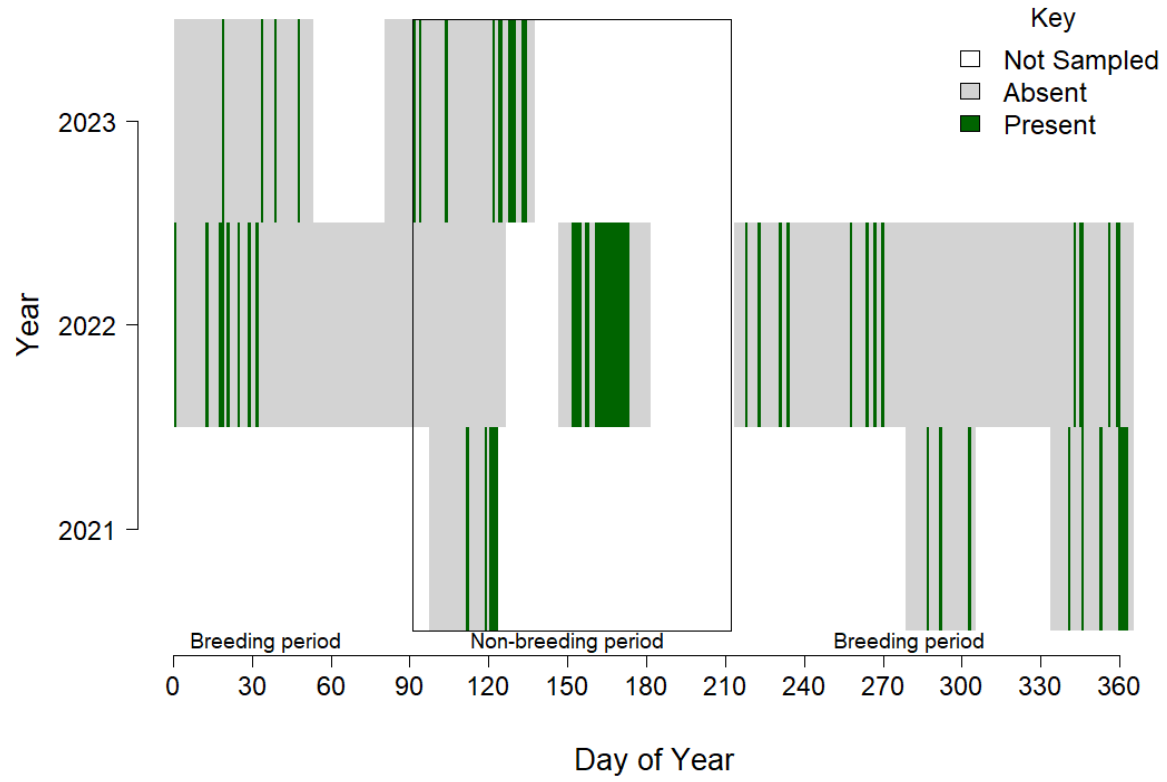

Figure 1. Summary of Ghost Bat detections at Python Cave between April 2021 and May 2024 (rectangular box delineates the non-breeding months of April to July).

3.1.2 Python Cave long-term thermal video recordings

Thermal video recordings made between 20 July 2024 and 16 November 2024 were not continuous, but spanned 92 nights in this period. Most of this period can be defined as being within the breeding months, though 12 nights in July are within the non-breeding period.

Based on the observation of individuals, the Ghost Bat had a moderate rate of visitation, with 3 nights where there was no diurnal roosting but a night visitation; and 37 days with diurnal roosting of at least one and up to three individuals (**Figure 2**). Ghost Bats were distinguishable from other bat species in the thermal video recordings (**Figures 3** and **4**). The overall rate of diurnal occupancy was therefore 40% (37 nights out of 92 sampled; breeding August – November: 32 nights out of 81 sampled, 35%; non-breeding July: 8 nights out of 11 sampled, 73%). These rates of occupancy can be used as criteria to match the cave to a roost category, along with the estimates of colony size (**Appendix 1**; **Table 5**). It is a slightly higher occupancy rate than is suggested by encounter rates from the much longer-term bat detector survey undertaken between April 2021 and May 2023 (**Table 2**; **Figure 1**).

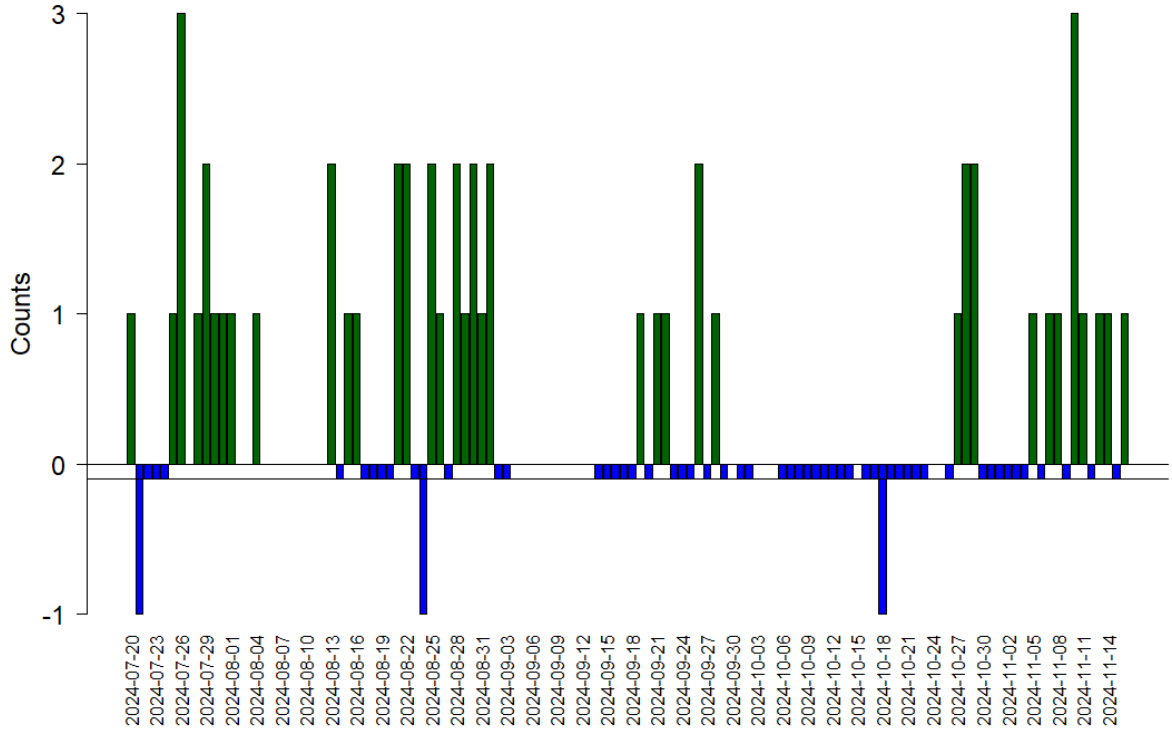

Figure 2. Summary of Ghost Bat colony counts at Python Cave between July 2024 and November 2024 (green bars: counts of individuals that were roosting inside during the day (net count excluding re-entries and re-emergence); long blue bars: number of individuals entering the cave during the post-sunset emergence period (i.e., the first detection is an entry of a bat that was roosting elsewhere during the day; excludes re-entries of individuals that had already emerged; these are instances where there was no diurnal roosting, i.e., this is 'night visitation'); short blue bars: indicate nights sampled but where no Ghost Bats were observed).

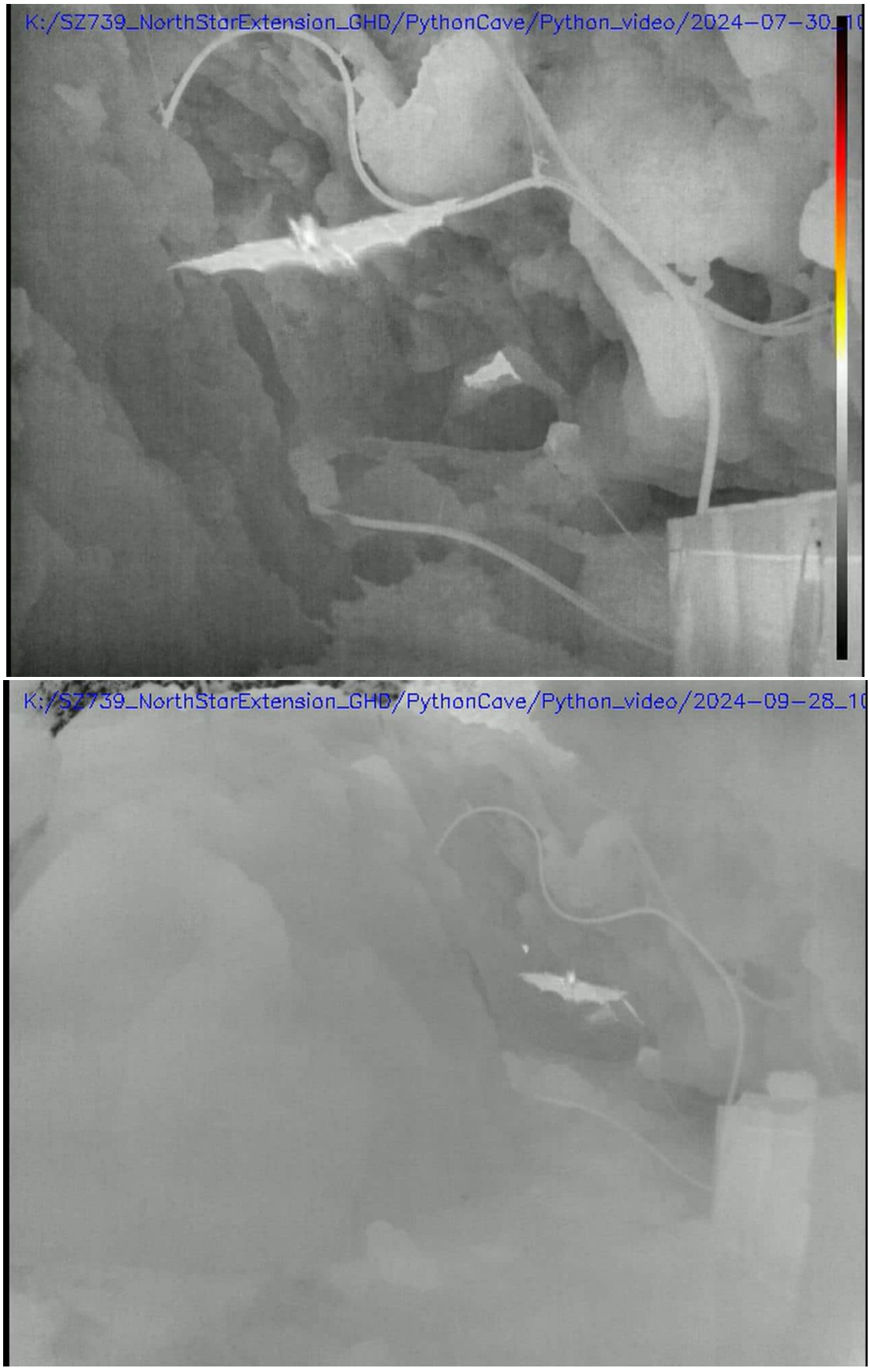

Figure 3. Example screenshots from the thermal camera at Python Cave illustrating the Ghost Bat (see *Figure 4* to compare the images of other bat species).

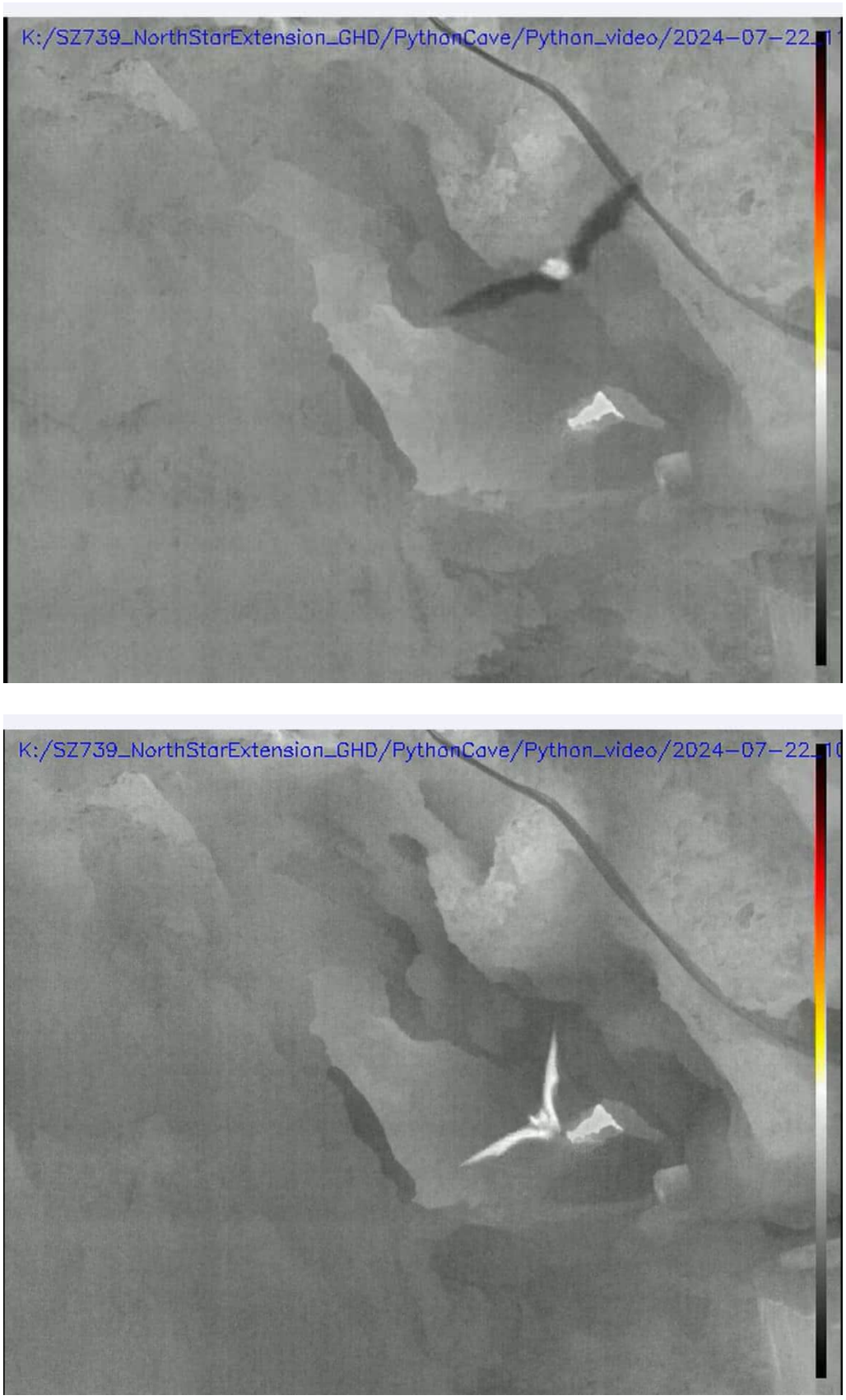

Figure 4. Example screenshots from the thermal video camera at Python Cave illustrating the other bat species (**top**: Pilbara Leaf-nosed Bat; **bottom**: Common Sheath-tailed Bat). The cave interior can be seen as a white-hot shape.

3.1.3 Python Cave long-term bat detector recordings—Pilbara Leaf-nosed Bat

Bat detector recordings were made over 102 nights with the SatBat installation between 3 August 2024 and 12 November 2024 (and continue to be collected with the continuous monitoring system). This period falls within the breeding months of this species.

The Pilbara Leaf-nosed Bat visits this cave on a nightly basis (**Figure 5**). The proximity of Python Cave to the known roost at Chateau Cave (4.2 km) means that the times of first and last detection are not reliable indications of diurnal roosting—because individuals that roost during the day in Chateau Cave can be present at Python Cave very soon after their emergence. Observations made over several years have established that Python Cave is used as a diurnal roost by this species occasionally, and by one or several individuals.

Further data is presented in the main report by GHD. An analysis that demonstrates how the historical data collected with Wildlife Acoustics Song Meters and the more recent collections with the SatBat system can be matched has yet to be undertaken. However, the overall patterns, longer term trends in the nightly total detections, and times of first and last detection are interpretable from both data types.

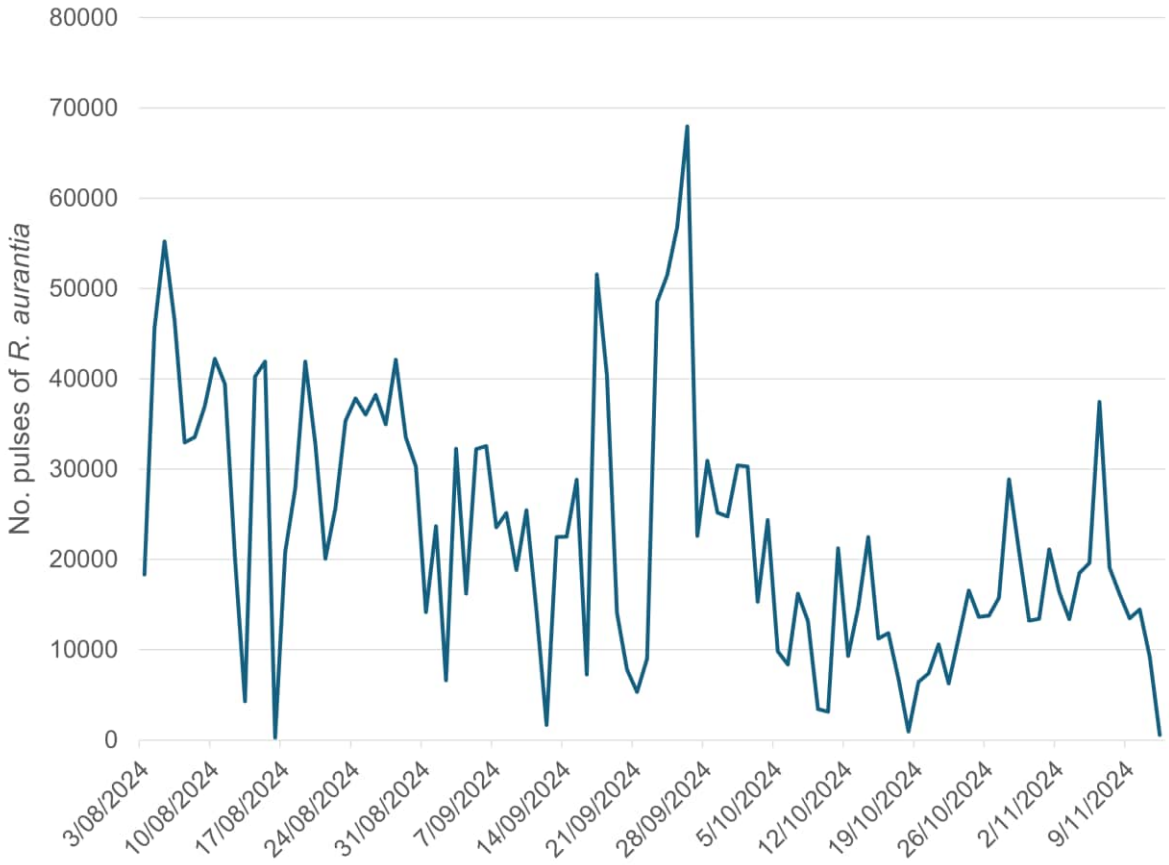

Figure 5. Levels of activity of the Pilbara Leaf-nosed Bat at Python Cave in the latter half of 2024.

3.1.4 Python Cave Passive Infrared Transponder (PIT tag) data—Pilbara Leaf-nosed Bat

Bats captured at Chateau Cave and Daltons Cave and fitted with Passive Infrared Transponders (PIT tags) have the potential to visit Python Cave. The Supersensory Technologies SatBat system at Python Cave contains a Biomark PIT tag receiver and antenna (this antenna can be seen as a lighter coloured loop in **Figure 3**). Data from this installation confirms that the Pilbara Leaf-nosed Bat does indeed visit at night. A total of 33 tagged individual bats visited Python cave once or more between 2024-07-26 and 2025-01-10 (168 nights).

Using this data, we can address a question of whether there might be evidence for diurnal roosting, in support of a roost categorisation that needs to consider diurnal occupancy as well as detections. It is a similar indirect approach to establishing the possibility of diurnal roosting as examining detections of echolocation calls with bat detectors. The time of first detection after sunset, and time of last detection prior to sunrise, can reveal whether bats are likely to be roosting inside a structure during the day. In general, a detection of this species between sunset and the end of civil twilight (dusk), or just after; or else between the start of civil twilight (dawn) and sunrise; is reasonable evidence that an individual might be present during the day. Similar patterns in PIT tag detection time can allow the same interpretation, but note that both of these data types do not provide an ambiguous confirmation of diurnal roosting (see the entrance blocking method in DEWHA 2010).

The pattern of detections at a confirmed diurnal roost with a relatively large colony size (Daltons Cave) contains many examples of detections during these periods of twilight, but especially just prior to sunrise (**Figure 6**). By contrast, and even though there are fewer detections, the times of detection at Python Cave have only a few examples of where a tagged bat was detected close to the beginning of dawn (**Figure 7**). The pattern at Python is indicative of mostly night visitation of individuals that have originated from a diurnal roost elsewhere (mostly likely Chateau Cave). The few detections close to periods of twilight could be indicative of occasional diurnal roosting. This pattern of use fits with the description of a Priority 3 transitory diurnal roost (Threatened Species Scientific Committee 2016).

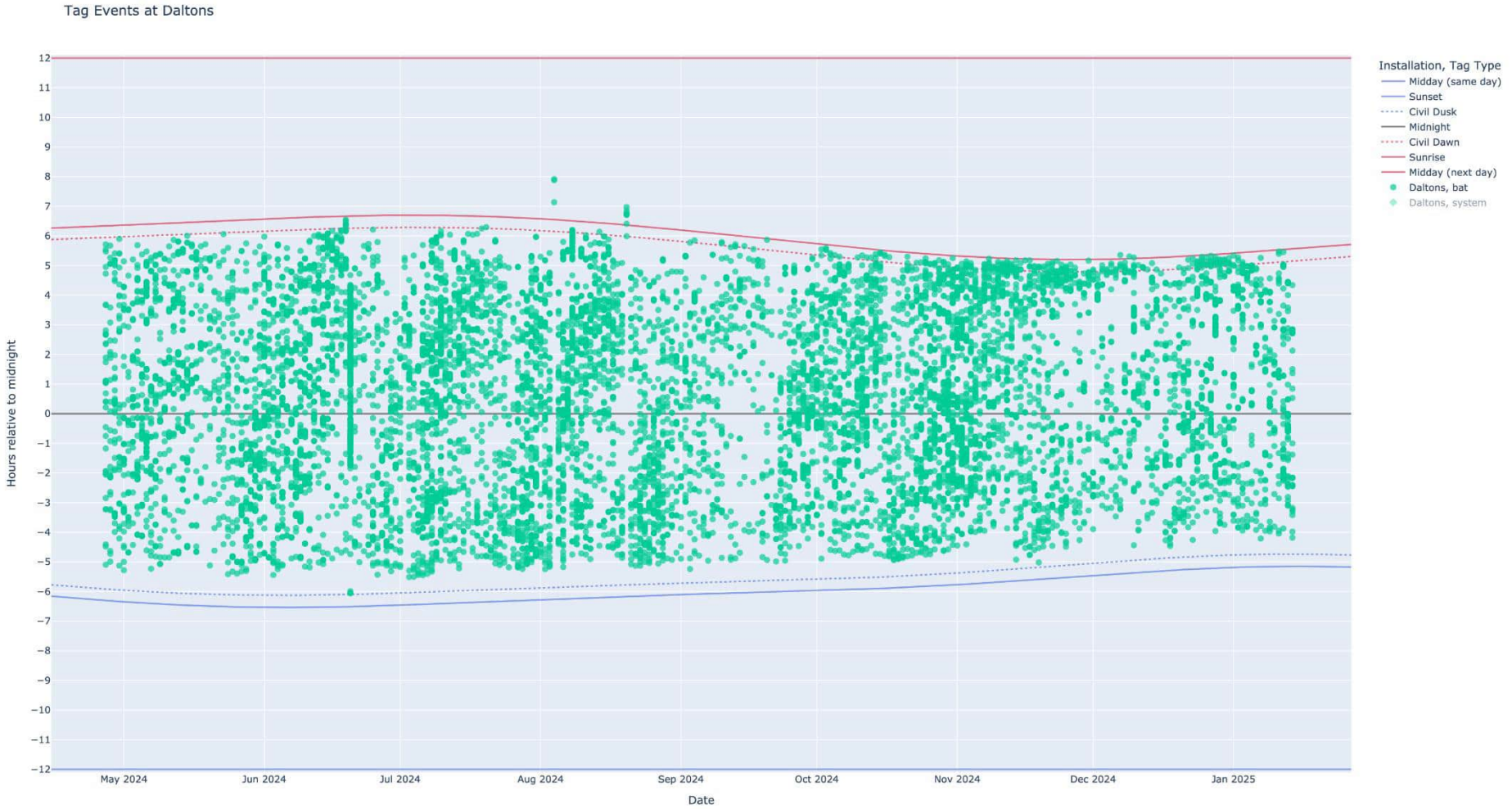

Figure 6. Times of detection of PIT tagged bats at Daltons Cave, a confirmed Priority 1 permanent diurnal roost as a basis of comparison for the patterns at Python Cave.

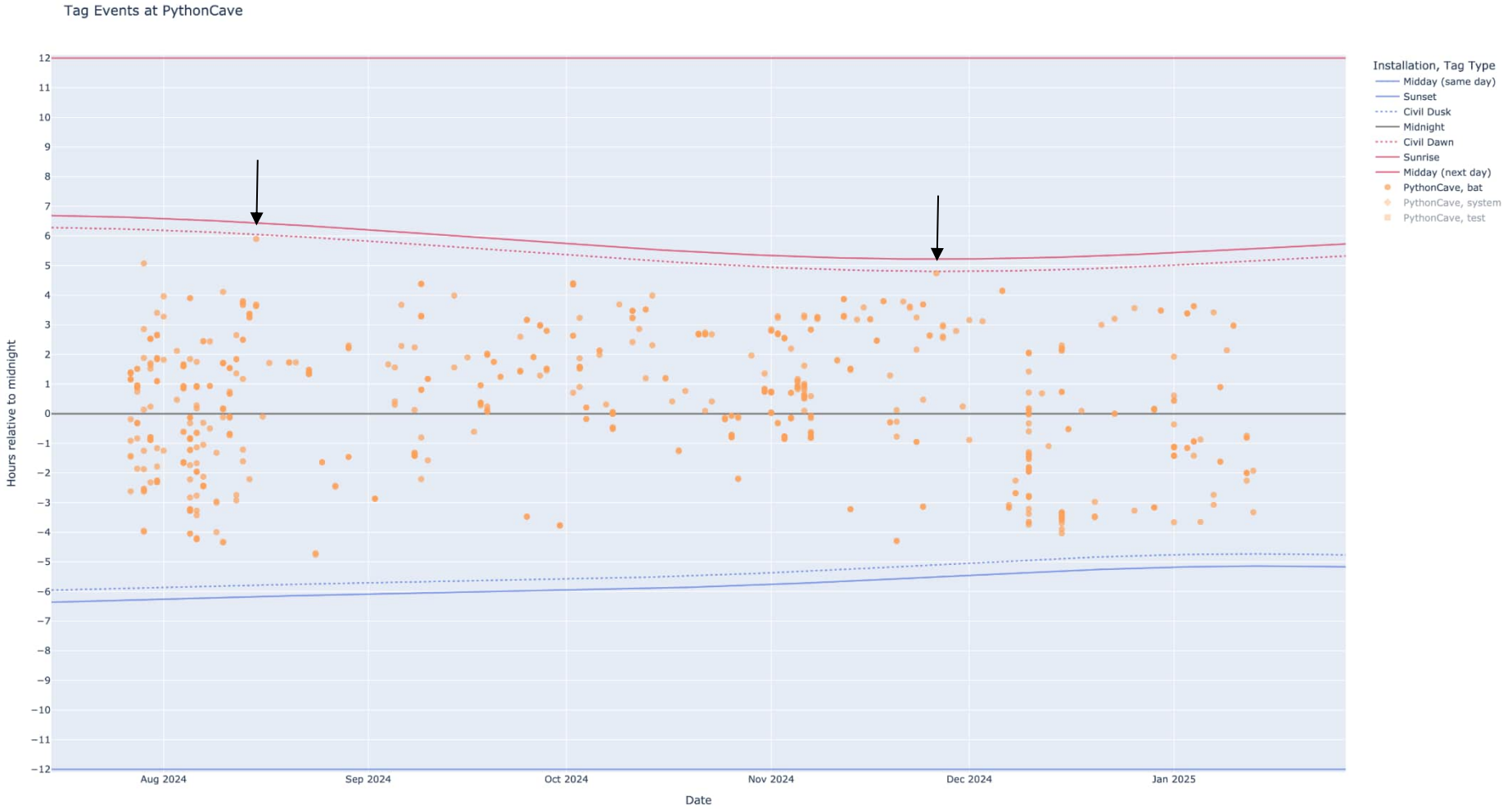

Figure 7. Times of detection of PIT tagged bats at Python Cave, illustrating visitation mostly well after sunset and well before dawn. Exceptions that might be indicative of diurnal roosting are highlighted with arrows.

3.2 Mundagoora

3.2.1 Caves near Mundagoora Pool

Three caves near Mundagoora Pool were assessed for their potential to function as either diurnal roosts or nocturnal refuges for the Ghost Bat. Recordings were made over a total of 99 nights with bat detectors between January 2022 and June 2022 (**Table 1**). This spans both the breeding and non-breeding periods of this species.

Echolocation calls of the Ghost Bat were not detected in these recordings.

However, it is important to note that 26 – 30 Ghost Bats were observed emerging from Mundagoora Cave 3; and diurnal roosting was confirmed subsequently using entrance screening methodology on the 21 January 2019 (GHD, 2021). There has been no substantive follow up survey to define usage at this cave, but it is reasonable to expect that it would match the criteria for a Category 2 roost, given the colony size. Mundagoora Cave 3 is not within the planned area of development, so is likely to continue to provide an important refuge for Ghost Bats, and function as a nodal connection for the movement of individuals and gene flow.

3.3 Other areas

3.3.1 Broad-scale cave survey 2024

An exploratory survey to discover and assess caves within the NSE Development Envelope as potential roosts of the Ghost Bat and Pilbara Leaf-nosed Bat was conducted by GHD Pty Ltd in July 2024. The dataset submitted for analysis included a total of 81,200 full spectrum bat detector sound files from 11 recording sites over six recording nights (2024-07-23 – 2024-07-28; total 34 recording nights; **Table 1**). A thermal video recording from one night at one site (‘Heritage Cave’) was also analysed.

Both bat species were detected.

The Ghost Bat was detected at five caves (total nine recording nights; 19 echolocation sequences) (**Table 3**). The detections of echolocation calls were corroborated with observations of Ghost Bats in flight at the same time in a recording from a thermal video camera on 2024-07-24 at Heritage Cave (**Figure 8**). Given the times of detection (**Table 4**), there was no strong indication that the Ghost Bat was using any of these caves for diurnal roosting.

The Pilbara Leaf-nosed Bat was detected at 11 caves (total 27 recording nights; 838 echolocation sequences) (**Table 3**). Given the times of first and last detection during the night, there was no strong indication that any of the caves were being used as a diurnal roost (**Appendix 3**: **Table A3.1**). We would expect time of first detection within 30 minutes after sunset time if bats were using the cave as a diurnal roost. Visitation is most likely from individuals roosting in Chateau Cave.

Table 3. Summary of detections of the Ghost Bat (Mg) and Pilbara Leaf-nosed Bat (Ra) from the 11 caves assessed in the July 2024 survey. Numbers are counts of WAV sound files with unambiguous examples of the echolocation calls of these species (blue highlight aids inspection).

Site	Serial	Coordinates	Night	Mg	Ra
Cave 1	642024	-21.294555, 119.055880	23/07/2024	1	76
		-21.294603, 119.055988	24/07/2024	6	35
		-21.294657, 119.056118	25/07/2024	.	89
Cave 2	642025	-21.294428, 119.055592	23/07/2024	1	34
		-21.294428, 119.055592	24/07/2024	1	17
		-21.294428, 119.055592	25/07/2024	1	52
Cave 3	633099	-21.294655, 119.054062	23/07/2024	.	33
		-21.294655, 119.054062	24/07/2024	.	8
		-21.294655, 119.054062	25/07/2024	.	24
Cave 11	724693	-21.275233, 119.063107	24/07/2024	1	6
		-21.275937, 119.063780	25/07/2024	.	36
		-21.274900, 119.062650	26/07/2024	.	355
Cave 14	S4U11698	-21.261050, 119.053990	26/07/2024	.	4
		-21.261050, 119.053990	27/07/2024	.	2
		-21.261050, 119.053990	28/07/2024	.	4
Cave 15 area	S4U11673	-21.278350, 119.048700	25/07/2024	.	.
		-21.278350, 119.048700	26/07/2024	.	1
		-21.278350, 119.048700	27/07/2024	.	1
Cave 16	724728	-21.287455, 119.056003	25/07/2024	.	.
		-21.287455, 119.056003	26/07/2024	.	.
		-21.287475, 119.055745	27/07/2024	.	1
		-21.287475, 119.055745	28/07/2024	.	1
Cave 21	S4U11728	-21.217090, 119.076820	26/07/2024	.	7
		-21.217090, 119.076820	27/07/2024	.	6
		-21.217090, 119.076820	28/07/2024	.	7
Cave 32	450091	-21.282468, 119.054910	25/07/2024	.	1
		-21.282468, 119.054910	26/07/2024	.	.
		-21.282468, 119.054910	27/07/2024	.	.
Cave 33	S4U11736	-21.256090, 119.054060	25/07/2024	1	.
		-21.256090, 119.054060	26/07/2024	.	6
		-21.256090, 119.054060	27/07/2024	.	5
Heritage cave	660654	-21.280567, 119.066372	24/07/2024	4	.
		-21.280567, 119.066372	25/07/2024	1	5
		-21.280567, 119.066372	26/07/2024	2	22

Table 4. Summary of the time of detection of the echolocation calls of the Ghost Bat at five caves assessed on the July 2024 survey.

Site-serial	Night	Time
Cave1-642024	23/07/2024	5:55:36
Cave1-642024	24/07/2024	18:56:05
Cave1-642024	24/07/2024	18:57:08
Cave1-642024	24/07/2024	2:04:26
Cave1-642024	24/07/2024	2:04:41
Cave1-642024	24/07/2024	4:49:03
Cave1-642024	24/07/2024	4:49:05
Cave2-642025	23/07/2024	4:40:41
Cave2-642025	24/07/2024	18:55:29
Cave2-642025	25/07/2024	5:34:39
Cave11-724693	24/07/2024	20:43:10
Cave33-S4U11736	25/07/2024	5:02:32
HeritageCave-660654	24/07/2024	21:16:06
HeritageCave-660654	24/07/2024	21:16:29
HeritageCave-660654	24/07/2024	3:32:29
HeritageCave-660654	24/07/2024	4:37:28
HeritageCave-660654	25/07/2024	20:28:06
HeritageCave-660654	26/07/2024	2:34:18
HeritageCave-660654	26/07/2024	2:56:59

Figure 8. Screenshots from the thermal camera of the large-sized Ghost Bat at times when echolocation calls were recorded at ‘heritage cave’.

3.3.2 Follow-up survey of Cave 11 and Heritage Cave

Further bat detector recordings were made in August and September 2024 at Cave 11 and Heritage Cave to gain a better understanding of how often they were used by the Ghost Bat and Pilbara Leaf-nosed Bat.

The Ghost Bat was not detected at Cave 11.

The Ghost Bat was detected at Heritage Cave from a total of 131 echolocation and social call sequences in 26 of 38 recording nights (**Appendix 4**: **Table A4.1**; see the assessment in **Table 5**). Ghost Bat calls were detected within an hour of sunrise on eight nights, which might suggest diurnal roosting in this structure, or somewhere nearby such as Python Cave. In the relatively large space of the Heritage Cave entrance, the resolution of the thermal video from the FLIR Tau camera was unfortunately too low to allow separation of Ghost Bats from the many Common Sheath-tailed Bats present, so diurnal presence could not be confirmed, nor could colony size be estimated should diurnal roosting have been confirmed.

The Pilbara Leaf-nosed Bat was detected at Cave 11 from 1,042 echolocation sequences over 28 sampling nights (**Appendix 5**: **Table A5.1**). No detections were within the period of civil twilight after sunset or prior to sunrise that might have suggested the presence of bats during the day.

The Pilbara Leaf-nosed Bat was detected at Heritage Cave from 226 echolocation sequences over 29 sampling nights (**Appendix 6**: **Table A6.1**). No detections were within the period of civil twilight after sunset or prior to sunrise that might have suggested the presence of bats during the day.

4.0 Discussion

4.1 Assigning categories to caves used by the Ghost Bat

The surveys discovered five caves in the NSE study area that have evidence of use by the Ghost Bat. Once detected, such caves are typically classified using a scheme such as that in Bat Call WA (2021) or the more recent consensus version in Cramer et al. (2022). It is challenging to match the situation of a particular cave to these categories because they are insufficiently structured and detailed for a robust assessment. Thus, a revised scheme has been provided in **Appendix 1**, and which has been applied to these five caves (**Tables 5** and **6**).

A match to categories in Bat Call WA (2021) and Cramer et al. (2022) was also undertaken for Python Cave for comparison, but matching to a single category was not possible (**Table 7**).

The final Substantiated Classification outcome for Python Cave is Category 3 Occasional Diurnal Roost (Low-priority Habitat) (**Table 6**; **Table A1.2**). This was derived using both the ultrasonic bat detector data (**Table 2**; **Figure 1**; total Roost Score 10), and the thermal video data (**Figure 2**; percentages listed for breeding and non-breeding periods in section *3.1.2 Python Cave long-term thermal video recordings*; total Roost Score 12). Category 3 roosts are listed as Low-priority Habitat in **Table A1.2**; and if there are plans to remove the roost, then the Risk Score as per **Table A1.4** would be 10, and the corresponding Risk Level to the Pilbara population of Ghost Bats as per **Table A1.5** would be Moderate.

Heritage Cave has been matched to a Provisional Classification of Category 4 Nocturnal Refuge (Marginal Significance; **Table A1.2**).

The roost categorisation scheme for the Pilbara Leaf-nosed Bat presented in the Conservation Advice for the species (Threatened Species Scientific Committee 2016) would also benefit from a similar revision but was not undertaken here because it was straightforward to allocate caves to categories (which are named as ‘Priorities’).

4.2 Further comment on the ‘apartment block’ concept

In **Appendix A1.1**, comment was made on how the concept of the ‘apartment block’ was an imprecise and confusing description of Ghost Bat occurrence. This term was introduced in the review by Bat Call WA (2021) but was not part of the more recent roost categorisation scheme presented by Cramer et al. (2022) that had input from a wider range of people experienced with the species. Thus, there is not a strong foundation for its prevailing usage in assessments. However, the application of the ‘apartment block’ concept to Python Cave is addressed here for completeness.

Bat Call WA (2021) uses the concept to give further weight to the importance of Category 2 roosts. A Category 2 roost could be deemed even more significant to the species if there are other caves and overhangs nearby that are used in some way by the Ghost Bat[1]. Likewise, a

[1] Note the provided citation of TSSC (2016) does not contain mention of ‘apartment blocks’.

Category 3 roost is considered to have greater importance ("critical habitat") if it is part of an 'apartment block' with a Category 2 roost.

Application of the 'apartment block' concept to Python Cave because of the proximity of Cave 1 and Cave 2 (within 40 m and 150 m, respectively, based on the coordinates in **Table 3**) would not be useful or equivalent for the following reasons:

- Python Cave was classified here as a Category 3 roost. It provides regular diurnal roost habitat for up to three individuals only. There is one Category 2 roost c. 2 km north on a separate ridge and adjacent to Mundagoora Pool (Mundagoora Cave 3); and the nearest Category 1 roost is the Lalla Rookh mine c. 35 km to the north-east. No equivalent Category 3 roost has been observed close to Python Cave or Mundagoora Cave 3; and the nearest other 'Category 3' caves used by the Ghost Bat are at least 7 km from Python Cave in a different geological unit, with few details available about their usage, and with diurnal roosting not confirmed nor colony size determined. The situation of the Category 3 Python Cave diurnal roost does not appear to be wholly consistent with this concept.
- A more applicable scenario for an 'apartment block' would be that described by Thavornkanlapachai et al. (2024) where 19 individuals use seven diurnal roosts in 2 – 3 cave aggregations within the West Angelas area. Presumably there are also numerous overhangs nearby that are visited at night.
- It is neither sensible, nor empirically justifiable, to suggest an elevated level of importance of Python Cave simply because the individuals that occupy it during the day visit nearby underground structures of relatively shallow depth after sunset (i.e., Category 4 Nocturnal Refuges). Any overhang surrounding a Category 3 roost could be visited at night by a Ghost Bat, and such structures do not have any feature that makes them especially suitable for this. Such sites of night visitation do not make up an 'apartment block'—presumably an 'apartment block' must have several diurnal roosts in proximity that together support more than a few individuals.
- Instead, the contention here is that the relative level of importance of Python is derived from:
    - Confirmation that it is a diurnal roost;
    - Its occupancy during some days by of colony of up to three individuals at a time;
    - The observation that diurnal occupancy is relatively regular, but not always consistent amongst successive nights; and
    - A conjecture that it might be important for regional dispersal, although it is unlikely to be critical given the nightly flight range of the species and the nearby presence of the Category 2 Mundagoora Cave 3 roost.

In conclusion, the 'apartment block' concept does not seem to add much to the assessment of the importance of Python Cave. However, it is certainly appropriate to consider the context of caves—its relative importance for the movement of dispersing individuals and gene flow—see section *4.3 Redundancy assessment*.

Table 5. Assessment of roost category for caves used by the Ghost Bat in the NSE study area (as per criteria set out in *Appendix 1*; note that there are two Roost Scores available for Python Cave, one based on bat detector recordings, and the other based on data from the thermal video camera; both result in the roost being allocated to Category 3).

Criteria	Python Cave	Heritage Cave	Cave 1 Cave 2 Cave 11 Cave 33
A. Diurnal occupancy rate Season 1 survey August – March (pregnancy, parturition, lactation)			
Greater than 90%			
Between 25% and 90%	(4)-thermal video		
Less than 25%	(3)-ultrasonic		
Never, night visitation only, >50% encounter rate per survey period		2	
Never, night visitation only, <50% encounter rate per survey period			1
B. Diurnal occupancy rate Season 2 survey April – July (independent young, mating)			
Greater than 90%			
Between 25% and 90%	(4)-thermal video		
Less than 25%	(3)-ultrasonic		
Never, night visitation only, >50% encounter rate per survey period		2	
Never, night visitation only, <50% encounter rate per survey period			1
C. Colony size (maximum over surveyed period)			
21 to 100s			
4 to 20			
1 to 3	4		
No diurnal occupancy		1	1
Total Roost Score A+B+C	**10 (ultrasonic) 12 (thermal)**	**5**	**3**
Category allocated	**Category 3**	**Category 4**	**Category 4**
Categorisation type	**Substantiated**	**Provisional**	**Provisional**
Usage Type (see Table A1.2)	**Occasional Diurnal Roost**	**Nocturnal Refuge**	**Nocturnal Refuge**
Habitat significance (see Table A1.2)	**Low-priority Habitat**	**Marginal significance**	**Marginal significance**

Table 6. Five variables that are useful for roost structure categorisation using standard survey methods, with highlight indicating support from observations at Python Cave.

	Detection of presence	Diurnal occupancy rate	Colony size	Size of structure	Focus for breeding
Category 1	Continuously	High	High	Usually deep, complex	High
Category 2	Medium to High	Medium to High	Medium	Moderately deep, complex	Medium
Category 3	Low to High	Low to High	Low	Relatively shallow	Low
Category 4	Low to High	Unoccupied	None	Overhang or analogue	None

Table 7. Matching Python Cave to category descriptions in Bat Call WA (2021) and Cramer et al. (2022) (text is verbatim). Some matches are tenuous despite the presence of a 'tick'.

Bat Call WA (2021)		**Cramer et al. (2022)**	
Category 2			
…present for 25 to 75% of nights over periods of up to several months, but then may be abandoned for weeks or even months…	×/✓	Ghost bats occupy these sites regularly over long periods but their presence is not continuous, i.e. most have roosting recorded for >25% of days but they may be abandoned for periods.	✓
…caves have similar features as Category 1 caves but are often less complex with only a single inner chamber	✓	These sites tend to be deep and have complex internal characteristics.	×
…and are often in less productive areas that the bats only utilise periodically.	?	All are assumed to be maternal sites and are therefore critical habitat.	×
Numbers have varied between zero and 5 with very occasional counts of 20 or more…	×/✓	.	
These caves typically have several other caves, shelters and overhangs within a few hundred meters. Together they make up an 'apartment block' grouping…	×	.	
Category 3			
…one to a few ghost bats roost occasionally, or rarely…	✓	These sites have internal characteristics that can support roosting, with roosting recorded <25% of days and the site abandoned for long periods.	×/✓
…less well-developed structures, such places are often used as feeding sites (as evidenced by middens with food scraps) or temporary refuges…	×/✓	These sites are important for the local, long-term persistence of ghost bats when located as part of a roosting complex that contains category 1 or 2 sites, and should be considered as critical habitat.	×
When adjacent to Category 2 caves, these are considered to be a part of an 'apartment block' and are therefore critical habitat.	.	.	
…isolated Category 3 caves are not considered critical habitat essential to the long-term viability of a local population.	✓	.	
Reproducing females have been reported…	?	.	

4.3 Redundancy assessment

The intention of the 'apartment block' concept is to allow consideration of the relative importance of a particular roost given the proximity and number of other diurnal roosts allocated to the same and different categories. In the scheme of Bat Call WA (2021), roosts with relatively small colonies (up to c. 20) are considered to be higher in value if they are part of an 'apartment' block. The basis given is that components of the 'apartment block' are "…critical habitat important for the ongoing presence of the species in the area" (Bat Call WA (2021: p. 11). Thus, a contribution to the value of a roost is derived from being part of a range of options for a group of Ghost Bats that might switch roosts within a local area according to their intrinsic behaviour.

There is a valid additional, but contrasting, perspective, which we present here. If there are several caves suitable for small colonies of Ghost Bats in a local area that comprises several ridge lines, then the loss of some proportion of these might not cause a local extirpation—because of roost redundancy. Thus, local persistence is likely to be promoted by having several options for roosting, so the relative value of a Category 3 roost (according to the scheme presented in **Appendix 1**) would be lower than a roost that is further away from others—the opposite of that proposed by Bat Call WA (2021).

The two perspectives cannot be reconciled within the scope of the present report, but there is a third perspective that can and should be given equal consideration—the role of roosts for population connectivity. Roost redundancy is also relevant for this third perspective. The Pilbara contains a single interbreeding population of the Ghost Bat (K.N. Armstrong unpublished genetic data; see Armstrong et al. 2017), much like the Pilbara Leaf-nosed Bat (K.N. Armstrong unpublished genetic data; see Armstrong et al. 2017; Umbrello et al. 2022). Perhaps the most helpful way of imagining how the Ghost Bat population is distributed in the Pilbara is as a series of interconnected 'nodes' (=diurnal roosts in Categories 1 – 3). Thus, roosts in categories 2 and 3 that are situated in intervening areas between Category 1 roosts are likely to be important for intra-population connectivity, and thus regional-scale gene flow. If there are several such roosts in intervening areas, then there is redundancy for this connectivity between Category 1 and 2 roosts.

Calculating the level of local redundancy of Category 3 roosts can be undertaken using the mathematical model that is presented in **Appendix A1.4**. This model provides an 'Adjusted Value' of the Roost Score from **Table A1.3** based on two primary variables:

- **The number of other surrounding roosts**—a 'density penalty' is applied that reduces value when surrounded by similar or higher-value roosts (because of redundancy);
- **The distance to other surrounding roosts**—a 'proximity bonus' is applied that increases value when isolated from similar or higher-value roosts (because of its role in connectivity).

The best understanding of the Adjusted Value of such a calculation for a single roost in a study area requires the context of the whole region. This is the subject of a publication in preparation. But there is still value in calculating the Adjusted Value of Python Cave given information of surrounding roosts as an exercise to demonstrate the level of redundancy within a small area (**Table 8**, **Figure 9**; data requested by Fortescue Ltd from the Department of Biodiversity,

Conservation and Attractions (DBCA) Threatened, Specially Protected, and Priority Fauna database; see main report by GHD Pty Ltd). The Adjusted Value V_i has been calculated for each roost, and the degree of increase or decrease relative to Roost Score C_i provides an indication of the level of redundancy around roosts of interest. Important here for interpretation in this exercise is not the actual Adjusted Value, but the level of change from the Roost Score.

In the case of Python Cave, the exercise using the model in **Appendix A1.4** demonstrated that Python Cave was relatively redundant because there was high level of negative change in Adjusted Value (**Table 8**; **Figure 10**). This is mainly because of the proximity of Mundagoora Cave 3, which is a Provisional Category 2 roost. While this Redundancy Assessment and its associated mathematical model is new and yet to be peer-reviewed, its application to the situation of Python Cave serves to demonstrate that its loss would likely have minimal impact on population connectivity and gene flow because other diurnal roosts are available nearby. The implication is that Mundagoora Cave 3 would need to be explicitly protected.

Table 8. List of Ghost Bat roosts in the Iron Bridge study area from the DBCA Threatened, Specially Protected, and Priority Fauna database (caves Rha1, Rha9 and Rha10 have been downgraded to Category 3 because there is no evidence that colonies with more than three individuals are present regularly; C_i: Roost Score that is derived from the criteria in *Table A1.3*, with many of these contrived for the purpose of the exercise; S_i: spatial redundancy factor; D_i: isolation factor; V_i: Adjusted Value; Change: the change from C_i to V_i, as a relative indication of the level of redundancy).

Cave / mine	Latitude	Longitude	Category	C_i	S_i	D_i	V_i	Change
Lalla Rookh	-21.05090	119.27654	1	20	0.00	1.00	30.00	10.00
Mt Ada Adit (CO-CA-35)	-21.43260	119.61350	2	15	0.57	0.64	13.00	-2.00
Mundagoora (South Star) Cave 3	-21.27811	119.04860	2	15	5.80	0.15	13.00	-2.00
Condo Cave (Rha45)	-21.26378	119.29746	3	12	0.00	1.00	18.00	6.00
Python Cave (previously Cave 1)	-21.29450	119.05568	3	12	5.13	0.16	1.00	-11.00
Heritage Cave	-21.28060	119.06639	3	10	5.35	0.16	1.00	-9.00
Wayne Manor	-21.21656	119.07700	3	10	4.17	0.19	1.00	-9.00
Wodgina Cave	-21.20602	118.69624	3	10	0.67	0.60	6.26	-3.74
Bone Cave	-21.24940	118.96810	3	5	4.64	0.18	1.00	-4.00
C2 (Wodgina)	-21.18530	118.65440	3	5	0.67	0.60	3.13	-1.87
Cave 13	-21.25790	119.05537	3	5	6.03	0.14	1.00	-4.00
Chateau Cave	[redacted]		3	5	6.04	0.14	1.00	-4.00
Corunna Downs Complex	-21.42000	119.67380	3	5	0.57	0.64	3.72	-1.28
Mt Webber Roost (MW-AN-27)	-21.51910	119.31338	3	5	0.68	0.59	3.08	-1.92
Rha1	-21.40953	119.09798	3	5	0.20	0.84	6.11	1.11
Rha10	-21.46516	119.23316	3	5	1.67	0.38	1.00	-4.00
Rha17	-21.22278	118.88822	3	5	1.20	0.46	1.00	-4.00
Rha2	-21.56408	119.11006	3	5	0.48	0.68	4.31	-0.69
Rha30	-21.23315	119.00299	3	5	5.51	0.15	1.00	-4.00
Rha5a	-21.51741	119.16716	3	5	1.37	0.42	1.00	-4.00
Rha9	-21.47199	119.23621	3	5	1.73	0.37	1.00	-4.00
UC3	-21.24530	118.95350	3	5	3.96	0.20	1.00	-4.00
Wallaby Cave	-21.23419	119.02329	3	5	5.77	0.15	1.00	-4.00

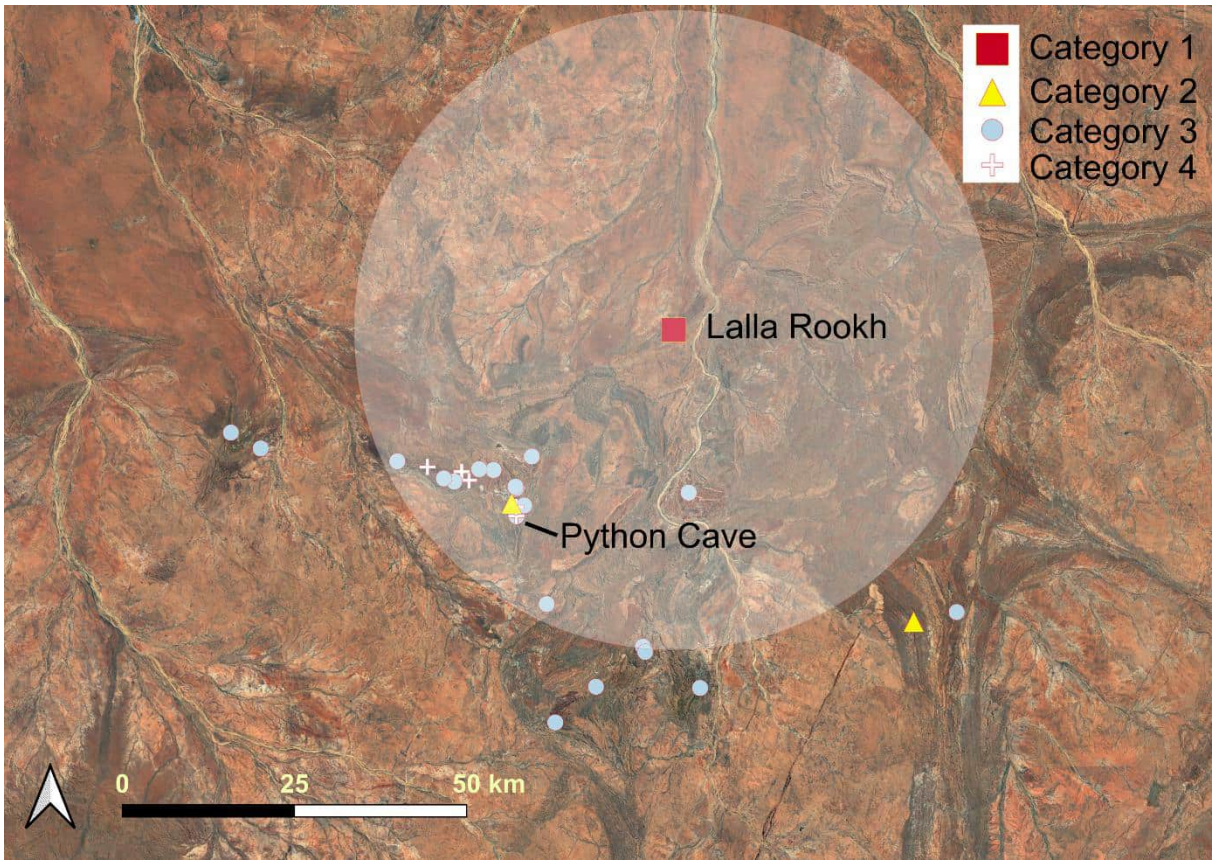

Figure 9. Location of known roosts in the Iron Bridge study area, with symbols indicating roost category as determined by others using the scheme of Cramer et al. (2022). The white-tinted area has a 50 km radius from the Lalla Rookh roost, and provides a general indication of the nightly flight range of a Ghost Bat.

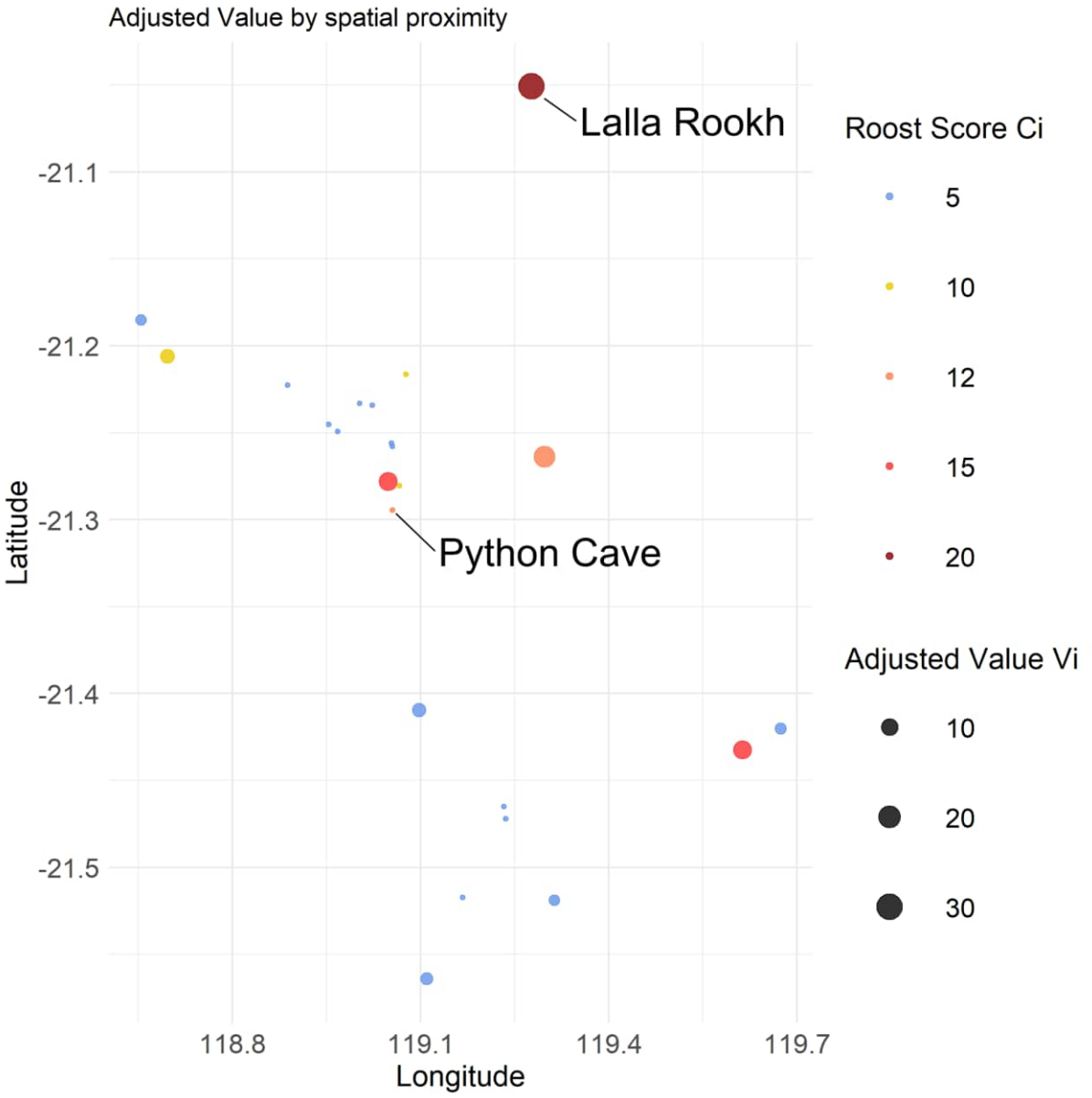

Figure 10. Illustration of how Adjusted Value can decrease relative to Roost Score if local redundancy is relatively high because of proximity (note that in this example analysis the Adjusted Value of Category 1 and 2 roosts has been prevented from decreasing because these should not be de-valued; a critical variable is the maximum distance of influence in the linear decay function that was set at 15 km).

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Appendix 1

The detail in this appendix will be the subject of an upcoming peer-reviewed publication, but we offer it here to support the assessment of bat habitat in the North Star Extension project area.

A1.1 Current categorisation schemes for Ghost Bat roost habitat

Schemes for the categorisation of Ghost Bat roost habitat have been presented in two recent key documents:

- The peer-reviewed and published collaborative journal paper by Cramer et al. (2022).
- The literature review report by Bat Call WA (2021) commissioned by the Commonwealth Government.

Both schemes present four categories that incorporate statements about the rates of diurnal occupancy, the size of structures that are used as roosts, the proximity of other roost habitats, bat behaviours and reproductive activity, signs of bat usage, and whether structures within the category should be considered as critical habitat. These are finding useful application in project assessments in the Pilbara, but there is no prescriptive standard that requires their application, and no comprehensive guidelines for their application.

The practical application of these categories can be challenging for several reasons:

- **Consideration of colony size**. There is no consideration of colony size. This is a critical factor to consider in the context of regional and local population size, and the basis for a useful metric that reflects both how caves are used and the relative importance of caves.
- **Based on definitions without levels**. An assessment can only be based on the relatively brief definitions supplied, which mix a variety of ‘concepts’ and anecdotes, and do not describe levels within each concept.
- **Lack of criteria to match measurements against**. There are no qualitative or quantitative criteria against which to match field observations when allocating a structure to a category. The development and application of such criteria would allow a standardised, objective and evidence-based (non-authoritative) process for allocating caves and cave analogues to a category.
- **Explicit consideration of method limitations**. The categories specify rates of occupancy of roosts, however there are no statements that distinguish interpretations of diurnal occupancy made from the analysis of videos and bat detector recordings. Diurnal roosting cannot be confirmed or assumed from bat detector recordings, only suggested.

- **Lack of clarity in the meaning of some terms**. The use of some terms is imprecise and does not reflect the reality of situations. For example, the term 'abandoned'—a roost is not abandoned if the animals return (or could return) at a later stage; instead these roosts should be thought of as 'unoccupied temporarily'. Other terms are undefined, ambiguous or not accurate reflections of the actual biology/behaviour of the species ('permanent', 'satellite roosts', 'priority', 'itinerant', 'apartment blocks').

- **Inappropriate analogies**. The concept of an 'apartment block' is an imprecise description of several roosts that are relatively close to each other. Use of this term invites immediate interpretation of how bats might use an area based on human behaviour rather than empirical observations of bat behaviour made in the local area. Further, I can conceive arguments for elevated protection of Category 2 – 3 roosts both when there is proximity of other roosts, and when there is not. It is more sensible to consider roost proximities after a diurnal roost has been confirmed and characterised as part of the categorisation process; i.e., when the results of field surveys and roost categorisation are mapped to underpin an assessment of how Ghost Bats might be using a particular ridge, and to support the development of responses such defining buffer zones of adequate size and actions for future monitoring and management. 'Itinerant' is a similarly unhelpful word to use because it is probably an imprecise description of how some Ghost Bats might move amongst caves in the Pilbara.

- **Lack of levels for grading habitat importance**. Categories 1 – 3 are all listed as critical habitat, which defeats the purpose of having different categories based on usage levels, and a basis for assigning value based on relative importance to the species. Over-stating the importance of Categories 2 – 4 diminishes the value and relative importance of a Category 1 diurnal roost, and does not provide a justifiable basis for different management strategies of different roost types.

- **Lack of clear empirical basis**. There has not been an effort to draw together into a single publication the empirical data to support each of these categories. This could be done collaboratively in the future by qualified and experienced biologists.

- **Unrepresentative**. The current categorisation in Bat Call WA (2021) and Cramer et al. (2022) is not a broad representation of the views or inputs of all people with extensive experience of this species.

A1.2 An improved Ghost Bat roost classification scheme

This report contains an assessment of several natural caves as roost habitat for Ghost Bats with an improved scheme. It retains four categories but assigns underground structures to them based on a more robust approach that uses quantitative criteria. The information in Bat Call WA (2021) and Cramer et al. (2022) has been distributed into more logical sets of information and expanded upon. While the scheme will benefit from some further development, it should allow for a more informed assessment and response than could be made based on the information in Bat Call WA (2021) and Cramer et al. (2022).

The revised and improved scheme took inspiration from six scenarios that I have encountered myself, and which have also been documented in various published journal articles and consultancy reports:

Scenario 1—large colony always present; focus of breeding.
Scenario 2—small-medium-sized colony; often present; pregnant females might be present.
Scenario 3—small medium-sized colony; sometimes present; pregnant females might be present.
Scenario 4—several individuals; often present, possibility that a pregnant female is present.
Scenario 5—several individuals; sometimes present; possibility that a pregnant female is present.
Scenario 6—night visitation only, one or few individuals; for resting, social interactions, or to feed on captured prey; no diurnal roosting.

These six scenarios can be matched to categories using standard non-invasive survey approaches (i.e., bat detectors, video recordings, and the detection of reproductive hormone metabolites in scats, if these can be collected at a site).

In revising the categories, I considered the same concepts as are mentioned in Bat Call WA (2021) and Cramer et al. (2022), but specified levels for each concept. The concepts ‘detection of presence’, ‘diurnal occupancy rate’, ‘colony size’, ‘size of structure’, and ‘focus for breeding’ are based on empirical observations, and are thus measurable variables (**Table A1.1**). The concept ‘usage type’ is an interpretation based on diurnal occupancy rate; and ‘habitat significance’ is a designation of value that is made after the categorisation based on variables (**Table A1.2**).

The improved scheme is presented in **Table A1.3**. It includes a scoring system to allocate criteria, and help determine category allocation based on a final Roost Score. Two sets of score ranges are available, for:

Components A, B and C—that are required to make an assessment. It often it will be necessary to allocate a category without the opportunity to determine whether there is evidence of breeding activity.

Component D—that is optional when making an assessment. An unambiguous and accurate allocation of a roost structure can still be made without testing directly for breeding activity because this is corelated with colony size and occupancy rates, which is the basis for a strong assumption. Some situations might require this assumption to be tested.

The information used to assess against the criteria can be obtained with a range of methods that are already being used in consultancy studies. The comprehensiveness of studies and the equipment used varies, but there is a general lack of attention given to confirming diurnal roosting with video (which can give unambiguous indications of diurnal roosting and colony size) and a primary reliance on bat detectors. It is therefore important to distinguish between two types of categorisation that are defined here:

Provisional Categorisation—for situations where interpretations about how Ghost Bats use a particular structure are based on bat detector recordings and other casual observations; and where there has been no determination of diurnal roosting behaviour using a method that allows unambiguous interpretation. Instead, the categorisation is made based on the variable 'detection of presence', which replaces 'diurnal occupancy rate' in components A and B.

Substantiated Categorisation—for situations where there has been a determination of diurnal roosting behaviour using a method that allows unambiguous interpretation. Other observations can be used to support the categorisation to provide further confidence in the designation.

Thus, useful categorisations can still be made when bat detectors have been the only means of data collection, but the provisional status of categorisations will need to be considered in the context of future plans, and whether it is meaningful (would be likely to change the categorisation; or should be undertaken given the commercial importance of a project) to collect further data to substantiate the initial interpretation.

Table A1.1. Five variables that are useful for roost structure categorisation using standard survey methods.

	Detection of presence	Diurnal occupancy rate	Colony size	Size of structure	Focus for breeding
Category 1	Continuously	High	High	Usually deep, complex	High
Category 2	Medium to High	Medium to High	Medium	Moderately deep, complex	Medium
Category 3	Low to High	Low to High	Low	Relatively shallow	Low
Category 4	Low to High	Unoccupied	None	Overhang or analogue	None

Table A1.2. Interpretations and terms that indicate the importance of an underground structure to the Ghost Bat and how assessments should consider them in the context of development proposals.

	Usage type	Habitat significance
Category 1	Permanent Diurnal Roost	Critical Habitat
Category 2	Regular Diurnal Roost	Important Habitat
Category 3	Occasional Diurnal Roost	Low-priority Habitat
Category 4	Nocturnal Refuge	Marginal significance

Table A1.3. A revised classification scheme and scoring system for allocating caves and analogous structures to roost type categories. Each category (C1 – C4) has a maximum score allocated for a particular criterion; observations are matched to criteria, and scores might be allocated from more than one category; and the final designation of category is derived from the total Roost Score, with each category having a non-overlapping range of possible scores; score weights were calculated to maintain the mutual exclusivity of category scores and give equal representation of colony size to diurnal occupancy rate. If diurnal roosting behaviour has only been predicted based on bat detector recordings, and not been confirmed with video or another method that provides unambiguous information, then it is regarded as a 'Provisional Categorisation'.

Required components	**Scores per category**				
Criteria	**C1**	**C2**	**C3**	**C4**	**Example**
A. Diurnal occupancy rate 'Wet season' survey August – March (pregnancy, parturition, lactation)					
Greater than 90%	5				
Between 25% and 90%		4			4
Less than 25%			3		
Never, night visitation only, >50% encounter rate per survey period				2	
Never, night visitation only, <50% encounter rate per survey period				1	
B. Diurnal occupancy rate 'Dry Season' survey April – July (independent young, mating)					
Greater than 90%	5				
Between 25% and 90%		4			
Less than 25%			3		3
Never, night visitation only, >50% encounter rate per survey period				2	
Never, night visitation only, <50% encounter rate per survey period				1	
C. Colony size (maximum over surveyed period)					
21 to 100s	10				
4 to 20		8			
1 to 3			4		3
No diurnal occupancy				1	
Total Roost Score A+B+C	**20**	**13–19**	**6–12**	**0–5**	**10**
Category allocated					**C3**
Categorisation type					**Sub**
Usage Type (see Table A1.2)					**Occasional Diurnal Roost**
Habitat significance (see Table A1.2)					**Low-priority Habitat**

Table A1.3 continued next page…

Table A1.3. *Continued*.

Optional component					
D. Detection of breeding condition and behaviour					
Females in breeding condition (e.g., pregnant females; elevated progesterone in scats)	1	1	1	1	
Females with young	4	4		1	
Juveniles (alive; remains on cave floor; call recordings)	4	4			
Males in breeding condition	1	1	1		
Observation of mating	1	1	1		
Total Roost Score A+B+C+D	**28+**	**16–27**	**8–15**	**0–7**	**10**
Category allocated					**C3**
Categorisation type					**Sub**
Usage Type (see Table A1.2)					**Occasional Diurnal Roost**
Habitat significance (see Table A1.2)					**Low-priority Habitat**

A1.3 Assigning levels of risk, value and response

The categorisations are useful as indications of how important a particular underground structure, or set of structures, is to the Ghost Bat; and therefore as the basis for their level of significance, and the type of response required. A risk matrix, as derived from a safety risk matrix, can be used to allocate a Risk Score by combining roost categorisations with expected levels of effects from nearby anthropogenic activity (**Table A1.4**).

In a safety matrix, the columns are levels of impact; here columns are levels of habitat significance (= importance to the species) that are associated with each roost category (see **Table A1.1**). The rows are levels of disturbance to the bat colony.

Recommended Actions can then be specified for different ranges of Risk Score (**Table A1.5**).

Table A1.4. Risk matrix used to calculate the level of risk (a Risk Score between 1 – 20) of a proposed project to a single Ghost Bat roost and a resident colony.

	Significance	High C1	Medium C2	Low C3	Insignificant C4
Effect of proposed activities	**Score**	4	3	2	1
Roost removal	5	20	15	10	5
Subject to long term elevated direct and indirect effects on a regular basis	4	16	12	8	4
Subject to minor direct and/or indirect effects; nearby; irregular or relatively brief	3	12	9	6	3
Subject to minor indirect effects only; nearby; irregular or relatively brief	2	8	6	4	2
Not subject to any direct or indirect effects; distant location	1	4	3	2	1

Table A1.5. Level of risk of a proposed project to a Ghost Bat colony, as well as the population more broadly and its genetic connectivity.

Risk Score	Risk Level	Recommended Action Level
15 – 20	Critical	Unacceptable risk; avoid where possible; or conduct comprehensive assessment to support any proposal for mining-related activity nearby.
12	High	Significant risk; action or mitigation, monitoring at an appropriate scale required, assessment required to support management actions.
6 – 10	Moderate	Manageable risk; action may be needed over time or for specific events, minor assessment to support management or a proposal.
1 – 5	Low	Acceptable risk; no immediate action required.

A1.4 Redundancy assessment

The Pilbara contains a single interbreeding population of the Ghost Bat (K.N. Armstrong unpublished genetic data; see Armstrong et al. 2017), much like the Pilbara Leaf-nosed Bat (K.N. Armstrong unpublished genetic data; see Armstrong et al. 2017; Umbrello et al. 2022). Perhaps the most helpful way of imagining how the Ghost Bat population is distributed in the Pilbara is as a series of interconnected 'nodes' (=diurnal roosts in Categories 1 – 3), with bats flying amongst roosts for reasons we still do not fully understand, and at rates that have not yet been defined. Thus, roosts in categories 2 and 3 that are situated in intervening areas between Category 1 roosts are likely to be important for population connectivity, and thus regional-scale gene flow. If there are several such roosts in intervening areas, then there is redundancy for this connectivity between Category 1 and 2 roosts. In contrast to the concept of the 'apartment block' (Bat Call WA 2021), the presence of more rather than fewer roosts in intervening areas between Category 1 and 2 roosts lowers the value of a particular roost in proximity to others because there is redundancy for this connectivity.

Following the assessment of a roost using the criteria in **Table A1.3**, which is conducted in isolation from its context (i.e., the proximity of other confirmed roosts), it can be helpful to undertake a 'Redundancy Assessment'. This modifies the **Roost Score C_i** to arrive at an **Adjusted Value V_i** of a roost based on two primary variables:

- **The number of other surrounding roosts**—a '**density penalty**' is applied that reduces value when surrounded by similar or higher-value roosts (because of redundancy); and
- **The distance to other surrounding roosts**—a '**proximity bonus**' is applied that increases value when further away from similar or higher-value roosts (because of its role in connectivity).

Mathematical Formulation

Define:

- C_i as the Roost Score of roost ***i*** (i.e., 0 – 20 as per **Table A1.3**)
- D_i as the **isolation factor** of roost ***i***
- $w_k(d)$ as a weight function for distance ***d***
- N_{ik} as the number of roosts in category $k \leq C_i$ (i.e., same or higher category) within a given distance weighting with a **linear decay function** around roost ***i***

$$w(d) = max\left(0, \frac{d_{max} - d}{d_{max}}\right)$$

where:

w(d) as a weight function for distance ***d***

d_{max} is the maximum influence distance (here set at 15 km)

d is the distance between objects

when d = 0, the weight is maximum (w(d) = 1)

when d = dmax, the weight is o (no influence)

when d > dmax, the weight remains 0 (completely out of range)

The **adjusted value V_i** is given by:

$$V_i = C_i \times (1 + \alpha D_i - \beta S_i)$$

where:

- S_i is the **spatial redundancy factor** that accounts for the number of surrounding roosts in similar or higher categories:

$$S_i = \sum_{k=1}^{C_i} \sum_{b} w_k(d_b) N_{ik}$$

- ***Di*** is the **isolation factor**:

$$D_i = \frac{1}{1 + \sum_{k=1}^{C_i} \sum_b w_k(d_b) N_{ik}}$$

- $w_k(d_b)$ is a **distance weight function**, which is either an **exponential decay** or **bin-based function**, such as:

$$w_k(d_b) = \frac{1}{(1 + d_b)^p}$$

where ***p*** controls how quickly distance reduces influence.

- ***α*** and ***β*** are tunable parameters (e.g., 0.5 and 1, respectively) that control the impact of **isolation** and **redundancy**.

Interpretation

- If a roost is **isolated** (few nearby roosts in its category or higher), D_i is **higher**, increasing V_i.
- If a roost is **densely clustered** with similar or higher-value roosts, S_i increases, reducing V_i.
- **Distance bins** modify the effect based on proximity. Distance bins might span: 0 – 5 km; 5 – 10 km; 10 – 15 km; 15 – 20 km; >20 km. An alternative to distance bins is a linear or exponential decay function. In the exercise presented in section *4.3 Redundancy analysis*, the linear decay function detailed above has been used, with a maximum distance set at 15 km.
- Tunable parameters used are **Isolation Weight *α*** = 0.5 and **Redundancy Weight *β*** = 1 in the exercise in section *4.3 Redundancy assessment*.

Overall, if V_i reduces relative to C_i, then we may interpret that a particular roost has redundancy, and the level of reduction is an indication of the level of redundancy (in future this will be incorporated into an index so that it is easier to interpret). This can be taken into consideration when a decision needs to be made about whether it can be subjected to the anticipated effects of nearby mining-related activity, or indeed its complete removal.

Appendix 2

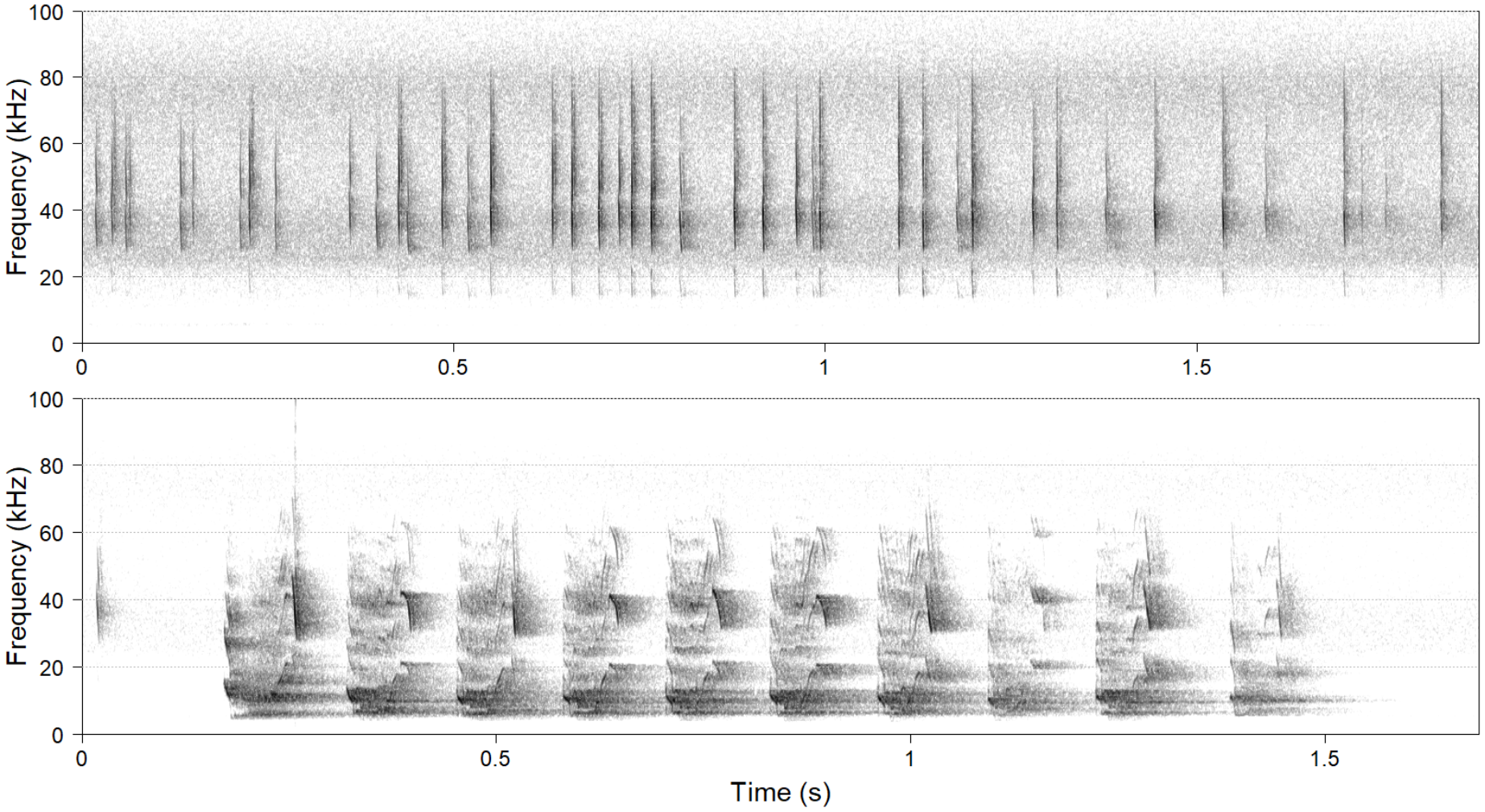


Figure A2.1. Representative calls from the Ghost Bat (**top**: echolocation call sequence; **bottom**: social call sequence).

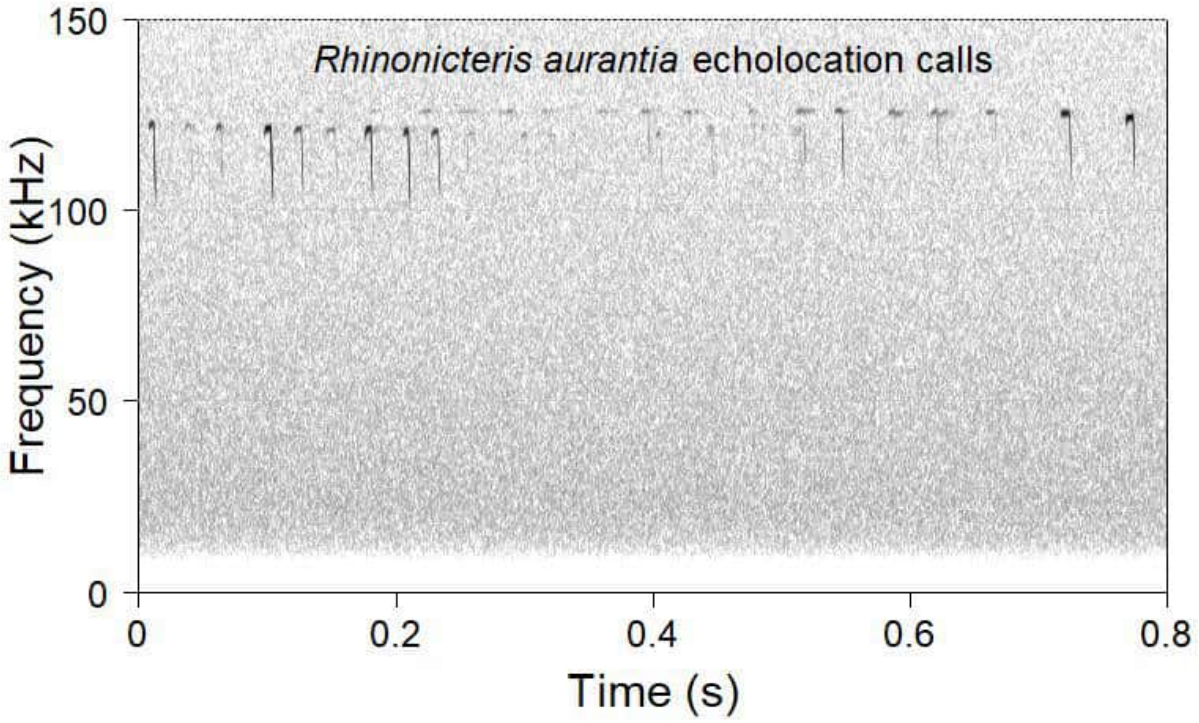


Figure A2.2. Representative echolocation call sequence portion of the Pilbara Leaf-nosed Bat.

Appendix 3

Table A3.1. Summary of numbers of detections of the Pilbara Leaf-nosed Bat from all recording nights and sites in the July 2024 survey.

Site	Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
Cave1-642024	23/07/2024	76	17:42	18:06	6:16	6:39	18:25:27	4:40:02	42M 58S	1H 59M 55S
Cave1-642024	24/07/2024	35	17:42	18:06	6:16	6:39	19:04:15	3:40:42	1H 21M 22S	2H 58M 54S
Cave1-642024	25/07/2024	89	17:43	18:06	6:15	6:39	18:56:52	2:02:10	1H 13M 36S	4H 37M 4S
Cave2-642025	23/07/2024	34	17:42	18:06	6:16	6:39	20:32:08	2:45:23	2H 49M 39S	3H 54M 34S
Cave2-642025	24/07/2024	17	17:42	18:06	6:16	6:39	18:39:27	3:39:12	56M 34S	3H 0M 24S
Cave2-642025	25/07/2024	52	17:43	18:06	6:15	6:39	18:54:50	0:58:49	1H 11M 34S	5H 40M 25S
Cave3-633099	23/07/2024	33	17:42	18:06	6:16	6:39	19:57:23	1:49:31	2H 14M 54S	4H 50M 26S
Cave3-633099	24/07/2024	8	17:42	18:06	6:16	6:39	18:59:01	22:17:56	1H 16M 8S	8H 21M 40S
Cave3-633099	25/07/2024	24	17:43	18:06	6:15	6:39	19:02:13	3:09:31	1H 18M 57S	3H 29M 43S
Cave11-724693	24/07/2024	6	17:42	18:06	6:16	6:39	20:07:40	3:25:16	2H 24M 47S	3H 14M 20S
Cave11-724693	25/07/2024	36	17:43	18:06	6:15	6:39	20:48:11	0:06:17	3H 4M 55S	6H 32M 57S
Cave11-724693	26/07/2024	355	17:43	18:07	6:15	6:38	20:06:45	3:26:17	2H 23M 5S	3H 12M 34S
Cave14-S4U11698	26/07/2024	4	17:43	18:07	6:15	6:38	20:13:57	21:34:16	2H 30M 17S	9H 4M 35S
Cave14-S4U11698	27/07/2024	2	17:44	18:07	6:14	6:38	19:34:56	2:30:01	1H 50M 52S	4H 8M 26S
Cave14-S4U11698	28/07/2024	4	17:44	18:07	6:14	6:38	19:34:10	23:18:32	1H 49M 43S	7H 19M 30S
Cave15area-S4U11673	26/07/2024	1	17:43	18:07	6:15	6:38	20:53:05	20:53:05	3H 9M 25S	9H 45M 46S
Cave15area-S4U11673	27/07/2024	1	17:44	18:07	6:14	6:38	20:51:24	20:51:24	3H 7M 20S	9H 47M 3S
Cave16-724728	27/07/2024	1	17:44	18:07	6:14	6:38	23:01:22	23:01:22	5H 17M 18S	7H 37M 5S
Cave16-724728	28/07/2024	1	17:44	18:07	6:14	6:38	23:20:51	23:20:51	5H 36M 24S	7H 17M 11S
Cave21-S4U11728	26/07/2024	7	17:43	18:07	6:15	6:38	19:21:43	4:30:01	1H 38M 3S	2H 8M 50S
Cave21-S4U11728	27/07/2024	6	17:44	18:07	6:14	6:38	21:49:11	1:25:41	4H 5M 7S	5H 12M 46S
Cave21-S4U11728	28/07/2024	7	17:44	18:07	6:14	6:38	20:01:38	2:55:10	2H 17M 11S	3H 42M 52S
Cave32-450091	25/07/2024	1	17:43	18:06	6:15	6:39	3:17:23	3:17:23	9H 34M 7S	3H 21M 51S
Cave33-S4U11736	26/07/2024	6	17:43	18:07	6:15	6:38	21:24:28	23:26:15	3H 40M 48S	7H 12M 36S
Cave33-S4U11736	27/07/2024	5	17:44	18:07	6:14	6:38	23:46:49	1:38:55	6H 2M 45S	4H 59M 32S

Site	Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
HeritageCave-660654	25/07/2024	5	17:43	18:06	6:15	6:39	21:30:56	1:06:13	3H 47M 40S	5H 33M 1S
HeritageCave-660654	26/07/2024	22	17:43	18:07	6:15	6:38	20:12:42	1:06:21	2H 29M 2S	5H 32M 30S

Appendix 4

Table A4.1. Summary of numbers of detections of the Ghost Bat from Heritage Cave.

Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
27/08/2024	2	27/08/2024 17:59	27/08/2024 18:22	28/08/2024 6:00	28/08/2024 6:22	3:53:40	4:48:24	9:54:05	1:34:16
28/08/2024	2	28/08/2024 17:59	28/08/2024 18:22	29/08/2024 5:59	29/08/2024 6:21	3:35:20	4:51:16	9:35:29	1:30:33
30/08/2024	3	30/08/2024 18:00	30/08/2024 18:22	31/08/2024 5:57	31/08/2024 6:20	4:26:32	4:49:13	10:26:10	1:30:52
31/08/2024	2	31/08/2024 18:00	31/08/2024 18:22	1/09/2024 5:56	1/09/2024 6:19	5:28:21	5:28:26	11:27:44	0:50:46
1/09/2024	4	1/09/2024 18:00	1/09/2024 18:23	2/09/2024 5:56	2/09/2024 6:18	4:30:44	4:44:37	10:29:52	1:33:42
2/09/2024	2	2/09/2024 18:01	2/09/2024 18:23	3/09/2024 5:55	3/09/2024 6:17	5:38:51	5:39:57	11:37:44	0:37:28
5/09/2024	8	5/09/2024 18:01	5/09/2024 18:24	6/09/2024 5:52	6/09/2024 6:14	3:57:10	5:06:17	9:55:20	1:08:24
6/09/2024	4	6/09/2024 18:02	6/09/2024 18:24	7/09/2024 5:51	7/09/2024 6:13	3:55:35	5:06:33	9:53:31	1:07:13
7/09/2024	4	7/09/2024 18:02	7/09/2024 18:24	8/09/2024 5:50	8/09/2024 6:12	20:11:55	4:58:53	2:09:38	1:13:57
8/09/2024	1	8/09/2024 18:02	8/09/2024 18:24	9/09/2024 5:49	9/09/2024 6:11	3:40:44	3:40:44	9:38:13	2:31:10
9/09/2024	2	9/09/2024 18:02	9/09/2024 18:24	10/09/2024 5:48	10/09/2024 6:10	19:28:03	4:28:34	1:25:18	1:42:23
10/09/2024	1	10/09/2024 18:02	10/09/2024 18:25	11/09/2024 5:47	11/09/2024 6:10	2:24:48	2:24:48	8:21:50	3:45:13
11/09/2024	4	11/09/2024 18:03	11/09/2024 18:25	12/09/2024 5:46	12/09/2024 6:09	2:40:29	4:41:51	8:37:17	1:27:13
12/09/2024	3	12/09/2024 18:03	12/09/2024 18:25	13/09/2024 5:45	13/09/2024 6:08	1:40:10	4:41:25	7:36:45	1:26:42
13/09/2024	2	13/09/2024 18:03	13/09/2024 18:25	14/09/2024 5:45	14/09/2024 6:07	2:40:53	5:03:51	8:37:14	1:03:19
14/09/2024	2	14/09/2024 18:03	14/09/2024 18:26	15/09/2024 5:44	15/09/2024 6:06	3:19:59	5:12:17	9:16:07	0:53:55
15/09/2024	11	15/09/2024 18:04	15/09/2024 18:26	16/09/2024 5:43	16/09/2024 6:05	21:18:49	4:32:07	3:14:44	1:33:07
17/09/2024	3	17/09/2024 18:04	17/09/2024 18:26	18/09/2024 5:41	18/09/2024 6:03	2:04:20	5:14:10	7:59:48	0:49:09
18/09/2024	1	18/09/2024 18:04	18/09/2024 18:26	19/09/2024 5:40	19/09/2024 6:02	5:07:35	5:07:35	11:02:50	0:54:46
19/09/2024	6	19/09/2024 18:04	19/09/2024 18:27	20/09/2024 5:39	20/09/2024 6:01	18:51:36	4:54:33	0:46:37	1:06:50
20/09/2024	2	20/09/2024 18:05	20/09/2024 18:27	21/09/2024 5:38	21/09/2024 6:00	4:23:23	4:23:29	10:18:11	1:36:56
21/09/2024	28	21/09/2024 18:05	21/09/2024 18:27	22/09/2024 5:37	22/09/2024 5:59	22:08:24	5:01:00	4:02:58	0:58:28

Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
22/09/2024	20	22/09/2024 18:05	22/09/2024 18:27	23/09/2024 5:36	23/09/2024 5:58	19:27:36	5:15:23	1:21:56	0:43:07
25/09/2024	8	25/09/2024 18:06	25/09/2024 18:28	26/09/2024 5:33	26/09/2024 5:55	2:22:23	3:42:21	8:16:01	2:13:16
2/10/2024	2	2/10/2024 18:08	2/10/2024 18:30	3/10/2024 5:26	3/10/2024 5:49	4:35:47	4:36:29	10:27:39	1:12:34
3/10/2024	4	3/10/2024 18:08	3/10/2024 18:30	4/10/2024 5:25	4/10/2024 5:48	21:43:55	4:48:21	3:35:30	0:59:47

Appendix 5

Table A5.1. Summary of numbers of detections of the Pilbara Leaf-nosed Bat from Cave 11.

Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
27/08/2024	147	27/08/2024 17:59	27/08/2024 18:22	28/08/2024 6:00	28/08/2024 6:22	20:17:57	3:30:52	2:18:22	2:51:48
28/08/2024	65	28/08/2024 17:59	28/08/2024 18:22	29/08/2024 5:59	29/08/2024 6:21	19:49:37	4:01:49	1:49:46	2:20:00
29/08/2024	45	29/08/2024 18:00	29/08/2024 18:22	30/08/2024 5:58	30/08/2024 6:20	20:21:20	4:34:37	2:21:13	1:46:20
30/08/2024	20	30/08/2024 18:00	30/08/2024 18:22	31/08/2024 5:57	31/08/2024 6:20	20:11:34	3:12:37	2:11:12	3:07:28
31/08/2024	118	31/08/2024 18:00	31/08/2024 18:22	1/09/2024 5:56	1/09/2024 6:19	21:31:47	4:04:49	3:31:10	2:14:23
1/09/2024	42	1/09/2024 18:00	1/09/2024 18:23	2/09/2024 5:56	2/09/2024 6:18	22:12:01	1:01:56	4:11:09	5:16:23
2/09/2024	55	2/09/2024 18:01	2/09/2024 18:23	3/09/2024 5:55	3/09/2024 6:17	20:31:15	4:27:40	2:30:08	1:49:45
3/09/2024	5	3/09/2024 18:01	3/09/2024 18:23	4/09/2024 5:54	4/09/2024 6:16	22:15:01	1:00:25	4:13:40	5:16:06
4/09/2024	4	4/09/2024 18:01	4/09/2024 18:23	5/09/2024 5:53	5/09/2024 6:15	23:46:54	1:12:40	5:45:19	5:02:56
5/09/2024	44	5/09/2024 18:01	5/09/2024 18:24	6/09/2024 5:52	6/09/2024 6:14	21:22:41	1:30:45	3:20:51	4:43:56
6/09/2024	32	6/09/2024 18:02	6/09/2024 18:24	7/09/2024 5:51	7/09/2024 6:13	20:30:08	2:52:49	2:28:04	3:20:57
7/09/2024	11	7/09/2024 18:02	7/09/2024 18:24	8/09/2024 5:50	8/09/2024 6:12	20:21:53	3:39:03	2:19:36	2:33:47
8/09/2024	10	8/09/2024 18:02	8/09/2024 18:24	9/09/2024 5:49	9/09/2024 6:11	21:23:05	23:51:42	3:20:34	6:20:12
9/09/2024	16	9/09/2024 18:02	9/09/2024 18:24	10/09/2024 5:48	10/09/2024 6:10	21:18:24	3:20:19	3:15:39	2:50:38
10/09/2024	3	10/09/2024 18:02	10/09/2024 18:25	11/09/2024 5:47	11/09/2024 6:10	0:04:39	0:05:30	6:01:41	6:04:31
11/09/2024	8	11/09/2024 18:03	11/09/2024 18:25	12/09/2024 5:46	12/09/2024 6:09	20:50:44	20:57:11	2:47:32	9:11:53
12/09/2024	1	12/09/2024 18:03	12/09/2024 18:25	13/09/2024 5:45	13/09/2024 6:08	21:01:04	21:01:04	2:57:39	9:07:03
13/09/2024	48	13/09/2024 18:03	13/09/2024 18:25	14/09/2024 5:45	14/09/2024 6:07	20:27:59	3:58:42	2:24:20	2:08:28
14/09/2024	4	14/09/2024 18:03	14/09/2024 18:26	15/09/2024 5:44	15/09/2024 6:06	0:10:44	1:14:30	6:06:52	4:51:42
16/09/2024	4	16/09/2024 18:04	16/09/2024 18:26	17/09/2024 5:42	17/09/2024 6:04	1:07:18	1:07:44	7:02:59	4:56:33
17/09/2024	33	17/09/2024 18:04	17/09/2024 18:26	18/09/2024 5:41	18/09/2024 6:03	20:36:16	2:59:51	2:31:44	3:03:28
18/09/2024	42	18/09/2024 18:04	18/09/2024 18:26	19/09/2024 5:40	19/09/2024 6:02	20:15:18	2:19:04	2:10:33	3:43:17

Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
19/09/2024	33	19/09/2024 18:04	19/09/2024 18:27	20/09/2024 5:39	20/09/2024 6:01	22:15:04	3:01:38	4:10:05	2:59:45
21/09/2024	19	21/09/2024 18:05	21/09/2024 18:27	22/09/2024 5:37	22/09/2024 5:59	20:01:23	1:47:09	1:55:57	4:12:19
22/09/2024	8	22/09/2024 18:05	22/09/2024 18:27	23/09/2024 5:36	23/09/2024 5:58	21:48:54	4:20:58	3:43:14	1:37:32
23/09/2024	46	23/09/2024 18:05	23/09/2024 18:28	24/09/2024 5:35	24/09/2024 5:57	21:07:43	4:01:34	3:01:49	1:55:58
24/09/2024	56	24/09/2024 18:06	24/09/2024 18:28	25/09/2024 5:34	25/09/2024 5:56	21:21:59	4:02:20	3:15:51	1:54:15
25/09/2024	123	25/09/2024 18:06	25/09/2024 18:28	26/09/2024 5:33	26/09/2024 5:55	21:43:43	2:50:48	3:37:21	3:04:49

Appendix 6

Table A6.1. Summary of numbers of detections of the Pilbara Leaf-nosed Bat from Heritage Cave.

Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
27/08/2024	15	27/08/2024 17:59	27/08/2024 18:22	28/08/2024 6:00	28/08/2024 6:22	19:12:06	2:13:56	1:12:31	4:08:44
28/08/2024	2	28/08/2024 17:59	28/08/2024 18:22	29/08/2024 5:59	29/08/2024 6:21	0:10:25	3:11:08	6:10:34	3:10:41
29/08/2024	4	29/08/2024 18:00	29/08/2024 18:22	30/08/2024 5:58	30/08/2024 6:20	22:19:55	1:57:28	4:19:48	4:23:29
30/08/2024	4	30/08/2024 18:00	30/08/2024 18:22	31/08/2024 5:57	31/08/2024 6:20	0:21:57	1:24:06	6:21:35	4:55:59
31/08/2024	9	31/08/2024 18:00	31/08/2024 18:22	1/09/2024 5:56	1/09/2024 6:19	22:38:17	1:52:46	4:37:40	4:26:26
1/09/2024	6	1/09/2024 18:00	1/09/2024 18:23	2/09/2024 5:56	2/09/2024 6:18	19:52:39	1:23:15	1:51:47	4:55:04
2/09/2024	20	2/09/2024 18:01	2/09/2024 18:23	3/09/2024 5:55	3/09/2024 6:17	20:38:05	4:28:46	2:36:58	1:48:39
3/09/2024	3	3/09/2024 18:01	3/09/2024 18:23	4/09/2024 5:54	4/09/2024 6:16	0:05:50	2:52:13	6:04:29	3:24:18
5/09/2024	4	5/09/2024 18:01	5/09/2024 18:24	6/09/2024 5:52	6/09/2024 6:14	0:56:35	1:53:12	6:54:45	4:21:29
6/09/2024	4	6/09/2024 18:02	6/09/2024 18:24	7/09/2024 5:51	7/09/2024 6:13	21:33:47	2:09:57	3:31:43	4:03:49
8/09/2024	3	8/09/2024 18:02	8/09/2024 18:24	9/09/2024 5:49	9/09/2024 6:11	23:25:25	2:01:36	5:22:54	4:10:18
10/09/2024	4	10/09/2024 18:02	10/09/2024 18:25	11/09/2024 5:47	11/09/2024 6:10	22:41:55	0:38:31	4:38:57	5:31:30
13/09/2024	1	13/09/2024 18:03	13/09/2024 18:25	14/09/2024 5:45	14/09/2024 6:07	22:39:58	22:39:58	4:36:19	7:27:12
14/09/2024	6	14/09/2024 18:03	14/09/2024 18:26	15/09/2024 5:44	15/09/2024 6:06	23:13:45	1:14:55	5:09:53	4:51:17
16/09/2024	5	16/09/2024 18:04	16/09/2024 18:26	17/09/2024 5:42	17/09/2024 6:04	23:27:08	0:51:15	5:22:49	5:13:02
17/09/2024	4	17/09/2024 18:04	17/09/2024 18:26	18/09/2024 5:41	18/09/2024 6:03	21:49:46	2:01:36	3:45:14	4:01:43
18/09/2024	3	18/09/2024 18:04	18/09/2024 18:26	19/09/2024 5:40	19/09/2024 6:02	23:49:16	1:06:56	5:44:31	4:55:25
21/09/2024	2	21/09/2024 18:05	21/09/2024 18:27	22/09/2024 5:37	22/09/2024 5:59	1:03:06	1:03:17	6:57:40	4:56:11
23/09/2024	26	23/09/2024 18:05	23/09/2024 18:28	24/09/2024 5:35	24/09/2024 5:57	21:48:39	1:33:55	3:42:45	4:23:37
24/09/2024	5	24/09/2024 18:06	24/09/2024 18:28	25/09/2024 5:34	25/09/2024 5:56	22:34:24	0:17:05	4:28:16	5:39:30
25/09/2024	24	25/09/2024 18:06	25/09/2024 18:28	26/09/2024 5:33	26/09/2024 5:55	22:41:57	3:14:18	4:35:35	2:41:19
26/09/2024	6	26/09/2024 18:06	26/09/2024 18:28	27/09/2024 5:32	27/09/2024 5:54	22:45:58	0:59:08	4:39:21	4:55:32

Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
27/09/2024	1	27/09/2024 18:06	27/09/2024 18:29	28/09/2024 5:31	28/09/2024 5:53	1:08:06	1:08:06	7:01:15	4:45:37
28/09/2024	24	28/09/2024 18:07	28/09/2024 18:29	29/09/2024 5:30	29/09/2024 5:52	23:26:15	2:29:19	5:19:09	3:23:28
29/09/2024	9	29/09/2024 18:07	29/09/2024 18:29	30/09/2024 5:29	30/09/2024 5:51	21:49:52	2:14:36	3:42:31	3:37:14
30/09/2024	6	30/09/2024 18:07	30/09/2024 18:29	1/10/2024 5:28	1/10/2024 5:50	21:08:52	1:46:20	3:01:15	4:04:34
1/10/2024	9	1/10/2024 18:07	1/10/2024 18:30	2/10/2024 5:27	2/10/2024 5:49	22:55:46	2:54:55	4:47:54	2:55:03
2/10/2024	3	2/10/2024 18:08	2/10/2024 18:30	3/10/2024 5:26	3/10/2024 5:49	23:34:33	2:38:22	5:26:25	3:10:41
3/10/2024	14	3/10/2024 18:08	3/10/2024 18:30	4/10/2024 5:25	4/10/2024 5:48	23:32:43	3:04:35	5:24:18	2:43:33

Appendix B

Detailed Habitat Assessment forms

Caves 4, 5, 6, 7, 10, 12, 13a, 22 and 23 habitat assessment

These caves consisted of small overhangs with narrow diameter and short depth (i.e. <2x2m) and were deemed not suitable for bat roosting habitat. No signs of bat occupancy (i.e. scat, feeding remains or scent) were observed at these caves. Coordinates for each of these caves are provided in the table below.

Cave number/name	Coordinates
Cave 4	-21.295467, 119.062612
Cave 5	-21.296714, 119.063937
Cave 6	-21.297499, 119.069577
Cave 7	-21.297519, 119.065277
Cave 10	-21.275528, 119.062971
Cave 12	-21.275665, 119.066972
Cave 13a	-21.273116, 119.063232
Cave 22	-21.272392, 119.053564
Cave 23	-21.272557, 119.053563

Cave 1a habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 1a	Date/time:	23/07/2024, 04:19 pm
Position (geography): At water level in a rocky gorge at the base of a cliff	Location (Coordinates): Latitude: -21.29459	Longitude: 119.05598
Cave morphology – ENTRANCE		
Cave position	Mid way along the length and height of a gully (the same gully as Python Cave, Cave 2 and Cave 3)	
Entrance shape / height (m) / width (m)	Horizontal slit / 0.4 m height x 1.8 m width	
Entrance aspect / position (of opening)	North	
Floor / ceiling type	Rough	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow	Ambient	
Bat evidence / other comments	Yes: heard at least one *T. georgianus*	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	1	
Entrance shape / height (m) / width (m) / orientation / position	As above	
Chamber shape / width (m) / height (m)	Large bowl shape, possibly over 2 m in height and 3 m wide	
Floor type / debris / fallen rocks/dust	Dusty with Wallaroo scats present	
Ceiling type		
Condition		
Temperature and humidity		
Airflow / evidence of moisture / water		
Bat evidence / other comments		
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	

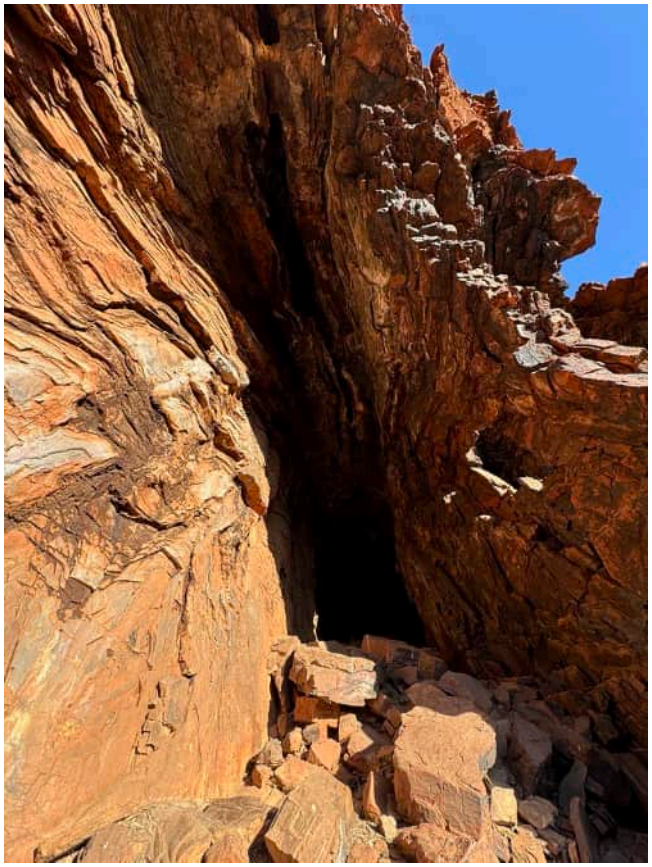
Comments		
DETECTOR DETAILS		
Type: Anabat Swift	Serial no: 642024	GHD no:
Dates operational: 23 – 26/07/2024	Latitude: -21.29459	Longitude: 119.05598
Photo Records		
		

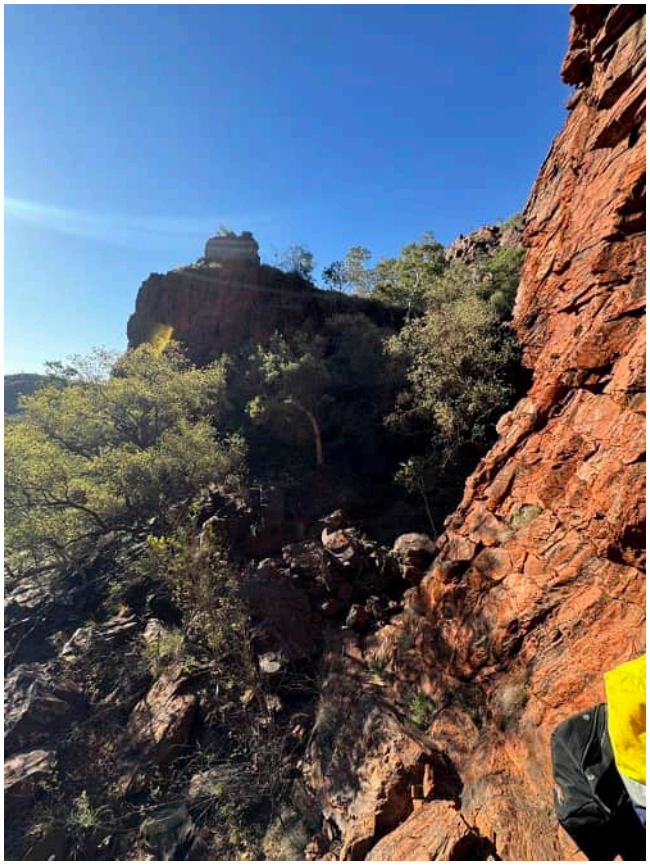
Cave 2 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 2	Date/time:	23/07/2024, 06:27
Position (geography): At water level in a rocky gorge at the base of a cliff	Location (Coordinates): Latitude: -21.29457	Longitude: 119.05544
Cave morphology – ENTRANCE		
Cave position	Within a larger overhang midway along the length of a gully (the same gully as Python Cave, Cave 1a and Cave 3)	
Entrance shape / height (m) / width (m)	Oval / 1.5 m height x 0.5 m width	
Entrance aspect / position (of opening)	North	
Floor / ceiling type	Rough	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow	Ambient	
Bat evidence / other comments	Yes: several *T. georgianus* individuals heard and *T. georgianus* scat seen.	
Cave morphology – CHAMBER(S)		
Number of chambers (description)		
Entrance shape / height (m) / width (m) / orientation / position	Chamber went back 7 m and angled down with small pockets in the ceiling.	
Chamber shape / width (m) / height (m)		
Floor type / debris / fallen rocks/dust		
Ceiling type		
Condition		
Temperature and humidity		
Airflow / evidence of moisture / water		
Bat evidence / other comments		
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	
Comments		
DETECTOR DETAILS		
Type: Anabat Swift and thermal video camera	Serial no: Swift: 642025; Thermal: Boson 1	GHD no:
Dates operational: 23 – 26/07/2024	Latitude: -21.29457	Longitude: 119.05544
Photo Records		

Cave 3 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 3	Date/time:	23/07/2024, 07:45
Position (geography): Towards the bottom of the gully (the same gully as Python Cave, Cave 1a and Cave 3)	Location (Coordinates): Latitude: -21.29508	Longitude: 119.05453
Cave morphology – ENTRANCE		
Cave position	North	
Entrance shape / height (m) / width (m)	Large square / 3 height x 2 width	
Entrance aspect / position (of opening)	North (southern side of gully)	
Floor / ceiling type	Rough / lots of vertical cracks in the ceiling and lots of fallen rocks on the floor of the cave	
Entrance condition	Unstable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	Yes / heard *T. georgianus* calling, scat seen at entrance. Small piece of bone found which could indicate GB feeding	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	1	
Entrance shape / height (m) / width (m) / orientation / position	3 height x 2 width / north	
Chamber shape / width (m) / height (m)	Narrowing square / 4 width x 6 height	
Floor type / debris / fallen rocks/dust	Rough / debris and rocks present	
Ceiling type	Cracking	
Condition	Lots of vertical cracks	
Temperature and humidity		
Airflow / evidence of moisture / water	Yes	
Bat evidence / other comments	Yes / at least 20 – 30 *T. georgianus* present. 2 x horizontal shoots at ground level at the rear of the main chamber (approx. 7 m long) absent of GB or PLNB scat. Potential GB scat found (collected) with small bones near them.	
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	
Comments		
DETECTOR DETAILS		
Type: Ananbat Swift	Serial no: 633099	GHD no:
Dates operational: 23 – 26/07/2024	Latitude: -21.29508	Longitude: 119.05453
Photo Records		



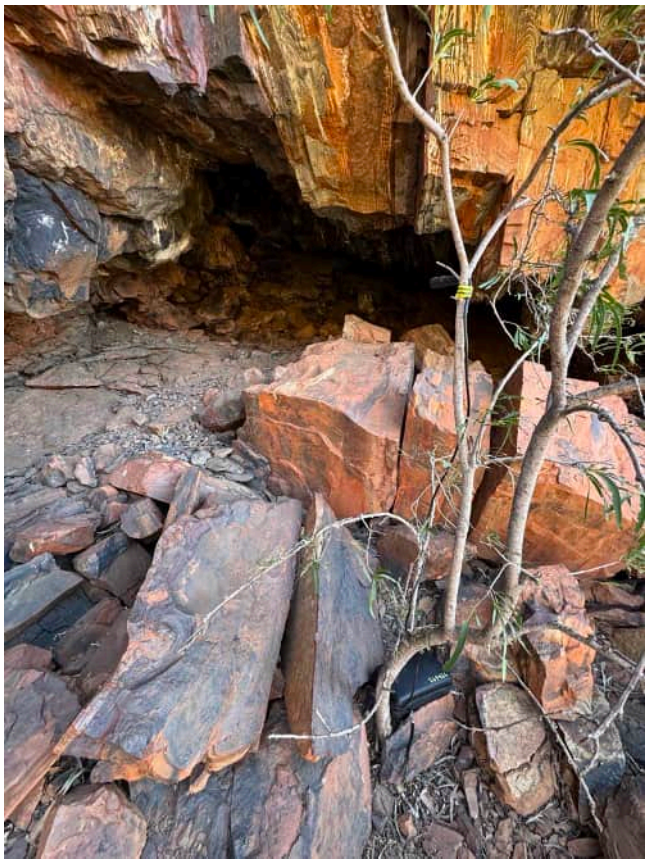


Cave 8 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 8	Date/time:	23/07/2024, 00:39
Position (geography): ¾ of the way up a small gully within small valley	Location (Coordinates): Latitude: -21.29887	Longitude: 119.06494
Cave morphology – ENTRANCE		
Cave position	¾ of the way up a small gully within small valley	
Entrance shape / height (m) / width (m)	Spearhead / 1.5 high x 1 wide	
Entrance aspect / position (of opening)	North / in rocky cliff face	
Floor / ceiling type	Rough / chamber is approx. 4 m deep	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	No / Wallaroo shelter	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	1 (see above; overhang only)	
Entrance shape / height (m) / width (m) / orientation / position		
Chamber shape / width (m) / height (m)		
Floor type / debris / fallen rocks/dust	Debris present / rock dust present	
Ceiling type	Crevices	
Condition		
Temperature and humidity	Ambient	
Airflow / evidence of moisture / water	No evidence of moisture/water	
Bat evidence / other comments	Very small chamber with cracked ceilings. Small amount of *T. georgianus* scat. Old Quoll scat present.	
FIELD NOTES		
Habitat category		
Comments	Not suitable for diurnal roosting	
DETECTOR DETAILS		
Type:	Serial no:	GHD no:
Dates operational:	Latitude: -21.29887	Longitude: 119.06494

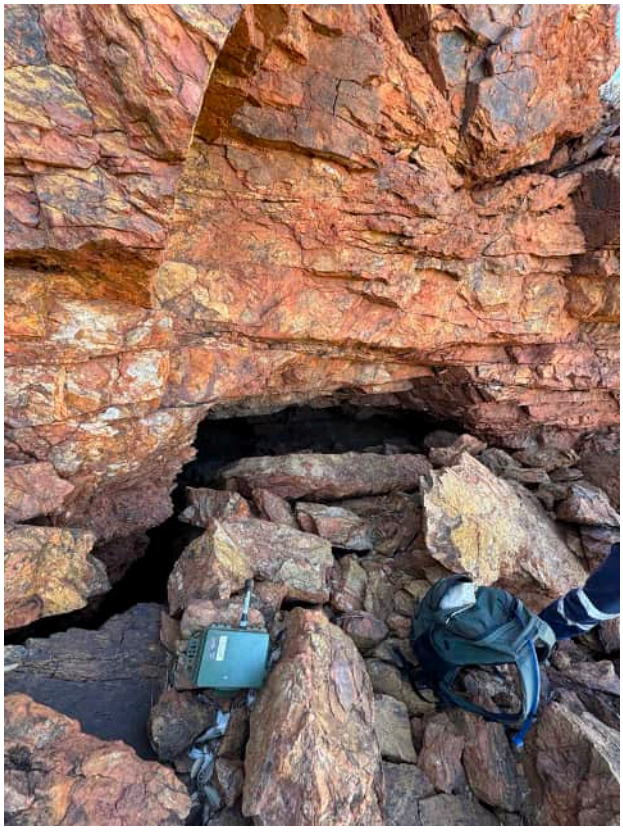
Cave 11 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 11	Date/time:	24/07/2024, 01:44 pm
Position (geography): Halfway up gully, at the base of a outcrop. Gully is part of several connected gullies that lead off to eastern side of the escarpment	Location (Coordinates): Latitude: -21.27535	Longitude: 119.06310
Cave morphology – ENTRANCE		
Cave position	Halfway up gully	
Entrance shape / height (m) / width (m)	Wide horizontal fissure / 1.8 height x 4.5 width	
Entrance aspect / position (of opening)	Southeast	
Floor / ceiling type	Rough / rough	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	Yes / cave entrance is large then turned into a small pinch point on the left through to a deeper chamber	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	1	
Entrance shape / height (m) / width (m) / orientation / position	Southeast	
Chamber shape / width (m) / height (m)	Horizontally wide (approx. 3 m) and height was low (approx. 1.5 m), sloping upwards at least 10 m in depth. Some vertical cracks also seen within chamber.	
Floor type / debris / fallen rocks/dust	Sloping / debris and rocks present	
Ceiling type	Crevices / horizontal racks present in chamber	
Condition		
Temperature and humidity		
Airflow / evidence of moisture / water	No	
Bat evidence / other comments	Yes / *T. georgianus* seen flying from chamber to entrance. Possible GB scat (collected) and PLNB scat seen in cave entrance.	
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	
Comments		
DETECTOR DETAILS		
Type: Anabat Swift	Serial no: 724693	GHD no:
Dates operational: 24 – 27/07/2024 and 27/08/2024 – 25/10/2024	Latitude: -21.27535	Longitude: 119.06310
Photo Records		



Cave 14 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 14	Date/time:	26/07/2024, 02:25
Position (geography): On northern side of broad low depression/valley on top of the ridge	Location (Coordinates): Latitude: -21.27047	Longitude: 119.05871
Cave morphology – ENTRANCE		
Cave position	On northern side of broad low depression on top of the ridge	
Entrance shape / height (m) / width (m)	Wide and low / 1 height x 4 width	
Entrance aspect / position (of opening)	South / behind rubble of fallen rocks at base of small outcrop	
Floor / ceiling type	Rough / floor dusty with fallen rocks	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	No	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	1	
Entrance shape / height (m) / width (m) / orientation / position	See above	
Chamber shape / width (m) / height (m)	0.5 – 2 m height x 15 m width 15 – 20 m deep with some small nooks	
Floor type / debris / fallen rocks/dust	Rough / floor dusty with fallen rocks	
Ceiling type		
Condition	Stable	
Temperature and humidity	Ambient	
Airflow / evidence of moisture / water		
Bat evidence / other comments	No bats sighted. Possible old GB found (collected).	
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	
Comments		
DETECTOR DETAILS		
Type: Songmeter SM4Bat	Serial no: s4u11698	GHD no:
Dates operational: 26 – 29/07/2024	Latitude: -21.27047	Longitude: 119.05871
Photo Records		



Cave 16 habitat assessment

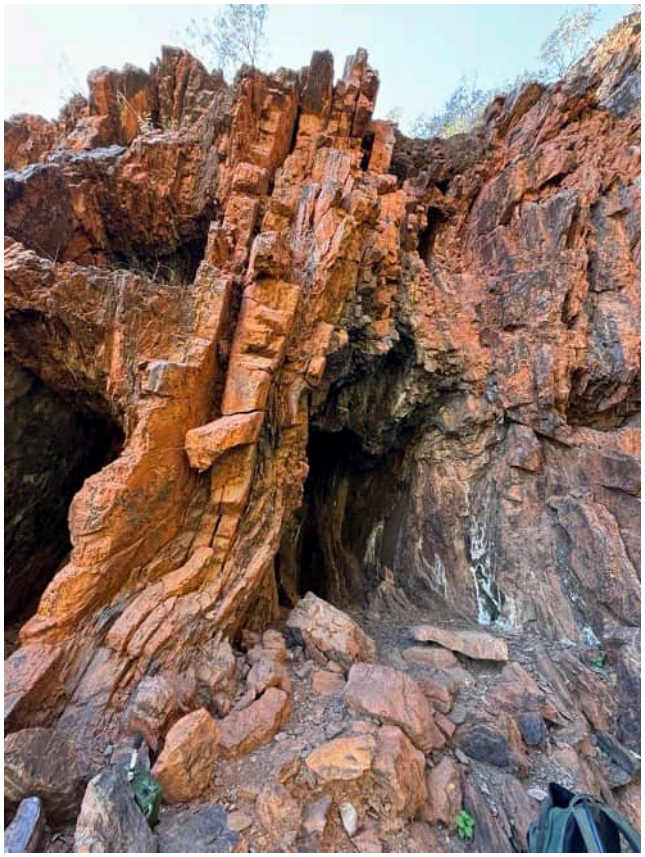
Cave habitat assessment form		
Cave number/ name: Cave 16	Date/time:	25/07/2024, 01:21
Position (geography): Halfway up gully on northern side	Location (Coordinates): Latitude: -21.28743	Longitude: 119.05603
Cave morphology – ENTRANCE		
Cave position	Halfway up gully on northern side	
Entrance shape / height (m) / width (m)	Natural window shaped entrance / 1 height x 1 depth	
Entrance aspect / position (of opening)	Southwest	
Floor / ceiling type	Rough / floor sloping upwards and bending slightly to the right into pinch point and then into chamber	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	Yes / 1x *T. georgianus* flew out of cave	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	2	
Entrance shape / height (m) / width (m) / orientation / position	Chamber 1: 1 m height x 1 m width Cahmber 2: 1 m high x 5 m wide x 5 m deep.	
Chamber shape / width (m) / height (m)	2 – 3 horizontal openings, 1 of them leads back at least 3 – 4 m, unable to see the end	
Floor type / debris / fallen rocks/dust	Rough / debris and rock present	
Ceiling type	Crevices	
Condition		
Temperature and humidity		
Airflow / evidence of moisture / water	No	
Bat evidence / other comments	Yes / possible GB scat found (collected) at entrance.	
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	
Comments		
DETECTOR DETAILS		
Type: Anabat Swift	Serial no: 724728	GHD no:
Dates operational: 25 – 29/07/2024	Latitude: -21.28743	Longitude: 119.05603
Photo Records		

Cave 32 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 32	Date/time:	25/07/2024, 03:06
Position (geography): southern side of gully, fault behind fig tree	Location (Coordinates): Longitude: 21.28257	 Longitude: 119.05492
Cave morphology – ENTRANCE		
Cave position	Southern side of gully, fault behind fig tree	
Entrance shape / height (m) / width (m)	Oval in curled rock layer fault / 0.5 height x 0.5 width	
Entrance aspect / position (of opening)	North / behind fig tree within curled rock layers, southern side of gully. Moisture at entrance.	
Floor / ceiling type	Smooth	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	Yes / *T. georgianus* heard calling inside	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	1	
Entrance shape / height (m) / width (m) / orientation / position	Long cylinder	
Chamber shape / width (m) / height (m)	1 m high x 5 m deep chamber with possible vertical chute at rear	
Floor type / debris / fallen rocks/dust	No debris present	
Ceiling type		
Condition		
Temperature and humidity		
Airflow / evidence of moisture / water	Yes, very water dripping down the cliff through and around entrance	
Bat evidence / other comments	Can hear *T. georgianus* chattering. Slight bat smell, lots of bat scat possible PLNB and *T. georgianus* scat.	
FIELD NOTES		
Habitat category	Potential diurnal roost – unknown category	
Comments		
DETECTOR DETAILS		
Type: Anabat Swift	Serial no: 450091	GHD no:
Dates operational: 25 – 28/07/2024	Latitude:	Longitude:
Photo Records		

Cave 33 habitat assessment

Cave habitat assessment form		
Cave number/ name: Cave 33	Date/time:	25/07/2024, 03:42
Position (geography): Northern side of gully, just south of Cave 32	Location (Coordinates): Latitude: -21.28250	Longitude: 119.05489
Cave morphology – ENTRANCE		
Cave position	Northern side of western facing gully. At top of gully base of cliff face.	
Entrance shape / height (m) / width (m)	Large archway / 3.5 height x 3 width	
Entrance aspect / position (of opening)	West / at base of cliff	
Floor / ceiling type	Rough	
Entrance condition	Stable	
Entrance temperature / humidity/ airflow		
Bat evidence / other comments	Yes / One *T. georgianus* present and no GB evidence.	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	Overhang only	
Entrance shape / height (m) / width (m) / orientation / position	3.5 height x 3 width	
Chamber shape / width (m) / height (m)		
Floor type / debris / fallen rocks/dust	Debris and rock dust present	
Ceiling type	Cracking	
Condition		
Temperature and humidity		
Airflow / evidence of moisture / water	Yes	
Bat evidence / other comments	No GB evidence	
FIELD NOTES		
Habitat category	Overhang only, not suitable for diurnal roosting	
Comments		
DETECTOR DETAILS		
Type: Anabat Swift	Serial no:	GHD no:
Dates operational: 25 – 28/07/2024	Latitude: -21.28250	Longitude: 119.05489
Photo Records		



Heritage Cave habitat assessment

Cave habitat assessment form		
Cave number/ name: Heritage Cave	Date/time:	23/07/2024, 23:59
Position (geography): Midway up gully within a long valley, on the southern side gully, with numerous trees and shrubs in front	Location (Coordinates): Longitude: 21.28062	Longitude: 119.06638
Cave morphology – ENTRANCE		
Cave position	Midway up gully within valley, side of watercourse in gully, trees and shrubs present in front	
Entrance shape / height (m) / width (m)	4 height x 20 width	
Entrance aspect / position (of opening)	Northwest / Broad amphitheatre	
Floor / ceiling type	Rough	
Entrance condition	Roof appears stable, but lots of fallen rocks on floor	
Entrance temperature / humidity/ airflow	Ambient	
Bat evidence / other comments	Yes / several *T. georgianus* roosting in rear of cave	
Cave morphology – CHAMBER(S)		
Number of chambers (description)	2	
Entrance shape / height (m) / width (m) / orientation / position	Chamber 1 entrance as above Chamber 2 entrance 2 x 2 m	
Chamber shape / width (m) / height (m)	Chamber 1: 4 m height x 20 m width x 20 m deep, rocky lumpy ceiling with small pockets / nooks off to the side. Chamber 2: approx. min 20 m deep (2 x 2m wide/high) and getting smaller towards the back	
Floor type / debris / fallen rocks/dust	There is a smooth dusty floor in the front chamber towards the entrance. Towards the back and into the second chamber the floor is very rough with large rocks and boulders	
Ceiling type	Rough throughout	
Condition	Stable, though there is evidence of rockfall throughout the cave, unclear how recent.	
Temperature and humidity	The second chamber may provide temp and humidity that slightly more constant than ambient	
Airflow / evidence of moisture / water	Yes; small amount of light coming from the rear (top of cliff) so not likely to be significantly different to ambient temp/humidity	
Bat evidence / other comments	Yes several *T. georgianus* roosting in rear of cave	
FIELD NOTES		
Habitat category	Potential diurnal roost.	
Comments	Heritage team previously spotted 6-7 (suspected) Ghost bats vacate the cave when they approached (the cave) during a survey.	
DETECTOR DETAILS		
Type: Anabat Swift; TAU 1 Thermal camera	Serial no: Swift 660654	GHD no:
Dates operational: 24-2707/2024	Latitude: 21.28062	Longitude: 119.06638
HERITAGE CAVE PHOTOS		

Appendix C

Summary of Survey Effort for Ghost bat and Pilbara leaf-nosed bat roost sites identified within the Approved Proposal and Proposed amendment areas

Table 1 Summary of Survey Effort for Ghost Bat and Pilbara leaf-nosed bat roost sites identified within the Approved Proposal and Proposed amendment areas

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
Caves inside the Proposed Amendment Envelope														
Python Cave (Cave 1)	***Category 3 - Occasional, isolated diurnal roost***	***Category 3 - Transitory diurnal roost***	Inside	-21.2945	119.0556	Discovered February 2016. Presence of a small Ghost Bat scat pile containing historical and fresh scat during February 2016 (GHD 2017) and May 2018, in combination with scattered Ghost Bat scat in other parts of the cave provide evidence of ongoing occasional usage by a small number of Ghost Bats (GHD 2020). PLNB were occasionally observed roosting within the cave in small numbers in 2021 (May n = 3, July, n = 1, September n = 3). Long-term monitoring of bat call activity data between April 2021 and March 2023 reveals call activity was generally higher than Cave 13 but lower than Chateau Cave (GHD 2023). Average nightly activity was 144 calls per night, but occasionally there were more than 1,000 calls per night (GHD 2023). Patterns in activity were strongly associated with time of year with the highest activity occurring in the winter months (GHD 2023). The transitory diurnal roost categorisation is further supported by bat call activity data recorded pre-sunset (GHD 2022).	•	• (610 nights)	• (92 nights)		• PLNB	• PLNB	Feb 2016 May 2018 Jan-Feb 2019 Apr 2021–present	GHD 2017, 2020, 2021, 2022, 2023, 2024
Heritage Cave	***Category 4 - Nocturnal refuge***	***Category 4 - Nocturnal refuge***	Inside	-21.2806	119.0664	Six or seven large white bats (assumed to be Ghost Bats) flushed from cave during heritage survey 3 June 2024 (GHD 2025).	•	• (41 nights)	• (13 nights)				Aug – Oct 2024	GHD 2020, 2025
Cave 1a	***Potential Category 4 - Nocturnal refuge***	***Category 4 - Nocturnal refuge***	Inside	-21.2945	119.0559	Located 'upstream' of Python Cave within gully (GHD 2025).	•	• (3 nights)					Jul 2024	
Cave 2	***Potential Category 4 - Nocturnal refuge***	***Category 4 - Nocturnal refuge***	Inside	-21.2945	119.0554	Located 'downstream' from Python Cave within gully. Old and recent Ghost Bat scat noted (GHD 2020).	•	• (3 nights)	• (1 night)		• GB		Jul 2024	
Cave 3	*No confirmed roosting to date.*	***Category 4 - Nocturnal refuge***	Inside	-21.2950	119.0545	Located 'downstream' from Python Cave within gully. Occasional old, scattered Ghost Bat scat (GHD 2020).	•	• (3 nights)					Jul 2024	
Cave 11	***Category 4 - Nocturnal refuge***	***Category 4 - Nocturnal refuge***	Inside	-21.2753	119.0631	Old Ghost Bat scat at entrance (GHD 2020).	•	• (33 nights)			• GB		Jul – Sep 2024	
Cave 14	*No confirmed roosting to date.*	***Potential Category 4 - Nocturnal refuge***	Inside	-21.2705	119.0587	One old Ghost bat scat noted (GHD 2020).	•	• (3 nights)			• GB		Jul 2024	

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
Cave 15	*No confirmed roosting to date.*	*No confirmed roosting to date*	Inside	-21.2742	119.0561			• (4 nights)					Jul 2024	
Cave 16	*No confirmed roosting to date.*	***Potential Category 4 - Nocturnal refuge***	Inside	-21.2874	119.0560		•	• (4 nights)			• GB		Jul 2024	
Cave 21	*No confirmed roosting to date.*	***Potential Category 4 - Nocturnal refuge***	Inside	-21.2678	119.0548		•	• (3 nights)					Jul 2024	
Cave 32	***Category 4 - Nocturnal refuge***	***Category 4 - Nocturnal refuge***	Inside	-21.2826	119.0549	One Ghost Bat flushed from a large fault into a roof cave in overhang during 2018 survey (GHD 2020).	•	• (3 nights)					Jan 2019 Jul 2024	
Cave 33	***Potential Category 4 - Nocturnal refuge***	***Category 4 - Nocturnal refuge***	Inside	-21.2825	119.0549	Ghost Bat feeding evidence in overhang entrance (GHD 2020).	•	• (3 nights)					Jan 2019 Jul 2024	
Caves inside the Approved Proposal Envelope														
Mundagoora (South Star) Cave 1	*No confirmed roosting to date.*	***Category 4 - Nocturnal refuge***	250 m	-21.2780	119.0485	Feeding evidence of Ghost Bats including scat and Diamond Dove feathers at entrance (GHD 2020).	•	•					Jan – Feb 2022 May – Jun 2022	GHD 2020, 2025
Mundagoora (South Star) Cave 2	*No confirmed roosting to date.*	***Category 4 - Nocturnal refuge***	250 m	-21.2780	119.0485		•	•					Feb – Mar 2022	GHD 2020, 2025
Mundagoora (South Star) Cave 3	***Category 2 - diurnal roost with regular occupancy***	***Category 3 - Transitory diurnal roost***	250 m	-21.2780	119.0485	26 to 30 Ghost Bats observed in cave January 2019, suggesting maternal roost (GHD 2020). No observation of roosting Ghost Bats or ultrasonic calls since the 2019 survey (GHD 2025).	•	•	•	•			Jan 2019 Jan 2022	GHD 2020, 2025
Cave 13	***Category 3 - Occasional, isolated diurnal roost***	***Category 3 - Transitory diurnal roost***	900 m	-21.2584	119.0560	First record of Pilbara leaf-nosed bat in 2012. PLNB rarely roost in this cave, therefore it is assumed that activity is primarily a result of visitation from Chateau Cave bats, and that the cave is most likely to function as a 'nocturnal refuge' and at times a 'temporary' or 'transitory diurnal roost' for PLNB (Specialised Zoological 2018; GHD 2023). A single Ghost Bat has been observed roosting within Cave 13 on three occasions, including June 2017 and November 2019 (GHD 2017, 2021). Ghost Bats were also observed exiting the cave during emergence surveys (Bat Call WA 2013). Information suggests that	•	•	•	•	• PLNB		2012-present	Ecologia 2012 Bat Call WA 2013, 2014 GHD 2015, 2016a, 2016b, 2017, 2021, 2022, 2023, 2024

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
						the cave is occupied occasionally by a small number of Ghost Bat.								
Chateau Cave	***Category 3 - Occasional, isolated diurnal roost***	***Category 1 – Permanent diurnal roost***	1.15 km	[redacted]		Discovered March 2015. PLNB are consistently present within the main chamber throughout the year, though colony size is known to fluctuate daily due to seasonal and other unknown factors (GHD 2023). PLNB pups were observed in the main chamber during Feb 2022, confirming that the cave can be used as a maternity roost by the species (GHD 2023). Ghost Bat was observed in main chamber August 2021 (GHD 2023).	•	•	•	•	• PLNB	•	2015-present	GHD 2016a, 2016b, 2022, 2023, 2024
Caves <u>outside</u> the Approved Proposal and Proposed Amendment Envelopes														
Wallaby Cave	***Category 3 - Occasional, isolated diurnal roost***	***Category 4 - Nocturnal refuge***	4.8 km NW	-21.2346	119.0232	Four Ghost Bat observed roosting in March 2015 (GHD 2015). One Ghost Bat observed roosting in August 2022 (GHD 2023). Information collected to date suggests this cave is occasionally occupied by a few Ghost Bats.	•	•					Mar 2015 Oct 2020 Apr 2021-2023	GHD 2015, 2023
Wayne Manor	***Category 3 - Occasional, isolated diurnal roost***.	***Category 3 - Transitory diurnal roost***	5.6 km N	-21.2157	119.0774	Large, complex cave structure. One Ghost Bat observed roosting during May 2021 (GHD 2023). PLNB activity at Wayne Manor is relatively low, with an average nightly call activity of 28 calls/night (GHD 2023). Evidence to date suggests this cave is possibly occupied on occasion during parts of the year by PLNB.	•	•	•				Feb 2015 2021-present	Bat Call WA 2015 GHD 2023
Twin Peaks Cave	***Category 4 - Nocturnal refuge*** *No confirmed roosting to date.*	*No confirmed roosting to date.*	5.9 km NW	-21.2478	118.9888	Ghost bat feeding midden and scat pile containing both old and fresh material.	•	•					Jan-Feb 2015	GHD 2015
Joe's Cave	*No confirmed roosting to date.*	***Category 3 - Transitory diurnal roost***	6.4 km W	-21.2523	118.9772	During roost occupancy surveys in 2016, two Ghost Bats were recorded flying around the entrance of the cave following civil twilight, with at least one intrusion attempt into the cave during the survey period (GHD 2016). Evidence to date suggests this cave is possibly occupied on occasion during parts of the year by PLNB (GHD 2023).	•	•		•			Feb 2016 Sep 2016 Aug-Oct 2018 2021-present	GHD 2016b, 2017, 2023

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
Rha30	***Category 3 - Occasional, isolated diurnal roost.***	*No confirmed roosting to date.*	6.7 km N	-21.2333	119.0029	Two Ghost Bats observed roosting within the cave. One flushed from cave during assessment (GHD 2023).	•						Jan 2022	GHD 2023
PC-NW-039	***Category 3 - Occasional, isolated diurnal roost.***	*No confirmed roosting to date.*	6.9 km NW	-21.2346	119.0031	One Ghost Bat observed roosting (GHD 2023).	•						Jan 2022	GHD 2023
RS4	***Category 4 - Nocturnal refuge*** *No confirmed roosting to date.*	*No confirmed roosting to date.*	7.5 km NW	-21.2364	118.9785	Deep, complex cave with multiple entrances. Ghost Bat scat and feeding remains (Diamond Dove) discovered during June 2017 (GHD 2017).	•						Jun 2017	GHD 2017
Bone Cave	***Category 3 - Occasional, isolated diurnal roost***	*No confirmed roosting to date.*	7.7 km NW	-21.2494	118.9681	Complex, multi-chamber caved within banded ironstone. A single Ghost Bat was observed roosting in March 2015, and three were observed roosting within the first chamber in November 2016 (GHD 2017). Scattered fresh and historical scat were also recorded during each visit, but no obvious large scat piles (GHD 2017, 2020).	•	•					Mar 2015 Nov 2016 Oct 2020	GHD 2017
UC3	***Category 3 - Occasional, isolated diurnal roost***	*No confirmed roosting to date.*	9.2 km W	-21.2453	118.9535	Multiple entrances on a steep cliff face, inaccessible. Ghost Bat observed flying from cave entrance in November 2016 (GHD 2017).	•						Nov 2016	GHD 2017
UC1	***Category 4 - Nocturnal refuge*** *No confirmed roosting to date.*	*No confirmed roosting to date.*	12 km W	-21.2303	118.9305	Old and fresh Ghost Bat scat located on rear chamber floor (GHD 2017).	•	•					Nov 2016	GHD 2017
Rha1	***Category 2 - diurnal roost with regular occupancy***	*No confirmed roosting to date.*	12.3 km S	-21.4098	119.0983	Ten fresh Ghost Bat scats recorded, foraging evidence (feathers) and cave size and structure suitable for diurnal roosting (GHD 2021). Calls recorded for four consecutive nights. Call activity patterns suggest mostly nocturnal usage although calls near emergence (n=9) and during dawn were recorded suggesting regular diurnal roosting (GHD 2021).	•	•					Oct 2020 Feb 2022	GHD 2021, 2023
Abydos Complex	*No confirmed roosting to date.*	***Category 3 - Transitory diurnal roost***	15 km NE	-21.1570	119.0871	A complex of natural caves located approximately 15 km north-east of the Amendment Envelope of which four caves (A, B, D and H) are suspected to be used as by PLNB. The information reviewed to date, including data from GHD (2022), suggests that one or more of the caves is possibly occupied for	•	•			• PLNB		May 2021-Apr 2022	Atlas Iron 2014 GHD 2022, 2023

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
						parts of the year by the PLNB. A visit to the site during May 2021 by a GHD ecologist revealed PLNB occupying at least one (Cave B) of the known roost sites (GHD 2022). The categorisation of 'transitory diurnal roost' is maintained with consideration of all the information reviewed.								
Dalton Creek roost (Rha12)	*No confirmed roosting to date.*	***Category 1 – Permanent diurnal roost***	24 km SE	-21.4637	119.2301	Regionally important PLNB roost. Largest known colony within the Chichester subregion, with a mean colony size over 600 individuals (GHD 2023, 2024). Ghost Bats have been observed flying around outside the roost at night during surveys, though the narrow entrance of the cave is not suspected to allow roosting (GHD 2023).	•	•	•	•	• PLNB	• PLNB	2022-present	GHD 2023, 2024
Pothole Cave (Rha31)	*No confirmed roosting to date.*	***Category 3 - Transitory diurnal roost***	24.2 km SE	-21.4639	119.2308	Five PLNB observed roosting in small sub-chamber (GHD 2023).	•	•					Feb 2022	GHD 2023
Rha10	***Category 2 - diurnal roost with regular occupancy***	***Category 3 - Transitory diurnal roost***	24.5 km SE	-21.4651	119.2331	One Ghost Bat flushed from cave during October 2020 survey (GHD 2021). Large amounts of scat recorded, cave size and structure suitable to suggest the roost has regular occupancy. The transitory diurnal roost categorisation for PLNB is supported by bat call activity data recorded pre-sunset and post-sunrise as well as a positive eDNA sample collected from the cave (GHD 2023).	•	•			• PLNB		Oct 2020 Feb 2022	GHD 2021, 2023
Condo Cave (Rha45)	***Category 3 - Occasional, isolated diurnal roost.***	***Category 3 - Transitory diurnal roost***	25 km E	-21.2637	119.2975	Ghost Bat observed in the roost at the time of survey (GHD 2023). Four positive PLNB eDNA samples were returned from the cave, however bat activity data suggests regular visitation during the night, rather than diurnal roosting (GHD 2023).	•	•			• PLNB		Jun-Oct 2022	GHD 2023
Rha9	***Category 2 - diurnal roost with regular occupancy***	*No confirmed roosting to date.*	25.2 km SE	-21.4719	119.2362	Three Ghost Bats flushed from cave during Oct 2020 survey (GHD 2021). Fresh and historical scat recorded, cave size and structure suitable	•	•					Oct 2020	GHD 2021
Rha5a	***Category 3 - Occasional, isolated diurnal roost***	*No confirmed roosting to date.*	25.8 km SE	-21.5174	119.1671	One roosting Ghost Bat flushed from cave during survey (GHD 2021).	•	•					Feb 2022	GHD 2021, 2023

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
Rha2	***Category 3 - Occasional, isolated diurnal roost*** *No confirmed roosting to date.*	***Category 4 - Nocturnal refuge*** *No confirmed roosting to date.*	29.4 km S	-21.5640	119.1100	Ghost Bat scats recorded (GHD 2021). Cave size and structure suitable for roosting.	•						Oct 2020	GHD 2021
Rha17	***Category 3 - Occasional, isolated diurnal roost.*** *No confirmed roosting to date.*	*No confirmed roosting to date.*	30.6 km S	-21.2227	118.8882	Few Ghost Bat scat (GHD 2021). Cave size and structure suitable for roosting.	•						Oct 2020	GHD 2023
Lalla Rookh	***Category 1 – Maternity roost***	***Category 1 – Permanent diurnal roost***	32 km NE	-21.0509	119.2766	Lalla Rookh is a historic, abandoned mine adit located 32 km to the northeast of the Amendment Envelope and contains a significant, permanent Ghost Bat colony (200+ individuals) (Stantec 2017; Biologic 2019, 2021). PLNB are also known to occupy Lalla Rookh as a permanent diurnal roost with over 4,500 calls per night over seven survey seasons between 2014-2021 (Biologic 2021).	N/A – abandoned mine adit	•	•	•	• PLNB	•	2017-present	Stantec 2017 Biologic 2019, 2021a GHD 2023, 2024
East Turner River Roost (Birthday Gift)	*No confirmed roosting to date.*	***Category 3 - Transitory diurnal roost***	32.5 km N	-20.9891	118.9339	The East Turner River roost is situated within the historic, abandoned 'Birthday Gift' mine workings, located north of Pilbara Mineral's Pilgangoora operations. An estimate of the number of PLNB at the roost based on ultrasonic calls and video counts ranged between 25 – 50. The roost has been inferred as 'maternal' due to survey timing coinciding with breeding period (BatCall WA 2021).	•	•				•	Jul 2024-present	BatCall WA 2021
Mt Webber Roost (MW-AN-27)	***Category 3 - Occasional, isolated diurnal roost.***	***Category 1 – Permanent diurnal roost***	34.5 km SE	-21.5191	119.3135	The roost has been identified as a significant diurnal roost in the area and is located approximately 600 m northeast of the Mt Webber mine operations. PLNB calls were detected on all recording nights (100% of 160 nights) (Biologic 2024). The calls regularly occurred before civil dusk and after civil dawn, confirming its status as a diurnal roost, however it is noted that PLNB activity at the roost fluctuates and shows substantial seasonal variation. Ghost bats have indicating roosting at the Mt Webber roost and also at an nearby cave (MW-AN-25).	•	•			•			Biologic 2021b, 2024

Site ID	Inferred Roost Status		Distance from Amendment Envelope	Latitude	Longitude	History / Observations	Habitat Assessment	Monitoring Method					Survey Timing	Survey Report
	Ghost Bat	Pilbara leaf-nosed bat						Ultrasonic recorder	IR or Thermal Camera	Entrance Sheeting	Scat or eDNA Analysis	PIT tag reader		
C2	***Category 3 - Occasional, isolated diurnal roost.***	***Category 3 - Transitory diurnal roost***	41 km W	-21.1853	118.6544	Two Ghost Bats observed emerging from cave during census in Sep 2010. Three PLNB observed roosting within the cave during 2016 survey.	•	•					2010 - present	Biologic 2018
Wodgina Cave	***Category 3 - Occasional, isolated diurnal roost.***	*No confirmed roosting to date.*	42 km W	-21.1194	118.6609	Two Ghost Bats roosting from ceiling. Ghost Bat scats and Zebra finch feathers noted on cave floor.	•	•	•				Mar 2023	GHD 2024
Mt Ada Adit (CO-CA-35)	***Category 2 - diurnal roost with regular occupancy***	***Category 4 - Nocturnal refuge***	58 km E	-21.4326	119.6135	Mt Ada is a historic, abandoned mine adit located 58 km east of the Amendment Envelope. A high level of Ghost Bat activity has been be measured at the site and presence is continuous across all months (Biologic 2023b). Timing of PLNB calls recorded at the site indicate that the species use the adit as a nocturnal refuge (Biologic 2023a).	•	•					2014 2016 2017-present	Biologic 2023a, 2023b
Wamerina (Yule River) Roost	*No confirmed roosting to date.*	***Category 1 – Permanent diurnal roost***	63 km W	-21.0576	118.4775	Located in July 2024, information is still being collected. Over one sampling night 4,762 calls were recorded (Stantec 2024).	•	•				•	Jul 2024 - present	Stantec 2024
Corunna Downs Complex	***Category 2 - Occasional, isolated diurnal roost.***	***Category 1 – Permanent diurnal roost***	67 km E	-21.4200	119.6738	A complex of natural caves located approximately 67 km east of the Amendment Envelope of which ten caves have been identified as Category 2 or 3 Ghost Bat roosts. Five caves (CO-CA-01, -05, -22, -24 and -33) demonstrated diurnal roosting by Ghost Bats from ultrasonic calls during August 2022, which one Ghost Bat has been recorded at CO-CA-30 and two individuals recorded at CO-CA-33 during the same survey (Biologic 2023b). Three caves (CO-CA-01, CO-CA-03 and CO-CA-05) have been assigned as Category 1, 2 and 3 roosts, respectively (Biologic 2023a). Approximately 200+ PLNB observed roosting in the rear chamber of CO-CA-01 and were detected on 100% of recording nights at the roost (349 nights), with an average activity of 1,567 calls per night (Biologic 2023a). PLNB have also been detected on 99.7% of nights at CO-CA-03 but the average number of calls was much lower at 472 calls per night, and diurnal roost was indicated intermittently (Biologic 2023a).	•	•	•		• PLNB and GB		2014 2016 2017-present	Biologic 2023a, 2023b GHD 2023

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