Biologic Environmental Survey Pty Ltd
PO Box 179
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21 December 2022

Attn: Kerryn McDonald

Principal Biodiversity Assessment

WAIO Environment

Dear Kerryn,

Please find below a memorandum summarising the significance of ghost bat (*Macroderma gigas*), habitat (caves and broad fauna habitats) previously recorded within the Study Area for the Western Ridge project.

Yours sincerely,

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Reviewed by:

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31st August 2022

1   Introduction

In progressing environmental approvals for the Western Ridge project (Western Ridge), BHP Western Australian Iron Ore (BHP WAIO) have identified the need to incorporate additional information published on ghost bats since the baseline fauna assessments were completed (Biologic, 2011, 2016, 2020b, 2021; ecologia, 2006). The key publication that has refined the understanding of the ghost bat and its supporting habitats (i.e. cave classifications) is '*A review of ghost bat ecology, threats and survey requirements*' (Bat Call, 2021). Additionally, BHP WAIO wish to incorporate data collected from the *Western Ridge and Jimblebar 2021-2022 Ghost Bat Monitoring Program* (Biologic, *in prep.*). To incorporate additional information, BHP WAIO commissioned Biologic Environmental Survey (Biologic) to undertake a review of caves and habitats recorded across the Western Ridge project area and assign significance categorisation in line with Bat Call (2021). The Study Area used for this assessment is consistent with that used by Biologic (2020b) and Biologic (2021), which comprises a 33,970 hectare (ha) area directly south and south-west of BHP WAIO's Whaleback mining operation (Figure 2.1). The specific objectives of this review were to:

- apply the new roost categories, as defined in Bat Call (2021), to the 19 caves previously recorded within the Study Area;

- review habitats mapped within the Study Area and classify as critical or supporting habitat, as informed by Bat Call (2021) and the conservation advice for the ghost bat (TSSC, 2016).

2   Methods

2.1   Cave Categorisation

Caves can be important features within a landscape, particularly in arid zone systems, often providing stable microclimates, shelter and protection (Medellin *et al.*, 2017). Ghost bats are known to move between a number of caves seasonally or as dictated by weather conditions and/or foraging opportunities, so they require a range of cave sites (Armstrong & Anstee, 2000). They disperse widely when not breeding, but may concentrate in a relatively few roost sites when breeding (Bat Call, 2021). Bat Call (2021) assigned four categories of roosting habitat used by ghost bats in the Pilbara region. These categories were used to define caves recorded within the Study Area based on all available visitation and sampling data (Biologic, 2011, 2016, 2020b, 2021, *in prep.;* ecologia, 2006). In summary, the four roost categories are:
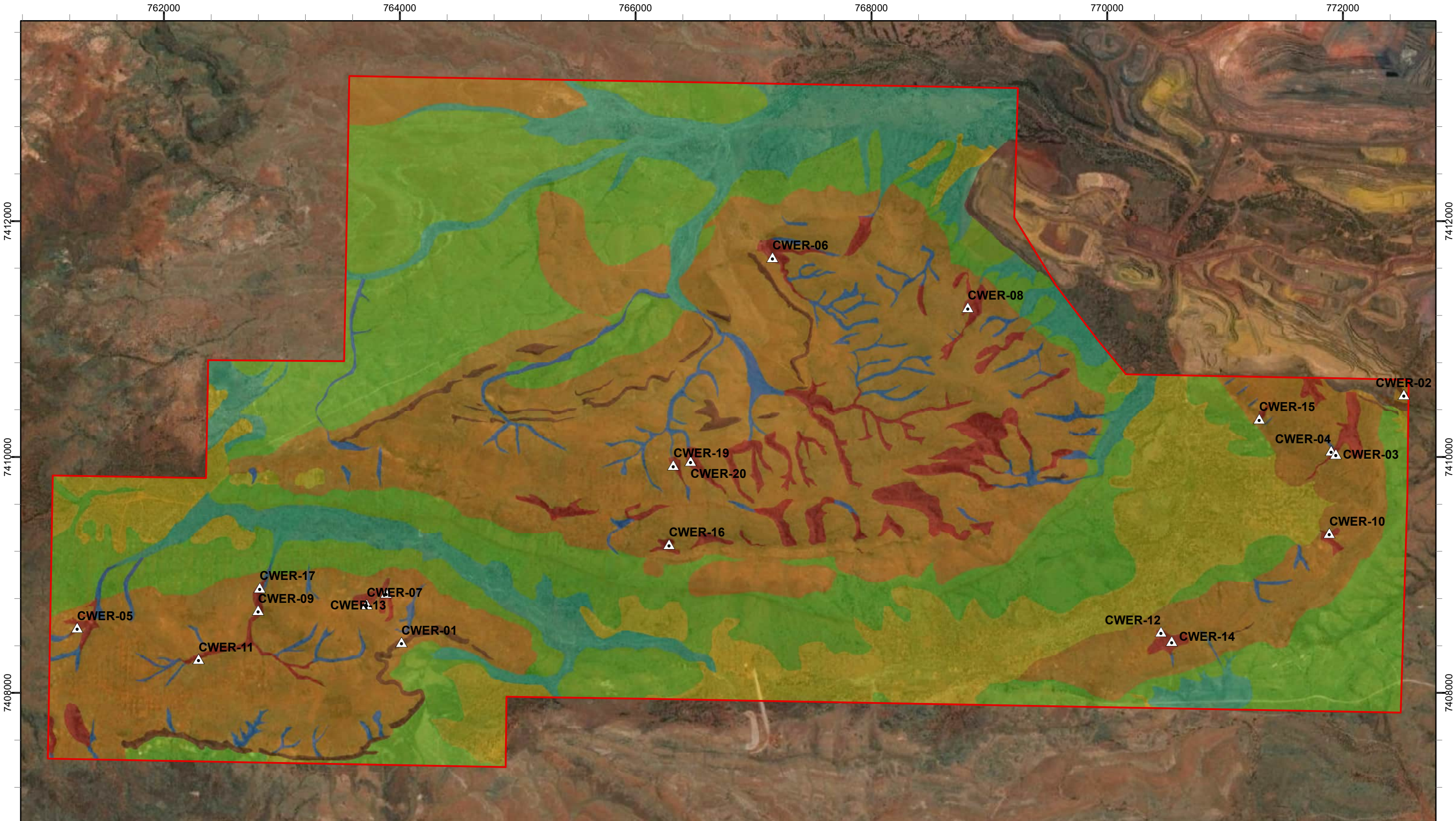
- **Category 1 maternity/ diurnal roost sites with permanent ghost bat occupancy**: maternity/ diurnal roost caves with permanent ghost bat occupancy. Very few such roosts exist in the Pilbara region and those that do, are located in abandoned mine adits, not natural caves. Furthermore, there are no currently documented natural Category 1 caves in the Hamersley Ranges, within which the Study Area is located. Usually, these caves are deep and dark, with one or more elevated roosting chambers that provide a stable microhabitat. Caves with proven permanent presence must all be assumed to be maternity caves, a source population for the surrounding district. They are therefore critical habitat for the ongoing presence of ghost bats in the area.

- **Category 2 maternity/ diurnal roost caves with regular occupancy**: maternity/ diurnal roost caves with regular, but not continuous, presence over long periods. These caves have similar features as Category 1 caves but are often less complex with only a single inner chamber and are often in less productive areas that the bats only utilise periodically. Based on recent monitoring of a number of Hamersley Range caves, ghost bats are present for 25 to 75% of nights over periods of up to several months, but then may be abandoned for weeks or even months. Females in various stages of the reproductive cycle are often recorded in such caves and therefore they are considered critical habitat. These caves on occasion have several other caves, shelter and overhangs within a few hundred metres. Collectively, they provide an 'apartment block' grouping that supports the ongoing presence of the bats.

- **Category 3 diurnal roost caves with occasional occupancy**: there are many caves and adits where one to a few ghost bats roost occasionally, or rarely. These caves are normally less well-developed structures, such places are often used as feeding sites (as evidenced by middens with food scraps) or temporary refuges. When adjacent to Category 2 caves, these are considered to be a part of an 'apartment block' and are therefore critical habitat important for the ongoing presence of the species in the area. 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 4 nocturnal roost caves with opportunistic usage**: numerous observations suggest that the majority of shallow caves, shelters and deep overhangs in the Pilbara are used in at least an opportunistic manner 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. These visits may or may not be repeated, depending on whether the bat is passing through a district or is a more permanent resident nearby. These are not considered critical habitat.

A fifth category of cave has been proposed by BHP:

- **Category 5** – caves are considered unsuitable for usage by ghost bats due to a restricted entrance or the dimensions of the cave. No evidence of ghost bat usage has ever been recorded. These caves are not considered critical habitat for the ghost bat.

With regards to the key characteristics of the diurnal roost caves, Category 1 and Category 2 caves are often deep, dark and have at least one roosting chamber deep within, behind a reasonably narrow entrance or in-cave constriction (Bat Call, 2021). The roosting chamber is normally elevated above the entrance to trap warm moist air. The ceiling heights are over 1.5 m (and generally higher than 2 m) while the depth of the cave may range from shallow (20 m depth) to deep (250 m to over 500 m). Category 3 diurnal caves are usually less well-developed as underground structures and may be shallower allowing some light into their deeper areas. Category 3 caves may also have a wide and not constricted entrance or not have a stable microclimate in an elevated roosting chamber. However, these caves do support a roosting chamber with a ceiling over 1.5 m high and generally (but not always) have significant scats and food middens.
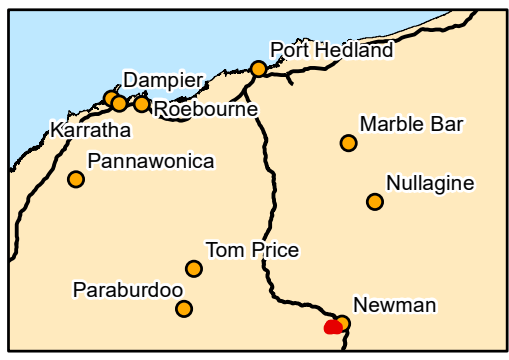
CWER-06

CWER-08

CWER-02

CWER-15

CWER-04

CWER-03

CWER-19

CWER-20

CWER-16

CWER-10

CWER-17

CWER-09

CWER-07

CWER-13

CWER-05

CWER-01

CWER-11

CWER-12

CWER-14

Legend

Study Area

Caves

Vertebrate Fauna Habitat (Biologic 2020b)

Breakaway/ Cliff

Drainage Area/ Floodplain

Gorge/ Gully

Hillcrest/ Hillslope

Minor Drainage Line

Mulga Woodland

Stony Plain

Cleared/ Disturbed

N

biologic
Environmental Survey

Scale: 1:30,000

0   0.5   1   1.5
Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994   Created 26/09/2022

Port Hedland
Dampier
Roebourne
Karratha
Pannawonica
Marble Bar
Nullagine
Tom Price
Paraburdoo
Newman

BHP WAIO

Western Ridge Ghost Bat Cave and Habitat Classification

Figure 2.1: Study Area and cave locations

2.2   Habitat Categorisation

As outlined in Section 2.1, three of the roost categories are considered to potentially provide critical roosting habitat:

- Category 1 - Maternity/ diurnal roost caves with permanent ghost bat occupancy;
- Category 2 - Maternity/ diurnal roost caves with regular (but not continuous) ghost bat occupancy that is capable of supporting one or more reproducing females and their habitat; and
- Category 3 - Diurnal roost caves with occasional occupancy if adjacent to one or more Category 2 cave(s).

Category 3 roosts that are not adjacent to a Category 2 roost, and Category 4 roosts, are considered to provide supporting roosting habitat.

The distinction of critical foraging habitats for ghost bats in the Pilbara is poorly understood, due to a lack of detailed published tracking and habitat utilisation data. However, recent studies on the foraging distance of ghost bats and foraging habitat preferences have assisted in identifying foraging areas of critical importance to the species. Recent studies using VHF tracking (e.g. Augusteyn *et al.*, 2018; Biologic, 2019) and GPS/satellite tracking technologies (Augusteyn *et al.*, 2018; Bullen, 2021) show that ghost bats forage over much larger areas up to 12 km from their diurnal roost. Bats transiting to distant sites have also been recorded between 20 and 30 km from their diurnal roost in a night (Augusteyn *et al.*, 2018; Bullen, 2021).

Unpublished satellite tracking data suggest ghost bats preferentially forage in areas of sparse, mature woodland over patchy and/ or clumped *Triodia* hummock grasslands on sand or stony plain (Bat Call, 2021). Ghost bats are believed to use vantage points presented by tall, isolated trees on the edge of the plains and grasslands, as well as along the edge of watercourse woodlands to search for prey (Bat Call, 2021). Ghost bats have a 'sit and inspect' foraging strategy; whereby they hang on a perch and visually inspect their surroundings for movement. Once their prey is detected it may be captured in the air, gleaned (taken from the surface of a substrate by a flying bat) from the ground or vegetation, or dropped on from a perch (Boles, 1999).

Based on the distance ghost bats have been shown to forage from a roost and the identification of preferred foraging habitats, critical foraging habitats are considered to comprise the following habitat within a 12 kilometre (km) radius of critical roosts (i.e. a Category 1 or 2 roosts, or Category 3 roosts adjacent to a Category 2 roost):

- productive plain areas with thin mature woodland over patchy or clumped tussock or hummock grass (*Triodia* spp.) on sand or stony ground;
- isolated trees and trees on the edge of thin thickets on the plains;
- trees along the edges of watercourse woodlands; and/or
- gully or gorge system that opens onto a plain or riparian line.

Supporting habitats are considered to comprise those foraging habitats listed above, though occurring >12 km from a critical roosting site.

3 Results

3.1 Cave Categorisation

A total of 19 caves have previously been recorded within the Study Area by Biologic (2020b) (Figure 2.1). Of these, 17 occur within Gorge/ Gully habitat and two within Breakaway/ Cliff habitat. Of the 19 caves known to occur within the Study Area; two are classified as Category 2 roosts, three as Category 3 roosts, 13 as Category 4 roosts and one that is classified as unsuitable for ghost bat usage (i.e. Category 5) (Table 3.1).

The two caves (CWER-01 and CWER-03) classified as Category 2 roosts represent deep complex caves with steady microclimates (Table 3.1). Importantly, both caves have been confirmed as a diurnal roost, by records of multiple roosting bats on multiple occasions (Biologic, 2021) and have shown evidence of use by pregnant females (Biologic, 2021). The three caves (CWER-10, CWER-16 and CWER-17) assessed as Category 3 roosts have not recorded ghost bats roosting; however, all three possess suitable characteristics to support occasional roosting (Table 3.1). Consistent with the definition by Bat Call (2021), these caves are *"less well developed as underground structures. They may be shallower allowing some light into their deeper areas, have a wide and not constricted entrance or not have a stable microclimate in an elevated roosting chamber. They will, though, have a roosting chamber with a ceiling over 1.5 m high".* Of the 13 Category 4 roosts, ghost bat evidence has previously only been recorded in three caves (CWER-02, CWER-06 and CWER-14), confirming they are used by the species. The remaining ten caves, despite not containing evidence of usage by the species, have characteristics of a Category 4 roost and are located within the nightly foraging range of the two Category 2 roosts. The remaining cave, CWER-19, has been re-classified as Category 5 (i.e. unsuitable for ghost bats). This cave, despite being recorded by Biologic (2020b) as a potential night roost, has since been revised to unsuitable based on further inspection - specifically, the dimensions of this cave are not permissible for ghost bat usage (Table 3.1).

Table 3.1: Cave classification for the Western Ridge Study Area

Cave ID	Location	Brief Description	Most Relevant Activity	Previous Categorisation (Biologic, 2020b)	New Categorisation
CWER-01	-23.4126, 119.5835	A large overhang leading to two discreet chambers, the deepest extending ~35 m back with a moderate incline leading to a completely dark domed chamber and a substantial ghost bat scat pile (>2,000 scats). The second chamber is ~10 m deep, with a domed roof, though some light visible.	Cave is a deep, dark cave that holds a stable microclimate. Cave has been monitored consistently since 2016 with multiple records of individuals and high scat counts on sheet (>1,000 over 4 months). Additionally, scats with elevated progesterone (which indicate the presence of breeding females) have been recorded here since 2016. Monitoring since March 2020 has failed to record evidence of the species, indicating a recent decline in the local population and/or reduction in activity in the Study Area. Structurally, and based on historical evidence, this cave is equally (with CWER-03) the most significant ghost bat cave currently known in the Newman area.	Maternity Roost	Category 2
CWER-02	-23.3979, 119.6662	A shallow (~7 m) cave opening to a single chamber ~3 in height. Simple layout with visible light from entrance.	Two recent (1–6 months) ghost bat scats recorded during visit in December 2019. No visitations since, possibly due to nearby mining activity. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow. Specifically, daylight extends well into the cave.	Night Roost	Category 4
CWER-03	-23.3969, 119.6607	A very deep (~40 m) complex cave with multiple (x4) chambers and two entrances. Two main scat piles, the largest (>2,000 scats) located at very rear in a discreet chamber, completely dark, ~3 m in height with a slight constriction.	Cave is deep, dark and holds a stable microclimate. Substantial amount of ghost bat scats indicating long-term, ongoing occupation. One ghost bat individual observed during visit in May 2016 and December 2019 (Biologic, 2020b). Activity levels in recent years suggests usage by only a small number of individuals (1–7) (Biologic, 2021), which is likely attributed to a general decline in species abundance in broader area and/or reduction in activity in the Study Area. Structurally, and based on historical evidence, this cave is equally the (with CWER-01) most significant ghost bat cave in the Newman area.	Potential Maternity Roost	Category 2
CWER-04	-23.3967, 119.6603	A shallow (~11 m), short low (~1.5 m) and structurally simple cave.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Ghost bat individuals flushed from CWER-03 have been seen retreating into this cave (March 2020). Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow.	Potential Night Roost	Category 4

Cave ID	Location	Brief Description	Most Relevant Activity	Previous Categorisation (Biologic, 2020b)	New Categorisation
CWER-05	-23.4120, 119.5567	A shallow (~15 m), short (~1 m) and fairly simple cave.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow.	Potential Night Roost	Category 4
CWER-06	-23.3827, 119.6137	A shallow (~5 m), short (~1 m) and fairly simple cave.	Eight ghost bat scats recorded in cave upon initial assessment in March 2020. No scats recorded since this time and November 2020, over 4 visits. Cave has not been visited since November 2020 due to safety restrictions. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow. Specifically, daylight extends well into the cave.	Night Roost	Category 4
CWER-07	-23.4098, 119.5806	A shallow cave (~10 m) very exposed to the light. A high ceiling (~4).	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Cave is structurally simple, shallow and is therefore unlikely to support diurnal roosting.	Potential Night Roost	Category 4
CWER-08	-23.3862, 119.6300	A shallow cave (<10 m), short (<2 m) and fairly simple cave.	No ghost bat scats recorded within cave during initial assessment in March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow.	Potential Night Roost	Category 4
CWER-09	-23.4104, 119.5716	A shallow cave (~15 m) simple cave, very exposed to the light.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow with daylight extending well into the cave.	Potential Night Roost	Category 4
CWER-10	-23.4030, 119.6603	A shallow cave (~10 m) leading to a dark chamber due to position of entrance.	Ten old (6–36 months) ghost bat scats recorded in cave in March 2020. No scats recorded in cave since this time despite regular monitoring. The cave structure makes it suitable to support diurnal roosting as, while a less well-developed structure than that characteristic of a Category 2 cave, it provides a suitable roosting chamber(s) to support occasional roosting.	Potential Day Roost	Category 3
CWER-11	-23.4142, 119.5667	A shallow cave (depth unknown) with a restricted entrance.	Cave not entered and unlikely to extend back extensively. Conservatively categorised as a feeding roost only and is unlikely to support diurnal roosting given its shallow depth.	Potential Night Roost	Category 4

Cave ID	Location	Brief Description	Most Relevant Activity	Previous Categorisation (Biologic, 2020b)	New Categorisation
CWER-12	-23.4108, 119.6465	A shallow cave (<15 m), short (<1.5 m) and fairly simple cave.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow with daylight extending well into the cave due to its wide entrance.	Potential Night Roost	Category 4
CWER-13	-23.4089, 119.5822	A shallow cave (~13 m) simple cave, very exposed to the light.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow with daylight extending well into the cave due to its wide entrance.	Potential Night Roost	Category 4
CWER-14	-23.4115, 119.6474	A shallow overhang (~10 m) with a small dome at rear, very exposed to the light.	Ten old (6–36 months) ghost bat scats recorded in cave in March 2020. No scats recorded in cave since this time despite regular monitoring. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow with daylight extending well into the cave due to its wide entrance.	Night Roost	Category 4
CWER-15*	-23.3944, 119.6543	A shallow overhang (~4 m), very exposed to the light.	No ghost bat scats recorded within cave during initial assessment in March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow with daylight extending well into the cave due to its wide entrance.	Potential Night Roost	Category 4
CWER-16	-23.4048, 119.6056	A complex cave with a single dark chamber accessed through a 1x1 m constricted entrance. Cave not deep (~12 m) but with high ceiling (15 m).	Approximately recent (1–6 months old) ghost bat scats recorded in cave in March 2020. Cave not accessed since August 2020 due to safety concerns. The cave structure makes it suitable to support diurnal roosting, however, the amount of scat material present in 2020 (~50 scats) is not enough to warrant classification as a Category 2 roost.	Potential Day Roost	Category 3
CWER-17	-23.4087, 119.5717	A moderately deep (~20 m) complex cave with multiple (x4) chambers. No scats recorded in cave; however, supports a large number of other cave dwelling bat species and holds a high and stable microclimate with no light.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Monitoring indicates ghost bats are not using the cave regularly over long periods, hence occupancy does not meet that of a Category 2 roost. The cave structure makes it suitable to support diurnal roosting as it provides suitable roosting chambers to support occasional roosting and a stable microclimate.	Potential Day Roost	Category 3

Cave ID	Location	Brief Description	Most Relevant Activity	Previous Categorisation (Biologic, 2020b)	New Categorisation
CWER-19	-23.3987, 119.6058	A small cavity with a very restricted entrance (0.6–0.6 m). Entrance too small for ghost bat usage.	No ghost bat scats recorded within cave during initial assessment in March 2020. Cave is considered unsuitable for usage by ghost bats due to its restricted entrance.	Potential Night Roost	Category 5
CWER-20	-23.3984, 119.6072	A shallow (~9 m) simple cave, very exposed to the light.	No ghost bat scats recorded within cave, including during regular monitoring since March 2020. Cave structure is unlikely to support diurnal roosting as it is structurally simple and shallow with daylight extending well into the cave due to its wide entrance.	Potential Night Roost	Category 4

*CWER-15 is proposed to be removed in Quarter 4 2022, under existing approvals

3.2   Habitat Categorisation

Of the 19 caves recorded by Biologic (2020b) from within the Study Area, two (CWER-01, CWER-03) are regarded as critical habitat, as they represent Category 2 caves. Three caves (CWER-10, CWER-16 and CWER-17), represent Category 3 caves. These Category 3 caves are not considered critical roosting habitat as they are not adjacent to the Category 2 caves within the Study Area. However, they may be of importance to the species in the local area as there is a general lack of such diurnal roosting caves within Study Area and surrounds (Biologic, 2021).

As discussed in Section 2.2, unpublished satellite tracking data suggest ghost bats preferentially forage in areas of sparse, mature woodland over patchy and/or clumped *Triodia* hummock grasslands (Bat Call, 2021). Ghost bats are believed to use vantage points presented by tall, isolated trees on the edge of these woodlands and grasslands, as well as along watercourses to search for prey (Bat Call, 2021). Recent satellite tracking information from within the Study Area (information on a male captured and tracked from CWER-03 in September 2022, Biologic, *in prep.*), recorded nine foraging locations within ($n = 2$) and surrounding ($n = 7$) the Study Area. The data, while preliminary in nature, suggested foraging within the following habitats: Drainage Area/ Floodplain (two locations in the Study Area, 3 locations outside the Study Area), Mulga Woodland ($n = 2$), Stony Plain ($n = 1$) and Minor Drainage Line ($n = 1$).

A total of seven broad fauna habitat types were mapped across the Study Area by Biologic (2020a), comprising, in order of extent of occurrence, Hillcrest/ Hillslope, Stony Plain, Mulga Woodland, Drainage Area/ Floodplain, Gorge/ Gully, Minor Drainage Line and Breakaway/ Cliff. Of these seven broad habitats, four (Stony Plain, Drainage Area/ Floodplain, Mulga Woodland, and Minor Drainage Line) are considered critical foraging habitat for ghost bats in the context of the Study Area. As suggested by Bat Call (2021) these habitats represent "productive plain areas with thin mature woodland over patchy or clumped tussock or hummock grass (*Triodia* spp.) on sand or stony ground" and/or contain "isolated trees and trees on the edge of thin thickets on the plains" and "trees along the edges of watercourse woodlands". Additionally, due to the size of the Study Area and the location of CWER-01 and CWER-03, all of these habitats are located within 12 km of a Category 2 roost. The three remaining habitat types, Hillcrest/ Hillslope, Breakaway/ Cliff and Gorge/ Gully are not considered to provide critical habitat, beyond any specific caves that they may contain (Figure 2.1, Table 3.2).

Bat Call (2021) recognises "gully or gorge system that opens onto a plain or riparian line" can represent foraging habitat, instances of this within the Study Area have been mapped to a finer scale and separated out as two discreet habitat types 'Gorge/ Gully' and 'Minor Drainage Line'. Thus, any critical foraging areas of gully and gorge systems are already covered under the Minor Drainage Lines habitat. Gorge/ Gully habitat may also provide some foraging opportunities, however, it does not support the key habitat features associated with critical foraging habitat (i.e. treed vegetation that provides foraging perches). Therefore Gorge/ Gully habitat within the Study Area is considered supporting habitat for the species. The remaining habitats, Hillcrest/ Hillslope and Breakaway/ Cliff, are likely to be scarcely used for foraging by the species as they provide limited foraging perches and/or are less productive when compared to the other habitats in the Study Area. Additionally, the landforms characteristic of the Breakaway/ Cliff habitat do not represent the species preferred foraging habitat, as detailed by Bat Call (2021). Therefore, Hillcrest/ Hillslope and Breakaway/ Cliff habitats are not considered critical or supporting foraging habitats in the context of the Study Area.

Table 3.2: Broad fauna habitats occurring within the Study Area

Habitat type and extent	Detailed habitat description	Foraging habitat value for ghost bat
Hillcrest/ Hillslope • 1,936.6 ha • 40.6%	This habitat comprises hills and undulating plains on the tops of ranges, supporting hard spinifex with a mantle of gravel and pebbles. Vegetation was dominated by a *Triodia* hummock grassland with scattered *Eucalyptus* trees and mallee and *Acacia* and *Grevillea* shrubs. The primary microhabitat is the spinifex hummocks. This habitat was differentiated from the remaining habitat types by limited rocky outcropping and vegetation diversity.	Limited foraging habitat – given limited availability of foraging perches (i.e. scattered isolated Eucalypts on hillslopes). This habitat also has a lower productivity when compared to the other habitats as result of the limited vegetation diversity. Therefore, ghost bats are unlikely to forage in this habitat when more favourable habitat exists in the surrounding area.
Stony Plain • 1,444.8 ha • 30.3%	Stony Plain habitat comprises flat to low undulating areas with vegetation dominated by *Triodia* hummock grasses with varying amounts of scattered shrubs and/or trees on gravelly clay loam substrates. Within the Pilbara, this habitat supports a diverse assemblage of suitable prey species (Doughty *et al.*, 2011; Gibson & McKenzie, 2009). While the density of perching locations (shrubs/ trees) vary, it is continuous throughout its extent.	Critical foraging habitat, where proximal (<12 km) to roosting habitat (entire extent within Study Area)
Mulga Woodland • 555.5 ha • 11.7%	Low lying areas on heavy alluvial soils, often heavy clays. Vegetation very patchy, dominated by open Mulga patches with sparse to no understory of mixed small shrubs and tussock grasses. Mulga woodland of varying density, often associated with minor Drainage Area/ Floodplain landforms or minor drainage systems subject to sheet flow following rainfall.	Critical foraging habitat, where proximal (<12 km) to roosting habitat (entire extent within Study Area)
Drainage Area/ Floodplain • 468.8 ha • 9.8%	Lower lying plain often subjected to sheet flow following large rainfall events. Vegetation of this habitat was variable, often comprising scattered *Eucalyptus* over *Acacia* and/or *Grevillea* shrubs with an understory dominated by *Triodia* hummock grasses on alluvial substrates, often comprising heavy clays and gravel.	Critical foraging habitat, where proximal (<12 km) to roosting habitat (entire extent within Study Area)
Gorge/ Gully • 165.7 ha • 3.5%	Gorges/ Gully habitat comprises rugged, sometimes steep-sided rocky valleys incised into the surrounding landscape forming shallow gullies and gorges. Gorges tend to be deeply incised, with vertical cliff faces, while gullies are shallower and more open. Caves and water bodies were most often encountered in this habitat type. Vegetation within this habitat is variable depending on position in landscape and can be dense and complex in areas of soil deposition or sparse and simple where erosion has occurred.	Supporting foraging habitat, where proximal (<12 km) to roosting habitat (entire extent within Study Area)

Habitat type and extent	Detailed habitat description	Foraging habitat value for ghost bat
Minor Drainage Line • 101.7 ha • 2.1%	Minor Drainage Line comprises low lying or sloping topography, particularly in Hillcrest/ Hillslope landforms where water flowing from higher to lower elevation follows existing sloping topography. Vegetation is often variable and dependent on the occurrence of water within the drainage line. Vegetation often sparsely vegetated with scattered Corymbia and/or Eucalyptus over a mixed small or medium shrub understory and patchy cover of hummock and/or tussock grasses on stony or gravelly substrates.	Critical foraging habitat, where proximal (<12 km) to roosting habitat (entire extent within Study Area)
Breakaway/ Cliff • 53.1 ha • 1.1%	Breakaways/ Cliffs are rugged, incised rocky hills and ranges. They tend to contain large rock fragments and more rock outcropping than other fauna habitats. Significant habitat features such as caves were sometimes encountered in this habitat type. Vegetation can be dense and complex in areas of soil deposition or sparse and simple where erosion has occurred.	Limited foraging habitat – this habitat does not represent the species preferred foraging habitat (Bat Call, 2021) and provides limited suitable foraging perches
Disturbed/ Cleared • 38.8 ha • 0.8%	Mount Whaleback pit area	Nil

4   References

Armstrong, K. N., & Anstee, S. D. (2000). The ghost bat in the Pilbara: 100 years on. *Australian Mammalogy, 22*, 93–101. doi:https://doi.org/10.1071/AM00093

Augusteyn, J., Hughes, J., Armstrong, G., Real, K., & Pacioni, C. (2018). Tracking and tracing central Queensland's *Macroderma* – determining the size of the Mount Etna ghost bat population and potential threats. *Australian Mammalogy, 40*(2). doi:https://doi.org/10.1071/AM16010

Bat Call. (2021). A review of ghost bat ecology, threats and survey requirements. Bat Call WA, Hillarys, WA.

Biologic. (2011). Orebody 35 and Western Ridge vertebrate fauna survey. Unpublished report prepared for BHP Billiton Iron Ore. Biologic Environmental Survey, Subiaco, WA.

Biologic. (2016). Western Ridge southern tenements vertebrate fauna desktop assessment. Unpublished report prepared for BHP Western Australian Iron Ore. Biologic Environmental Survey, Subiaco, WA.

Biologic. (2019). Warrawoona Gold Project VHF bat foraging studies. Unpublished report prepared for Calidus Resources Ltd. Biologic Environmental Survey, East Perth, WA.

Biologic. (2020a). Central Pilbara ghost bat monitoring 2018-2019. Unpublished report prepared for BHP WAIO. Biologic Environmental Survey, East Perth, WA.

Biologic. (2020b). Western Ridge targeted vertebrate fauna survey. Unpublished report prepared for BHP Western Australian Iron Ore. Biologic Environmental Survey, East Perth, WA.

Biologic. (2021). Western Ridge matters of national environmental significance fauna study. Biologic Environmental Survey, East Perth, WA.

Biologic. (*in prep.*). Western Ridge and Jimblebar 2021-2022 Ghost Bat Monitoring Program. Unpublished report prepared for BHP Western Australian Iron Ore. Biologic Environmental Survey, East Perth, WA.

Boles, W. E. (1999). Avian prey of the Australian ghost bat *Macroderma gigas* (Microchiroptera: Megadermatidae): Prey characteristics and damage from predation. *Australian Zoologist, 31*(1), 82-91.

Bullen, R. D. (2021). *Pilbara Ghost Bat: Review of current ecological knowledge*. Paper presented at the Ghost bat research priorities in the Pilbara workshop, Perth, Western Australia.

Doughty, P., Rolfe, J. K., Burbidge, A. H., Pearson, D. J., & Kendrick, P. G. (2011). Herpetological assemblages of the Pilbara biogeographic region, Western Australia: ecological associations, biogeographic patterns and conservation. *Records of the Western Australian Museum, Supplement, 78*, 315-341.

ecologia. (2006). Western Ridge exploration project biological survey. Unpublished report prepared for BHP Billiton Iron Ore. ecologia Environmental Consultants, West Perth, WA.

Gibson, L. A., & McKenzie, N. L. (2009). Environmental associations of small ground-dwelling mammals in the Pilbara region, Western Australia. *Records of the Western Australian Museum, 78*, 91-122. doi:http://doi.org/10.18195/issn.0313-122x.78(1).2009.091-122

Medellin, R. A., Wiederholt, R., & Lopez-Hoffman, L. (2017). Conservation relevance of bat caves for biodiversity and ecosystem services. *Biological Conservation, 211*(Part B), 45-50. doi:https://doi.org/10.1016/j.biocon.2017.01.012

TSSC, Threatened Species Scientific Committee. (2016). Conservation Advice: *Macroderma gigas*, Ghost Bat. Australian Government, Canberra, Australian Capital Territory.