Western Ridge Targeted Vertebrate Fauna Survey

Biologic Environmental Survey

Report to BHP WAIO

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EXECUTIVE SUMMARY

BHP Western Australian Iron Ore (BHP WAIO) are investigating the biological values of the Western Ridge Study Area (hereafter referred to as the Study Area) to provide local and contextual information to inform future environmental approvals for the area. The Study Area is located directly south of BHP WAIO's Whaleback mining operation, approximately 8 kilometres (km) south-west of Newman and covers an area of approximately 33,970 hectares (ha).

Of particular interest is the potential for the Study Area to support species considered to be Matters of National Environmental Significance (MNES), being listed as threatened under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), and threatened under the Western Australian *Biodiversity Conservation Act 2016* (BC Act). To support future approvals, BHP WAIO commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake a single-season targeted vertebrate fauna survey of the Study Area, with a focus on MNES species (this assessment). The overarching objective of this assessment was to identify the occurrence of target conservation significant species and their supporting habitats within the Study Area. Specifically, to assess the likelihood of occurrence and determine the spatial and quantitative extent of occurrence of MNES species and their habitats. MNES species targeted for the survey were:

- Northern quoll (*Dasyurus hallucatus*) – Endangered;
- Greater bilby (*Macrotis lagotis*) – Vulnerable;
- Pilbara leaf-nosed bat (*Rhinonicteris aurantius* 'Pilbara form') – Vulnerable;
- Ghost bat (*Macroderma gigas*) – Vulnerable;
- Night parrot (*Pezoporus occidentalis*) – Endangered; and
- Pilbara olive python (*Liasis olivaceus* subsp. *barroni*) – Vulnerable.

The assessment for each species was based on the results of a comprehensive desktop assessment, comprising a thorough literature review and database searches, and a detailed targeted fauna field survey. The desktop assessment comprised a search of four databases and 26 previous consulting reports completed in the area, including nine which overlap with the Study Area. The field survey was completed by four zoologists between the 11th and 16th of March 2020. The methodology was specific to recording the presence of the targeted species and comprised habitat assessments, motion camera transects, targeted searches, nocturnal searches, cave assessment, water feature assessments and eDNA sampling, and ultrasonic and acoustic sound recording.

The survey recorded seven habitat types and numerous habitat features, in the form of caves and water features, within the Study Area. Three of the targeted species (northern quoll, ghost bat and Pilbara olive python) were recorded within the Study Area. Additionally, the Pilbara leaf-nosed bat has previously been recorded in the near vicinity and is deemed highly likely to exist within the Study Area despite not being recorded during this survey. The remaining two species, the greater bilby and night parrot, are deemed unlikely to occur.

Fauna Habitats

A total of seven broad fauna habitat types were mapped across the Study Area, comprising, in order of occurrence, Hillcrest/ Hillslope, Stony Plain, Mulga Woodland, Drainage Area/ Floodplain, Gorge/ Gully, Minor Drainage Line and Breakaway/ Cliff. Two fauna habitats, the Gorge/ Gully and Breakaway/ Cliff, were considered to be of significance as it represented primary habitat for numerous target species occurring in the Study Area. All habitats present within the Study Area represented primary foraging and dispersal habitat for various target species occurring in the Study Area.

Caves

A total of 19 caves have been recorded within the Study Area, of which 12 were recorded during the current survey, primarily within Gorge/ Gully habitat. Ghost bat have been recorded from direct observation or secondary evidence (scats) in seven of these caves. Of the 19 caves, one represents a maternity roost, one was identified as a potential maternity roost (and confirmed diurnal roost), three as potential diurnal roosts, five as night roosts and five as potential night roosts. The remaining four caves showed no evidence of usage by the ghost bat and are unlikely to be suitable for the species. The maternity roost (CWER-01) and potential maternity roost (CWER-03) are considered to be of high local and regional significance for the species. No Pilbara leaf-nosed bats were recorded from any caves during the current survey; though all caves were considered possible nocturnal refuges for the species. Additionally, three northern quoll scats were also recorded within two caves (CWER-10 and CWER-16) during the survey.

Water Features

A total of 14 water features have been recorded in the Study Area, comprising; two seeps, two rock pools fed by a seep, ten surface water rock pools and one artificial water feature. The Pilbara olive python was recorded at five of these features. The two seep fed rock pools (WWER-01 and WWER-04) are of high significance to the northern quoll, ghost bat, Pilbara leaf-nosed bat and Pilbara olive python as they provide core foraging habitat for all or most of the year. The remaining water features provide habitat of moderate significance providing foraging habitat for temporary periods only.

Northern Quoll

The species had not been recorded within the Study Area prior to this survey and the nearest record of the species was located approximately 5.5 km north of the Study Area from 2007. During the survey, northern quoll was recorded by three scats in two caves within Gorge/ Gully habitat. Within the Study Area, important habitat for the species is provided primarily in Gorge/ Gully habitat and Breakaway/ Cliff habitat, which represents primary breeding and foraging habitat. Instances of the Hillcrest/ Hillslope and Minor Drainage Line habitats also provide secondary breeding habitat, though these habitats generally represent foraging and dispersal habitat. Based on the paucity of records within the Study Area from the current, and the scarcity of records in the broader vicinity of the Study Area, it is likely that the species occurrence within the Study Area is infrequent. This was supported by the age of the scats recorded, which were likely very old and preserved in the caves and thus indicative of historic occupation only. It is therefore unlikely that the species occurrence in the Study Area represents a

'population important for the long-term survival of the species', as defined by the federal environmental department (DoE, 2013).

Greater Bilby

The species has not been recorded within the Study Area previously. The nearest record of the species is located approximately 13.5 km east of the Study Area. No evidence of greater bilby occurrence was recorded during the current survey. Two habitats mapped within the Study Area, Mulga Woodland and Drainage Area/ Floodplain, provide marginal suitable habitat for the species, though are unlikely to support the species exclusive of primary habitat. Due to the lack of contemporary records and the absence of quality habitat, it is unlikely that the greater bilby occurs within the Study Area or that the Study Area is capable of providing for an important population, as defined by DoE (2013).

Pilbara Leaf-nosed Bat

The species has previously been recorded approximately 50 m south of the Study Area in Mulga Woodland habitat in November 2019. The origin of this record (i.e. potential diurnal roost location) is unknown, though highly unlikely to be within the Study Area, given the lack of records and high intensity sampling effort. No evidence of Pilbara leaf-nosed bat occurrence was recorded within the Study Area during the current survey, though all 19 caves assessed may represent nocturnal refuges for the species. The Gorge/ Gully habitat is regarded as primary foraging habitat to the species due to the presence of overhangs, nocturnal refuges, rocky outcrops, and water features. Additionally, this habitat type represents Priority 1 and 2 foraging habitats (as defined by DAWE) for the species. The Breakaway/ Cliff habitat and limited instances where outcropping occurs within the Hillcrest/ Hillslope are regarded as Priority 3 habitat to the species due to the presence of overhangs, nocturnal refuges. The Minor Drainage Line habitat is also categorised as primary foraging habitat for the species. Open grasslands and woodlands contained within the remaining habitats; Stony Plain, Mulga Woodland and Drainage Area/ Floodplain; are considered secondary foraging habitat for the species. Based on the scarcity of records within and in the vicinity of the Study Area, it is unlikely that the Study Area represent a significant area for the species.

Ghost Bat

The species has previously been recorded within the Study Area from direct observation and secondary evidence on multiple occasions during previous surveys. Evidence of ghost bat was recorded at seven caves from secondary evidence (scats) during the current survey, with scat abundance ranging between 8 and 500 (CWER-01, CWER-02, CWER-03, CWER-06, CWER-10, CWER-14 and CWER-16). Additionally, the species was recorded from direct observation and ultrasonic calls at one cave, CWER-03. Of the 19 caves, 15 represent habitat for the ghost bat, comprising one maternity roost, potential maternity roosts (and confirmed diurnal roost), three potential diurnal roosts, five night roosts and five potential night roosts. As targeted searches could not be completed over all instances of suitable habitat (Gorge/ Gully and Breakaway/ Cliff where suitable cave forming geology occurs), it is possible that additional roost sites occur within the Study Area. Two caves (CWER-01 and CWER-03) have had diurnal roosting confirmed over multiple sampling events since 2016 and are considered to be of high local and regional significance for the species.

The Gorge/Gully and Breakaway/ Cliff habitat is regarded as primary breeding, roosting and foraging habitat for the species within the Study Area. Mulga Woodland, Drainage Area/ Floodplain and Minor Drainage Line habitats provide primary foraging habitat and Stony Plain provides secondary foraging habitat for the species, particularly when adjacent to roosting caves.

The presence of one maternity roost (CWER-01) and one potential maternity roost (CWER-03) within the Study Area, indicates that individuals from the Study Area form part of a 'key source population either for breeding or dispersal' (as defined by DAWE). Additionally, records from within the Study Area represent the south-eastern extent of the species distribution in the Pilbara region, therefore forming part of a 'population that [is] near the limit of the species range' (as defined by DAWE). Together these definitions suggest the ghost bats occurring within the Study Area form part of an 'important population' (as defined by DAWE).

Night Parrot

The nearest publicly available contemporary record (<20 years) of the species is located approximately 126 km northwest of the Study Area from April 2005, which despite extensive monitoring, has not been recorded since. An additional record is known to occur within 100 km of the Study Area, though further information is unavailable due to sensitivity reasons. No evidence of night parrot occurrence was recorded during the current survey. Though instances of suitably sized *Triodia* hummock grasses for breeding were present in the Drainage Area/ Floodplain and Stony Plain habitats, these were sparsely distributed, not associated with known habitat preferences of the species and were therefore considered to be of low suitability. Furthermore, there is an absence of high-quality foraging habitat (as defined by foraging studies of the species) within or within 10 km of the Study Area.

Due to the lack of contemporary records in the region and the absence of high quality habitat in the Study Area, it is unlikely that the night parrot occurs within the Study Area, or that the Study Area may support a population of the species, as defined by DoE (2013).

Pilbara Olive Python

The species has previously been recorded within the Study Area on three occasions, comprising an individual observed in a small cave, accumulated scats and sloughs at another location in the same gorge and a slough recorded approximately 1 km north of these records at Afghan pool (near water feature WWER-01). The nearest record outside the Study Area is located approximately 7 km north. The Pilbara olive python was recorded on 14 occasions during the current survey, comprising two records of live individuals (one adult and one juvenile), four records of scats and six positive eDNA results from water sampled at selected water features. As the species is cryptic, targeted eDNA sampling for the species was trialled as a novel sampling method. This technique proved to be successful during the current survey, with positive detection of the species at six of the eight water features sampled. Records of the species were primarily located in Gorge/ Gully habitat (n = 5) but also Hillcrest/ Hillslope habitat (n = 1) adjacent to Gorge/ Gully habitat. Gorge/ Gully habitat was the most significant habitat for the Pilbara olive python within the Study Area as it represents primary breeding and foraging habitat. Instances of the Breakaway/ Cliff, Minor Drainage Line and Hillcrest/ Hillslope habitats also provide breeding and foraging qualities, though these habitats generally represent

foraging and dispersal habitat, particularly where they facilitate connectivity between areas of primary Gorge/ Gully habitat and/or where water features are present.

The Pilbara olive python population occurring within the Study Area represents a likely permanently residing and breeding population, and therefore a ‘key source population either for breeding or dispersal’, as defined by DoE (2013). Furthermore, the species occurrence within the Study Area represents the south-eastern extent of the species distribution, therefore forming part of a ‘population that [is] near the limit of the species range’, as defined by DoE (2013). Together, these population attributes indicate the species’ occurrence within the Study Area forms part of an ‘important population’, as defined by DoE (2013).

1 INTRODUCTION

1.1 Background

BHP Western Australian Iron Ore (BHP WAIO) are investigating the biological values of the Western Ridge Study Area (hereafter referred to as the Study Area) to provide local and contextual information to inform future environmental approvals for the area. The Study Area is located directly south of BHP WAIO's Whaleback mining operation, approximately 8 kilometres (km) south-west of Newman and covers an area of approximately 33,970 hectares (ha) (Figure 1.1).

Of particular interest is the potential for the Study Area to support species considered to be Matters of National Environmental Significance (MNES), being listed as threatened under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), and threatened under the Western Australian *Biodiversity Conservation Act 2016* (BC Act). To support future approvals, BHP WAIO commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake a single-season targeted vertebrate fauna survey of the Study Area, with a focus on MNES species (this assessment).

1.2 Survey Objectives

The overarching objective of this assessment was to identify the occurrence of target conservation significant species and their supporting habitats within the Study Area. Specifically, to assess the likelihood of occurrence and determine the spatial and quantitative extent of occurrence of MNES species. MNES species targeted for the survey was:

- Northern quoll (*Dasyurus hallucatus*) – Endangered;
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- Pilbara olive python (*Liasis olivaceus* subsp. *barroni*) – Vulnerable.

1.3 Compliance

This assessment was carried out in a manner consistent with the following documents developed by the Western Australian Environmental Protection Authority (EPA), the Department of Biodiversity, Conservation and Attractions (DBCA - formerly Department of Parks and Wildlife [DPaW]), the Department of Agriculture, Water and the Environment (DAWE - formerly the Department of Environment [DoE], Department of Sustainability, Water, Population, and Communities [DSEWPaC] and Department of Environment, Water, Heritage and Arts [DEWHA]) and BHP WAIO:

- BHP (2011) Guidance for vertebrate fauna surveys in the Pilbara (SPR-IEN-EMS-012);
- DBCA (2017a) Guidelines for surveys to detect the presence of bilbies, and assess the importance of habitat in Western Australia;
- DEWHA (2010a) Survey guidelines for Australia's threatened bats;
- DEWHA (2010b) Survey guidelines for Australia's threatened birds;

- DoE (2016) EPBC Act referral guideline for the endangered northern quoll (*Dasyurus hallucatus);*
- DPaW (2017) Interim guideline for the preliminary surveys of night parrot (*Pezoporus occidentalis*) in Western Australia;
- DSEWPaC (2011a) Survey guidelines for Australia's threatened mammals;
- DSEWPaC (2011b) Survey guidelines for Australia's threatened reptiles; and
- EPA (2016a) Technical guidance: Sampling methods for terrestrial vertebrate fauna; and
- EPA (2016b) Technical guidance: Terrestrial fauna surveys;

738000 742500 747000 751500 756000 760500 765000 769500 774000 778500 783000 787500 792000 796500

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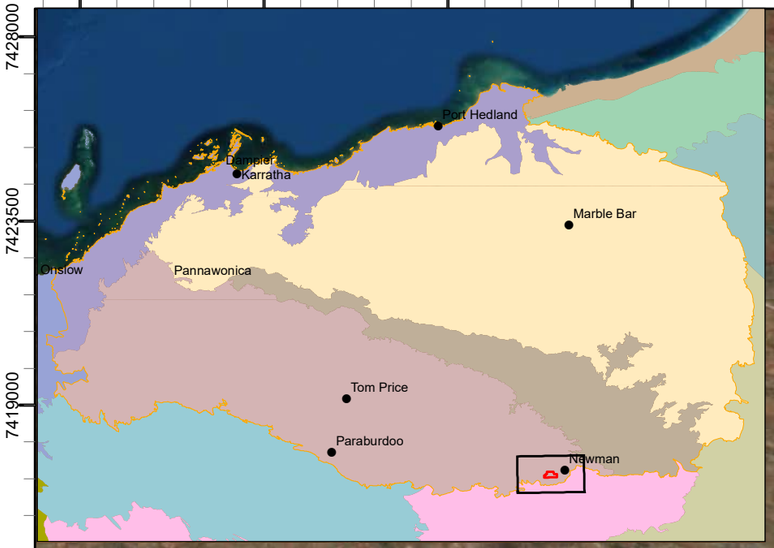

OB 24 Far W
OB 24 W
OB 24 E
OB 24 Int
OB 24 Far E
OB 25 - Pit 4
OB 25 - Pit 3
Mt Whaleback
OB 30
OB 29
OB 35

Legend

- StudyArea
- Pilbara Bioregion
- Road
- Rail
- Regional mine site

IBRA Subregions

- Ashburton
- Augustus
- Cape Range
- Chichester
- Fortescue
- Hamersley
- Mackay
- McLarty
- Pindanland
- Roebourne
- Trainor
- Wooramel

biologic Environmental Survey

N

1:150,000

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BHP WAIO

Western Ridge Target Fauna Survey

Figure 1.1: Study Area and regional location

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 08/05/2020

1.4 Target Species

1.4.1 Northern Quoll (*Dasyurus hallucatus*)

The northern quoll is listed as Endangered under the EPBC Act and Western Australian *Biodiversity Conservation Act 2016* (BC Act). The species was once widely distributed across northern Australia; however, it is now restricted to three isolated populations; the Pilbara, the Kimberley and Northern Territory, and Queensland, in addition to a number of islands along the north coast (DoE, 2016). Northern quolls are opportunistic omnivores, consuming a wide range of invertebrates and small vertebrates but they also eat fruit, nectar, carrion and human refuse (van Dyck & Strahan, 2008).

As a result of facultative die-off (semelparity), the abundance of the species is cyclical, and the annual reproduction is highly synchronised (Oakwood *et al.*, 2001). In the Pilbara, abundance is lowest toward the end of winter into early spring after the mating season, as a significant proportion of adult males die off and young have not yet begun to forage independently (Braithwaite & Griffiths, 1994; Oakwood, 2000). Conversely, the population density is thought to be highest in the summer months, prior to the mating season and when juveniles have begun foraging independently (Oakwood, 2000). Schmitt *et al.* (1989) reported relatively small home ranges in rugged habitat in the Kimberley (i.e. 2.3 ha for females and 1.8 ha for males), whereas in the western Pilbara, minimum activity areas are 75 – 443 ha for females and 5 – 1,109 ha for males (King, 1989).

The northern quoll is both arboreal and terrestrial, inhabiting ironstone and sandstone ridges, scree slopes, granite boulders and outcrops, drainage lines, riverine habitats (Braithwaite & Griffiths, 1994; Oakwood, 2002), dissected rocky escarpments, open forest of lowland savannah and woodland (Oakwood, 2002, 2008). Rocky habitats tend to support higher densities, as they offer protection from predators and are generally more productive in terms of availability of resources (Braithwaite & Griffiths, 1994; Oakwood, 2000). Other microhabitat features important to the species include: rock cover; proximity to permanent water and time-since last fire (Woinarski *et al.*, 2008). Dens occur in a wide range of situations including rock overhangs, tree hollows, hollow logs, termite mounds, goanna burrows and human dwellings/infrastructure, where individuals usually den alone (Oakwood, 2002; Woinarski *et al.*, 2008). At present, northern quolls are relatively common in the northern Pilbara region (generally within 150 km of the coast) but are much less common in southern and south-eastern parts of the region (Cramer *et al.*, 2016b).

The species has experienced a precipitous decline in much of its former range in northern Queensland and the Northern Territory in direct association with the spread of the cane toad, *Bufo marinus* (Braithwaite & Griffiths, 1994; Fitzsimons *et al.*, 2010). Other threats include predation from feral predators such as foxes and cats, inappropriate fire regimes, disease, habitat degradation through grazing and weed invasion, habitat destruction through mining and agriculture (Woinarski *et al.*, 2011). The potential invasion of the Pilbara by the cane toad is regarded as the most significant future threat to the northern quoll in the Pilbara; however, there is little knowledge of the relative impact of the other key threats, and their interactive effects, currently and in the future (Cramer *et al.*, 2016b).

1.4.2 Greater Bilby (*Macrotis lagotis*)

The greater bilby is listed as Vulnerable under the EPBC Act and BC Act. It is one of many Australian arid zone marsupial species that are within a 'critical weight range' (35 grams [g] to 5,500 g) considered significant based on the high risk of predation by introduced foxes (*Vulpes vulpes*) and feral cats (*Felis catus*) (Johnson & Isaac, 2009). Greater bilbies are semi-fossorial and nocturnal, remaining in their burrows during the day and intermittently during the night for rest and refuge. Greater bilby populations naturally occur as scattered solitary individuals or small groups (Smythe & Philpott, 1968; Southgate, 1990a). They are regarded as having low site fidelity and high mobility (Southgate *et al.*, 2007); males regularly move three to five kilometres between burrows on consecutive days and have been recorded moving up to 15 km in a few weeks (Southgate & Possingham, 1995). This high mobility, together with low population density, ensures that the area of occupancy is often far less than the extent of occurrence. As greater bilbies are solitary in nature, lack territoriality and have large home ranges, it is likely that males adopt a roving strategy to find receptive females, consistent with an overlapping promiscuous mating system (Miller *et al.*, 2010).

Populations of greater bilby exist in the Pilbara bioregion (particularly the Chichester subregion, along the Fortescue River and north-east to Goldsworthy and Shay Gap), in the Dampier bioregion (along 80 Mile Beach north to Beagle Bay) and in the Central Kimberley and Ord-Victoria Plains bioregions south of the Fitzroy and Margaret Rivers (Southgate, 1990a). The species' distribution within the Pilbara region is highly fragmented (Cramer *et al.*, 2017).

Greater bilbies occupy three major vegetation types - open tussock grassland on uplands and hills, mulga woodland/shrubland growing on ridges and rises, and hummock grassland in plains and alluvial areas (Southgate, 1990b). Laterite and rock feature substrates are an important part of greater bilby habitat as they support shrub species, such as *Acacia kempeana, A. hilliana* and *A. rhodophylla*, which have root-dwelling larvae prone to supporting a constant food source (Dziminski & Carpenter, 2017; Southgate *et al.*, 2007). These habitats also contain spinifex hummocks, which are quite uniform and discrete, providing runways between hummocks and enabling easier movement and foraging (Southgate *et al.*, 2007). Minimal ground cover is a common feature in greater bilby habitats, as it allows easy foraging (Dawson, 2018). Habitat within the Pilbara bioregion seems to consist mostly of spinifex sand plain associated with major drainage line sandy terraces. In general, the distribution of greater bilbies can be limited by the availability of suitable burrowing habitat, such as dunes where burrow excavation is easier (Moseby & O'Donnell, 2003), and are not found in predominantly rocky areas or mountains where they would be unable to dig suitable burrow systems or dig for food.

1.4.3 Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*)

The Pilbara leaf-nosed bat is listed as Vulnerable under the EPBC Act and the BC Act. The Pilbara leaf-nosed bat is recognised as a geographically isolated population of the orange leaf-nosed bat, distributed across northern Australia and separated from the Pilbara populations by approximately 400 km of the Great Sandy Desert (Armstrong, 2001). The Pilbara population is regarded as representing a single interbreeding population comprising multiple colonies (TSSC, 2016b). The most updated conservation advice (TSSC, 2016b) stated that there were at least 10 confirmed day roosts (including maternity

roosts) and a further 23 unconfirmed roosts throughout the Pilbara region, although this is likely to be an underestimate based on unpublished data.

Pilbara leaf-nosed bats typically roost in undisturbed caves, deep fissures or abandoned mine shafts (Armstrong, 2000, 2001). The species' limited ability to conserve heat and water (Baudinette *et al.*, 2000) means they require warm (28-32ºC) and very humid (85-100%) roost sites to persist in arid and semi-arid climates (Armstrong, 2001; Churchill, 1991). Roost sites with such attributes are relatively uncommon in the Pilbara and the limiting factor of the species' distribution (Armstrong, 2001). During the dry season (June to November), individuals are believed to aggregate in roosts that provide a suitably warm, humid microclimate (Armstrong, 2000, 2001; Bullen & McKenzie, 2011). While in the wet season (December to May), when conditions are generally wetter and more humid, individuals typically disperse roosting in seasonally suitable features (Armstrong, 2000, 2001; Bullen & McKenzie, 2011). TSSC (2016b) categorised underground refuges used by the species into four categories:

- **Permanent Diurnal Roosts** (Priority 1 – critical habitat for daily survival): are occupied year-round and are likely to be the focus for some part of the 9-month breeding cycle.
- **Non-Permanent Breeding Roosts** (Priority 2 - critical habitat for daily and long-term survival): are used during some part of the 9-month breeding cycle but not year-round.
- **Transitory Diurnal Roosts** (Priority 3 – critical habitat for daily and long-term survival): are occupied outside the breeding season and could facilitate long distance dispersal.
- **Nocturnal Refuge** (Priority 4 – not considered critical but important for persistence in a local area): are occupied or entered at night for resting, feeding or other purposes (excluding overhangs).

The species forages within and in the vicinity of roost caves and more broadly along waterbodies with suitable fringing vegetation supporting prey species (TSSC, 2016b). Foraging sites surrounding known or suspected roosts can be critical to the survival of the species. TSSC (2016b) categorised foraging habitat into five categories: gorges with pools (Priority 1); gullies (Priority 2); rocky outcrops (Priority 3); major watercourses (Priority 4); and open grassland and woodland (Priority 5) (TSSC, 2016b). The species is predicted to travel up to 20 km from roost caves during nightly foraging (Cramer *et al.*, 2016a); however, seasonal variation is known to occur, with foraging occurring up to 20 km in the dry season and up to 50 km during the wet season (Bullen, 2013). Long-distance movements by the species have also been recorded, with a single monitored individual recorded from two roost caves located 170 km distant approximately 12 months apart (Bullen & Reiffer, 2019).

1.4.4 Ghost Bat (*Macroderma gigas*)

The ghost bat is listed as Vulnerable under the EPBC Act, the BC Act and by the International Union for Conservation of Nature (IUCN). The ghost bat occurs in disjunct colonies across northern Australia (TSSC, 2016a). In the Pilbara region, the species occurs in all four subregions. The Pilbara population is estimated to be between 1,300 and 2,000 individuals (TSSC, 2016a). The largest population occurs within the Chichester subregion (estimated at approximately 1,500 individuals) where known populations are largely restricted to disused mines (TSSC, 2016a).

The distribution of ghost bats in the Pilbara is determined by the presence of suitable roosting sites. Natural roosts generally comprise deep, complex caves beneath bluffs or low rounded hills (Armstrong & Anstee, 2000). Centralised breeding sites in the Pilbara are largely restricted to abandoned mines in the Chichester Ranges; however, there are also a number of smaller maternity roosts in the Chichester and Hamersley Ranges (Armstrong & Anstee, 2000). Based on available data, breeding has been documented in natural caves at Mining Area C, Mt Brockman and West Angeles in the Hamersley sub-region, and at Callawa and Tambrey Station in the Chichester subregion (Armstrong & Anstee, 2000). Ghost bats move between a number of caves seasonally, or as dictated by weather conditions, and require a range of cave sites (Hutson *et al.*, 2001). Outside the breeding season, male bats are known to disperse widely, most likely during the wet season when conditions would allow bats to use caves that would otherwise not be suitable (Worthington-Wilmer *et al.*, 1994). Genetic studies indicate that females are likely to stay close to the maternity roosts (Worthington-Wilmer *et al.*, 1994).

Caves used by the species can be classified into five categories (Biologic, 2015):

- **Potential Night Roosts:** caves that are only utilised during the night, mostly to feed on prey items or to rest, and are typically shallow caves and shelters/overhangs that can be well lit during the day.
- **Potential Day Roosts:** in addition to being utilised to feed during the night, these caves are more complex in structure and provide suitable temperature and humidity conditions for roosting during the day, but no ghost bats have been recorded using them during the day.
- **Day Roosts:** caves that are used for shelter during the day.
- **Potential Maternity Roosts:** in addition to being used for shelter during the day, these caves have attributes suitable to support breeding, and ghost bats have been recorded in these caves during the breeding season.
- **Maternity Roosts:** in addition to being used for shelter during the day, these caves have attributes suitable to support breeding, and ghost bats have been recorded in these caves during the breeding season, including pregnant females or females with pups.

Ghost bats appear to have a short-range foraging strategy of up to 3 km (average 1.9 km), with vantage points changing approximately every 15 minutes, and average foraging areas of 61 ha having been recorded in the Northern Territory (Tidemann *et al.*, 1985). It also appears that the bats generally return to the same area each night (Tidemann *et al.*, 1985), although it has been suggested that ghost bats in the arid zone are semi-transient through most areas and will readily travel large distances (>4 km) (Biologic, 2020d). Ghost bats have a ‘sit and inspect’ foraging strategy; they hang on a perch where they 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). Recent studies of ghost bat home range and foraging behaviour in the Pilbara region have indicated that the species prefers plains and low-lying habitat for foraging, particularly Drainage Area/ Floodplain (ghost bats have also been observed exiting caves and moving immediately towards broad drainage plains), Mulga Woodland and Major Drainage Line

(Biologic, 2020d). Such areas are highly productive and comprise and abundance of foraging structures (Biologic, 2020d).

1.4.5 Night Parrot (Pezoporus occidentalis)

The night parrot is a small, elusive ground dwelling parrot endemic to Australia (DPaW, 2017). This highly cryptic and nocturnal parrot inhabits arid and semi-arid areas that comprise dense, low vegetation. Based on accepted records, the habitat of the night parrot consists of *Triodia* grasslands in stony or sandy environments (McGilp, 1931; North, 1898; Whitlock, 1924; Wilson, 1937), and of samphire and chenopod shrublands, including genera such as *Atriplex*, *Bassia* and *Maireana*, on floodplains and claypans, as well as on the margins of salt lakes, creeks or other sources of water (McGilp, 1931; Wilson, 1937). The current interim guidelines for preliminary surveys of night parrot in Western Australia suggest this species requires old-growth spinifex (*Triodia*) (often more than 50 years' unburnt) for roosting and nesting (DPaW, 2017). Although little is known about foraging sites, habitats that comprise various grasses and herbs are thought to be suitable. Foraging habitat is not necessarily within or adjacent to roosting habitat as the night parrot has been known to fly up to 40 km in a single night to forage (Murphy *et al.*, 2017b). It is reasonably assumed that the species may fly cumulative distances of up to 100 km per night during productive seasons and considerably greater than 100 km per night during drought conditions between roosting habitat and foraging habitat (Night Parrot Recovery Team, 2017). *Triodia* is likely to provide a good food resource, particularly in times of mass flowering and seeding. The succulent *Sclerolaena* also provides a source of food and moisture, and other succulent chenopods are also likely to be significant habitat (DPaW, 2017). As such, foraging areas include highly productive and floristically diverse alluvial habitats, stony herb fields, sparse ironstone pavements, and quaternary sand drifts and ridges (Night Parrot Recovery Team, 2017). Foraging habitat is likely to be more important if it is adjacent to or within about 10 km of suitable roosting habitat (DPaW, 2017). During adult or juvenile dispersal, or nomadic movements, night parrots may travel distances in the order of several hundred kilometres.

The distribution of the night parrot is very poorly understood. The small number of confirmed or verifiable records prevents the population size from being assessed with any accuracy; however, the population size is speculatively estimated to consist of approximately 50 breeding birds that occur in five subpopulations. The largest of these subpopulations is estimated, with low reliability, to consist of 20 breeding birds (Garnett & Crowley, 2000)

1.4.6 Pilbara Olive Python (*Liasis olivaceus barroni*)

The Pilbara olive python is listed as Vulnerable under the EPBC Act and the BC Act. The Pilbara olive python is Western Australia's largest snake, averaging 2.5 metres (m) with records up to 4.5 m (Bush & Maryan, 2011; Cogger, 2014). The species has a dull olive-brown upper surface and is pale cream below (Burbidge, 2004; Cogger, 2014). This python is endemic to the Pilbara region, distributed from Burrup Peninsula, Ord Ranges and Meentheena south to Nanutarra and Newman (Bush & Maryan, 2011).

This species is primarily nocturnal and tends to shelter in small caves or under vegetation during the day. During summer months they will emerge from daytime shelters soon after dark and continue to move until the early hours of the morning (DSEWPaC, 2011b). In the winter months, the species is primarily nocturnal, although adult pythons can sometimes be found basking in the morning sun (DSEWPaC, 2011b; Pearson, 2001). The breeding season of the Pilbara olive python takes place in the cooler months, which extends from June to August and males will travel up three kilometres in search of a mate (DSEWPaC, 2011b). The species is a well-adapted ambush predator and common prey items include rock-wallabies, small Euros, fruit bats, waterbirds, doves/pigeons and there are instances of northern quoll (Oakwood & Miles, 1998).

The species commonly inhabits moist areas such as gorges, rivers, pools and surrounding hills, but can be found in a range of habitats (Burbidge, 2004; DSEWPaC, 2011b). In the Hamersley region, the Pilbara olive python is most often encountered in the vicinity of permanent waterholes in rocky ranges or among riverine vegetation (DSEWPaC, 2011b; Pearson, 1993). It is a common misconception that the species is reliant and restricted to areas near permanent water; however, the species is attracted to these areas due to the productivity and abundance of suitably-sized prey (Pearson, 2003). The species is known to occur at 17 locations within the Pilbara (Pearson, 1993), including populations at Pannawonica, Millstream, Tom Price and Burrup Peninsula (Pearson, 2003)

Threats to the species include major fire events, competition for prey with introduced predators, habitat loss (TSSC, 2008), predation of food sources (quolls and rock-wallabies) by foxes, habitat destruction by gas and mining development, deliberate and accidental road kills, and deliberate killings around tourist and residential areas associated with mistaken identification as a venomous brown snake (Pearson, 2003).

2 METHODS

The assessment comprised a comprehensive desktop assessment, including a thorough literature review and database searches, and a detailed targeted fauna field survey.

2.1 Desktop Assessment

A desktop assessment, comprising database searches and a literature review, was undertaken prior to the field survey. The purpose of the desktop assessment was to identify vertebrate fauna potentially occurring in the Study Area, with a focus on species of conservation significance.

2.1.1 Database Searches

Five fauna databases were searched (Table 2.1), three to obtain information on all species previously recorded (NatureMap, Birdata and BHP WAIO Fauna Records Database), one to identify species of conservation significance previously recorded (DBCA Threatened Fauna Database), and one to identify species of conservation significance known or likely to occur within the region (Protected Matters Database).

Table 2.1: Details of database searches conducted

Database	Data Access/ Receival Date	Search Area
DBCA (2020a) NatureMap	09/01/2020	Centre point of Study Area (-23.4027 S, 119.6144 E) with a 40 km buffer
DBCA (2020b) Threatened and Priority Fauna Database	09/01/2020	Centre point of Study Area (-23.4027 S, 119.6144 E) with a 40 km buffer
Birdlife Australia (2020) Birdata	09/01/2020	Centre point of Study Area (-23.4027 S, 119.6144 E) with a 40 km buffer
DoEE (2020) Protected Matters Search Tool	09/01/ 2020.	Centre point of Study Area (-23.4027 S, 119.6144 E) with a 40 km buffer
BHP (2020) BHP WAIO Fauna Records Database	06/02/2020	Study Area with a 20 km buffer. Includes any biological surveys completed for BHP WAIO within search area.

2.1.2 Literature Review

A review of available literature relevant to the Study Area was undertaken to compile a list of vertebrate fauna species with the potential to occur within the Study Area. A total of 26 assessments were reviewed, comprising two targeted surveys, seven Level 2 surveys and 17 Level 1 surveys (Table 2.2). Of the 26 assessments reviewed, nine assessments overlapped with the Study Area, 13 assessments were within 10 km, three assessments were within 10–20 km and one assessment was within 20–35 km of the Study Area.

Table 2.2: Literature sources used for the review

Report Title	Survey Type	Distance from Study Area (km)
Onshore (2014) Western Ridge Biological Survey	Level 1	Overlapping
Biologic (2011) Orebody 35 and Western Ridge Vertebrate Fauna Survey	Level 2	Overlapping
ENV (2010) Orebody 35 Vegetation Clearing Permit Area Flora and Fauna Assessment	Level 1	Overlapping
Ecologia (2006) Western Ridge Exploration Project Biological Survey	Level 1	Overlapping
Ecologia (2005) Western Ridge Exploration Project Biological Survey	Level 2	Overlapping
Onshore and Biologic (2009a) Mt Whaleback Mine Site Flora & Vegetation Survey and Fauna Assessment	Level 1	Overlapping
Biota (2001) Baseline Biological and Soil Surveys and Mapping for ML244SA West of the Fortescue River	Level 2	Overlapping
Halpern Glick Maunsell (1999) Orebody 30 and Orebody 35 Soil & Biological Survey	Level 1	Overlapping
Ecologia (1998) Mt Whaleback Fauna Monitoring Programme: Baseline Sampling 1997-1998	Level 2	Overlapping
Biologic (2020c) Coombanbunna Well Level 2 Vertebrate Fauna Survey	Level 2	Overlapping (eastern portion) and directly adjacent S
ENV (2006) Mount Whaleback Fauna Assessment Survey Phase III	Level 2	~0.08km N
Biologic (2009) Newman Power Network Level 2 Flora and Level 1 Fauna Survey	Level 1	~0.3km NE
Astron (2010) Mt Whaleback TSF Flora, Vegetation and Fauna Assessment	Level 1	~0.5km E
ENV (2011b) Mt Whaleback East Flora, Vegetation and Fauna Assessment	Level 1	~4km E
Eco Logical (2011) Newman Power Line Corridor Level 1 Flora and Fauna Survey	Level 1	~5.5km NE
Ecologia (2008) RGP5 Fauna Survey Newman to Jimblebar Junction	Level 1	~5.5km NE
GHD (2008) Myopic Project Area, Newman Flora and Fauna Assessment	Level 2	~6.5km S
ENV (2009b) Newman to Yandi Transmission Line Terrestrial Vertebrate Fauna Assessment	Level 1	~7km NE
Biologic (2016a) Cathedral Gorge Level 1 and Targeted Vertebrate Fauna Survey	Level 1	~7km S
ENV (2011a) Eastern Ridge (OB23/24/25) Fauna Assessment	Level 1	~7.5km SW
ENV (2009a) Newman to Jimblebar Transmission Line and Newman Town Substation Terrestrial Fauna Assessment	Level 1	~7.5km NE
Onshore and Biologic (2009b) Myopic Exploration Leases Biological Survey	Level 1	~8km S
Eco Logical (2012b) Orebody 37 Level 1 Vertebrate Fauna Assessment	Level 1	~8km NE
Biologic (2014a) Orebody 25 Targeted Vertebrate Fauna Survey	Targeted	~11km NE
Ecologia (2004) Orebody 24 Expansion Biological Survey	Level 2	~12km NE

Report Title	Survey Type	Distance from Study Area (km)
Biologic (2013b) Orebody 24 Targeted Vertebrate Fauna Survey	Targeted	~16km NE
Eco Logical (2012a) Level 1 Flora and Fauna Surveys Along the Great Northern Highway for Jimblebar Mine Module Transport	Level 1	~33km NW

2.2 Field Survey

2.2.1 Survey Timing

The targeted vertebrate fauna survey was conducted between the 11th and 16th March 2020. The field survey was undertaken by experienced zoologists Chris Knuckey, Andrew Hide, Brighton Downing and Ashleigh Jenkins, whom collectively have over 25 years of experience surveying fauna within the Pilbara region. Additionally, Senior Zoologists Mark Gresser and Ryan Ellis conducted cave visitations at three known caves (CWER-01, CWER-02 and CWER-03) within the Study Area in November-December 2019.

The survey was conducted under DBCA Regulation 27 “Fauna Taking (Biological Assessment)” licences, issued to Ashleigh Jenkins (licence number BA27000215-2). Under Section 40 of the BC Act, threatened species sampling was completed under a DBCA “Authorisation to Take or Disturbed Threatened Species” issued to Ashleigh Jenkins (authorisation number TFA 2020-0014).

2.2.2 Climate and Weather

The Pilbara bioregion has a semi-desert to tropical climate, with rainfall occurring sporadically throughout the year, although mostly during summer (Thackway & Cresswell, 1995). Summer rainfall is usually the result of tropical storms in the north or tropical cyclones that impact upon the coast and move inland (Leighton, 2004). The winter rainfall is generally lighter and is the result of cold fronts moving north easterly across the state (Leighton, 2004). The average annual rainfall ranges from 200-350 mm, although there are significant fluctuations between years, with some locations receiving up to 1,200 mm in some years (McKenzie *et al.*, 2009).

Long-term climatic data is not available for the Study Area itself; however, long-term data is available from the Bureau of Meteorology (BoM) weather station at Newman Aero (Station 007176), located approximately 14 km east of the Study Area (BoM, 2020). The Newman Aero weather station is expected to provide the most accurate long-term average (LTA) dataset for climatic conditions experienced within the Study Area (Figure 2.1).

In the 12 months prior to the survey, mean minimum and maximum were comparable to long-term averages; however, were regularly warmer and dryer on average (Figure 2.1). Rainfall in the 12 months prior to the surveys was below long-term averages for most months, with the exception of January 2020, which recorded well above the long-term average for the month (Figure 2.1). This above average rainfall occurred as a result of multiple cyclones occurring in the north-west of Western Australia.

Observed temperatures during the survey was slightly above long-term averages on all days, with minimum temperature averaging 25.2°C (3.1°C above long-term average) and maximum temperature

averaging 35.4°C (3.5°C above long-term average) (BoM, 2020). No rainfall was recorded during the survey (BoM, 2020). The combination of above long-term average temperatures and above average rainfall recorded preceding the survey is likely to have resulted in ideal conditions for detecting the target species.

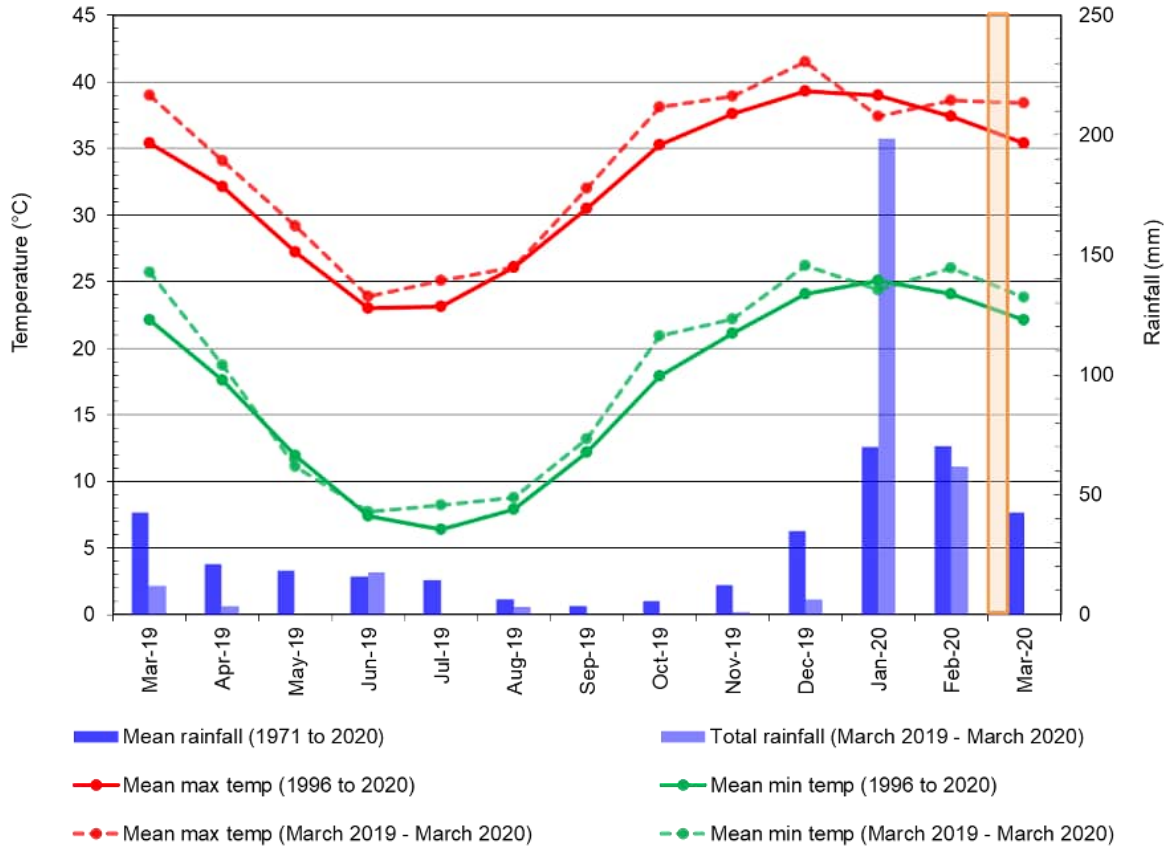


Figure 2.1: Long-term and current climatic data for Newman Aero (BoM, 2020) with approximate survey timing shown in orange shaded box

2.2.3 Sampling Techniques

The field survey was carried out in a manner consistent with the guidelines and recommendations listed in Section 1.3. Survey effort and sampling locations were selected based on a number of principles:

a) Survey effort was focused in areas deemed most likely to record the target species based on the type and quality of habitat present;
b) Survey effort was, where possible, spread across the Study Area to ensure adequate geographical coverage, though was constrained by access;
c) Survey effort focussed on areas that had not had any prior sampling effort; and
d) Sampling was often focussed at or near previous records of the target species, including within records from outside the Study Area, though within instances of the same habitat.

Habitat Assessments and Mapping

Habitat assessments were undertaken in the field to characterise and define habitats and their attributed relevance to vertebrate fauna, particularly in relation to species of conservation significance. Habitat assessments were undertaken at all sampling locations (*n* = 52) across the Study Area (Figure 2.2).

Habitat assessments were conducted and attributes assessed using attribute terminology prescribed by BHP, which have been modified from the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain, 2009). The characteristics recorded during the habitat assessments were:

- Site information, photo and location;
- Landform: slope, relative inclination of slope, morphological type and landform type;
- Vegetation: leaf litter %, wood litter, hollow bearing trees, broad floristic formation, vegetation structure (tall, mid and low), and dominant species;
- Land surface: micro relief, sheet erosion, rill erosion, gully erosion, gully depth, abundance and size of coarse fragments, rock outcropping, water bodies, comments on nests, burrows, roosts and diggings;
- Soil: texture, colour;
- Substrate: bare ground, rock size, rock type, rock outcropping; and
- Disturbance: time since last fire, evidence of weeds, grazing, or human disturbances.

Fauna habitat mapping was completed over the Study Area using the vertebrate fauna habitat assessments conducted during the field survey, as well as high-resolution aerial imagery, vegetation, topographical, land system and drainage mapping. Habitats were delineated and mapped across the Study Area at a scale of approximately 1:20,000.

Water Feature Assessments

Water feature assessments were conducted at 14 water features recorded within the Study Area comprising seven new water features recorded during the survey and seven water features identified during previous surveys in Study Area. The assessments were aimed to define and characterise the features and identify the likelihood of target species utilising them. The characteristics recorded during water feature assessments were:

- Dimensions: length, width, depth;
- Water presence: above the surface, in the intermediate zone;
- Location;
- Vegetation: obligate phreatophytes, emergent macrophytes;
- Presence of fauna;

Targeted Searches

Targeted searches were undertaken throughout the Study Area where habitats considered likely to support the target species occurred. Targeted searches comprised searching for occurrence of target species from direct observation, secondary evidence (i.e. tracks, scats, sloughs and foraging evidence)

and/or habitat features of importance to the target species (i.e. dens, roost caves and water features). Cave searching was focussed in areas that represented suitable cave forming geology, which also coincided with areas of suitable habitat for other target species (i.e. northern quoll and Pilbara olive python). During the survey, targeted searches were undertaken at 32 sites across the Study Area, for a total of approximately 61 person hours (Figure 2.2).

Preliminary assessment of targeted search areas was facilitated by a DJI Phantom 4 Remotely Piloted Aircraft (RPA). The RPA was used to conduct preliminary searches of habitats for important habitat features (i.e. caves for ghost bat and Pilbara leaf-nosed bat, and water features) and to locate suitable habitat for targeted searches (i.e. rocky terrain for northern quoll). Where prospective habitat was identified by the RPA, on-foot targeted searches were undertaken as a follow-up to search for evidence of the target species. Approximately 2.33 hours of RPA flight time was undertaken over seven flights at six locations (Figure 2.2).

Additionally, due to the overlap and close association of critical habitats for the target species, opportunistic sampling was also undertaken while completing other sampling methods, such as cave assessments, deployment of camera transects or eDNA sampling.

Northern Quoll Camera Transects

Targeted sampling for northern quoll was undertaken by deploying motion camera transects, which is the “recommended detection technique” of DoE (2016). Five northern quoll motion camera transects were established across the Study Area (Table 2.3; Figure 2.2). Transects were established within good examples of ‘critical habitat’ (as defined by DoE, 2016) such as Gorge/ Gully habitats. The configuration and sampling duration of motion camera sites also followed recommendations of DoE (2016). Each transect comprised ten motion cameras placed 50-100 metres apart and deployed for four nights, for a total of 200 sampling nights (Table 2.3; Figure 2.2). Cameras were baited with universal bait (a mixture of oats, peanut butter, and sardines) within a non-reward receptacle (perforated and capped PVC pipe).

Table 2.3: Camera locations within the Study Area

Site	Species targeted	Habitat	Latitude	Longitude	Trap Nights
VWER-10	Northern quoll	Gorge/ Gully	-23.3833	119.6146	40
VWER-15	Northern quoll	Gorge/ Gully	-23.4131	119.5688	40
VWER-16	Northern quoll	Gorge/ Gully	-23.3975	119.6599	40
VWER-17	Northern quoll	Gorge/ Gully	-23.3941	119.6171	40
VWER-18	Northern quoll	Gorge/ Gully	-23.4004	119.6261	40
				Total	**200**

Pilbara Leaf-nosed Bat and Ghost Bat Cave Assessments and Sheeting

In December 2019, three caves previously recorded within the Study Area were visited and assessed for the presence (primary or secondary) of ghost bat (CWER-01, CWER-02 and CWER-03). Where ghost bat scats were recorded within the caves, up to 20 scats were collected and a scat collection sheet (measuring approximately 18.3 m^2) was deployed - to collected fresh scats deposited between sampling events (i.e. between December 2019 and March 2020) and to assess the scat deposition

rates (the number of scats deposited divided by the number of sampling nights) over this period. Where fresh scats were deposited between surveys, up to 20 samples were collected when revisited during the March 2020 survey, for further analysis.

During the survey, cave assessments were conducted for every cave recorded within the Study Area (*n* = 19), comprising 12 newly discovered caves and seven caves previously recorded during other surveys (Figure 2.2). The cave assessments were designed to characterise the physical features of each cave and to identify the potential importance to the ghost bat and the Pilbara leaf-nosed bat. Each cave assessment recorded the following characteristics:

- Entrance location;
- Entrance photograph;
- Entrance type, position, aspect, exposure, width, and height;
- Floor slope;
- Cave depth;
- Chambers: main chamber height, and number of total chambers;
- Water presence;
- Indicative roost type; and
- Presence of target species: no. individuals, and/or secondary evidence.

Where access permitted, a selection of caves considered more significant or prospective for ghost bat and/or Pilbara leaf-nosed bat were also sampled using ultrasonic recorders (Table 2.4; Figure 2.2). The process by which a caves significance was assessed is outlined in Section 1.4.4.

Pilbara Leaf-nosed Bat and Ghost Bat Ultrasonic Recorders

Overnight recordings of bat echolocation calls were undertaken with Song Meter (SM; Wildlife Acoustics Inc.) ultrasonic bat recorders. Units were deployed at 17 locations, targeting areas where bat usage was assessed as likely to be highest, such as at the entrance of caves, at water features and within primary foraging habitats (Table 2.4; Figure 2.2). At each location, ultrasonic recordings were performed for between one and four nights, resulting in a total of 26 recording nights. The audio settings used for the SM units followed the manufacturer's recommendations (Wildlife Acoustics, 2011, 2017) and were set to account for all species known to occur within the region (McKenzie & Bullen, 2009). Recordings were analysed by Robert Bullen of Bat Call WA.

Table 2.4: Ultrasonic sampling locations within the Study Area

Site	Habitat Feature- ID	Habitat	Latitude	Longitude	Sampling Nights
VWER-01	Cave - CWER-01	Breakaway/ Cliff	-23.4127	119.5835	2
VWER-03	Cave - CWER-03	Gorge/ Gully	-23.3970	119.6607	2
VWER-10	Water Feature - WWER-01	Gorge/ Gully	-23.3833	119.6146	4
VWER-13	-	Gorge/ Gully	-23.3912	119.6381	1
VWER-17	Water Feature - WWER-07	Gorge/ Gully	-23.3941	119.6171	3
VWER-17	Water Feature - WWER-11	Gorge/ Gully	-23.3941	119.6171	1
VWER-19	-	Gorge/ Gully	-23.4102	119.5578	2
VWER-20	-	Breakaway/ Cliff	-23.3991	119.6382	1
VWER-25	-	Gorge/ Gully	-23.4091	119.5824	1
VWER-26	Cave - CWER-10	Gorge/ Gully	-23.4037	119.6605	1
VWER-28	Cave - CWER-14	Gorge/ Gully	-23.4117	119.6467	1
VWER-30	Water Feature - WWER-12	Stony Plain	-23.4007	119.6402	1
VWER-31	Cave - CWER-17	Gorge/ Gully	-23.4103	119.5716	2
VWER-35	Water Feature - WWER-13	Gorge/ Gully	-23.3972	119.6123	1
VWER-44	Cave - CWER-16	Gorge/ Gully	-23.4047	119.6053	1
VWER-45	-	Gorge/ Gully	-23.4023	119.5953	1
VWER-50	Water Feature - WWER-16	Gorge/ Gully	-23.3972	119.6141	1
				Total	**26**

Pilbara Leaf-nosed Bat and Ghost Bat VHF Monitoring Towers

A VHF towers were installed within the Study Area to feed into the existing Motus network established on BHP tenure elsewhere in the Pilbara region. The network has been established to study the movements of ghost bat and Pilbara leaf-nosed bat across and within BHP tenure, though no tracking was conducted as part of this assessment. The towers was installed in the central section of the Study Area (Figure 2.2). The tower comprised a single mast, measuring approximately 3 m in height, which was fitted with a 3 m high collinear omni-directional antenna.

Night Parrot Acoustic Recordings

Song Meter 4 acoustic recorders (SM4; Wildlife Acoustics, USA) were deployed to passively record bird calls through the night. Recorders were set in the most suitable roosting and nesting habitat occurring within the Study Area, including Stony Plain (*n* = 9), Drainage Area/ Floodplain (*n* = 2) and Hillcrest/ Hillslope (*n* = 1). The units were set to record between 0-20,000 Hz, using two built-in omnidirectional microphones, and were deployed off the ground (~1.5 to 2.0 m) to maximise the detection range. Each unit was preconfigured to record each night, between sunset and sunrise. Acoustic sampling for night parrots was undertaken at 12 locations (Table 2.5; Figure 2.2). At each location, acoustic recording was performed between five and six nights (as recommended by DPaW, 2017), resulting in a total of 66 recording nights (Table 2.5).

All recordings were analysed by ornithologist Nigel Jackett using Kaleidoscope Pro software (v5.1.8; Wildlife Acoustics, USA) and publicly available night parrot calls (Night Parrot Recovery Team, 2017) and call information (Jackett *et al.*, 2017; Leseberg *et al.*, 2019; Murphy *et al.*, 2017a).

Table 2.5: Acoustic sampling locations within the Study Area

Site	Habitat	Latitude	Longitude	Sampling Nights
VWER-04	Hillcrest/ Hillslope	-23.3816	119.6088	6
VWER-05	Stony Plain	-23.3902	119.5874	6
VWER-06	Stony Plain	-23.3967	119.5739	6
VWER-07	Drainage Area/ Floodplain	-23.4043	119.5849	6
VWER-08	Stony Plain	-23.4117	119.6215	6
VWER-09	Stony Plain	-23.4152	119.6326	6
VWER-11	Stony Plain	-23.4015	119.6401	5
VWER-12	Stony Plain	-23.3907	119.6401	5
VWER-14	Drainage Area/ Floodplain	-23.4159	119.6513	5
VWER-37	Stony Plain	-23.4213	119.5640	5
VWER-48	Stony Plain	-23.4059	119.5561	5
VWER-49	Stony Plain	-23.4079	119.5963	5
			Total	**66**

Pilbara Olive Python Nocturnal Searches

Nocturnal searches for the Pilbara olive python were conducted on the 15th March 2020 for a total of 14 person hours. Searches were conducted at two locations where the species had previously been recorded, as identified during the desktop assessment. Captured animals were processed at point of capture, during which standardised measurements were recorded (i.e. snout-vent length, tail length and weight) and overall general condition was assessed. A tissue sample (ventral scale clip) was collected from all captured individuals and stored in 100% ethanol for possible future genetic analysis. Any individuals captured were permanently marked for future identification using microchips, and following procedures developed by (DBCA, 2017b). Opportunistic road spotlighting and searches were also undertaken whilst driving between sites.

Table 2.6: Nocturnal searches completed within the Study Area

Site Name	Microhabitat (ID)	Habitat	Latitude	Longitude	Person hours
VWER-10	Water Feature (WWER-01 and WWER-04)	Gorge/ Gully	-23.3833	119.6146	9
VWER-17	Water Feature (WWER-06 and WWER-09)	Gorge/ Gully	-23.3941	119.6171	4
VWER-46	Road	Hillcrest/ Hillslope (adjacent to Gorge/ Gully)	-23.3927	119.6316	1
				Total	**14**

Pilbara Olive Python eDNA

Environmental DNA (eDNA) is a by-product of the metabolic process, derived from sources such as faeces, urine, scales mucous secretions and are recoverable from environmental substrates (i.e. water or substrate) (Huerlimann *et al.*, 2020). The extraction of eDNA has emerged as a novel sampling technique in the realm of environmental surveying, monitoring and conservation with potentially greater sensitivity in detecting rare and cryptic species (Bylemans *et al.*, 2019; Harper *et al.*, 2018; Huerlimann *et al.*, 2020).

Water samples were collected at eight water features (not including one water feature sampled twice) within the Study Area to maximise the detection of Pilbara olive python (Table 2.7). Two collection methods and associated analyses (i.e. quantitative polymerase chain reaction (qPCR) and PCR (PCR) plus DNA metabarcoding) were undertaken for a total of 52 eDNA samples. The number of samples and total water volume filtered at each site was dependent on the sampling method used, the abundance of water available for sampling and accessibility to the water feature (Table 2.7).

To provide a baseline comparison data of each sampling and analysis method, two trial sampling events were completed for each method, one positive control sample purposely contaminated using a captive olive python specimen and a negative control with no olive python contamination. Both trial methods confirmed the presence of olive python within the positive control samples, verifying that both techniques can accurately detect the species via the field sampling methods.

Table 2.7: Pilbara olive python eDNA sampling locations within the Study Area

Site Name	Sample Date	Habitat	Latitude	Longitude	Collection Method and Analyses (# samples)		eDNA samples
					EnviroDNA (qPCR)	Edna Frontiers (PCR + metabarcoding)	
WWER-01	15/03/20	Gorge/ Gully	-23.3832	119.6145	3	5	8
WWER-04	15/03/20	Gorge/ Gully	-23.3825	119.6136	3	5	8
WWER-05	13/03/20	Gorge/ Gully	-23.3949	119.6174	3	N/A	3
WWER-07 (Day 0)	13/03/20	Gorge/ Gully	-23.3944	119.6172	3	5	8
WWER-07 (Day 3)	16/03/20	Gorge/ Gully	-23.3944	119.6172	3	N/A	3
WWER-11	13/03/20	Gorge/ Gully	-23.3943	119.6196	3	5	8
WWER-13	15/03/20	Gorge/ Gully	-23.3971	119.6122	3	N/A	3
WWER-14	15/03/20	Gorge/ Gully	-23.3967	119.6135	3	5	8
WWER-16	15/03/20	Gorge/ Gully	-23.3972	119.614	3	N/A	3
						Total	**52**

Quantitative polymerase chain reaction analysis: EnviroDNA

Using a 60 millilitres (mL) disposable syringe, water from a site was drawn up and pushed through a 0.22 µm filter (Sterivex) units until no more water could be pushed through the filter (ranged from 40560 mL, average 157 mL). This was repeated until three filter units were processed per site. Approximately 30-50 mL of ethanol was then pushed through each of the filter units to preserve the DNA. The samples from each site were then placed into a labelled ziplock bag, stored on ice until moved to a 20ºC freezer at the end of the day. Subsequent analysis was completed by EnviroDNA (see Appendix C for a detailed description of analysis techniques).

EnviroDNA have generally defined a positive result via a minimum threshold of three positive replicates out of nine to rule out the potential effects of cross-contamination and false positives and thus, confidently determine the site as positive for a species eDNA. Therefore, sites were defined as equivocal (one or two out of nine replicates returned positive results at a site). Equivocal results indicate

that trace amounts of DNA are present and results from: (a) the species being present in low abundance; (b) the species being present for only a short period; (c) the species leaving little genetic material behind; (d) facilitated movement of DNA between waterbodies (such as by water birds, water transfers, predator scats); (e) DNA degradation one account of oxygen exposure and/ or high temperatures (Huerlimann *et al.*, 2020) (rock pools in the Pilbara would commonly be exposed to such conditions) and; (f) sample contamination through the sampling or laboratory screening process. Non-avian reptiles (possessing a keratinised integument) are unlikely to shed eDNA at comparable rates to other vertebrates (possessing a mucous integument). Moreover, reptiles are likely to shed integument in large fragments that will sink to the bottom of the water feature and are consequently less likely to be detected (Adams *et al.*, 2019). Moreover, there is currently no guidance on the number of replicates requiring positive results to conclude a positive result at a site (Harper *et al.*, 2018).

Polymerase chain reaction analysis: eDNA Frontiers (Curtin University)

Five 1L sampling bottles were rinsed internally with site water. The sample bottles were then filled with water from the site and stored upright in a cooler of ice. At the end of the sampling day, the water samples were passed through a filter membrane using a powered Sentino Magnetic Filter Funnel. As a control, a sample of the water used to rinse the filtering equipment (after it had been sterilised in a 10% bleach solution) was also passed through a filter membrane. Once the water had been filtered, the filter membrane was folded, placed into a sample bag and stored at approximately -20^{o}C until it could be delivered to eDNA Frontiers for analysis (see Appendix D for a detailed description of analysis techniques).

Opportunistic Records

At all times while surveying, all records pertaining to species of conservation significance, particularly target MNES species were documented. These records include those from primary (i.e. direct observation of species) or secondary (e.g. burrows, scratching's, diggings, and scats) evidence.

2.3 Assessment of Significance

2.3.1 Fauna Habitats

Habitats mapped within the Study Area were compiled and used to delineate critical habitat for each of the target species. For the purposes of this assessment, critical habitat followed that of DoE (2013), being areas necessary "for activities such as foraging, breeding, roosting, or dispersal". Within these categories, habitat types were recognised as providing primary habitat (i.e. critical habitat as per the definition above), or secondary habitat (i.e. habitats not critical for foraging, breeding, roosting or dispersal, but may support such activities and/ or habitats of marginal suitability for such activities). Due to differing habitat preferences of conservation significant species (including habitat features and/or microhabitats), habitat significance was assessed on a species by species basis.

It should be noted that assessment of habitat significance applies only to habitat occurring within the Study Area, and therefore may not be representative of significance applied to the same habitat in other areas outside the Study Area. For example, a habitat within the Study Area may be deemed unsuitable

due to the absence of certain habitat features which are required for the species persistence, despite the same habitat occurring outside the Study Area being considered of greater significance. The significance of a habitats within the Study Area may also be influenced by other habitats occurring within the Study Area and more broadly, including areas adjacent to the Study Area, particularly if representative of primary habitat.

2.3.2 Habitat Features – Caves

Each cave identified from the field surveys was categorised based on data from the cave assessments, including the presence of any target bat species via primary or secondary (i.e. scats and individual remains) evidence and follow-up sampling such as via ultrasonic recorders. 'Potential' categories were used to depict the highest likely category based on the information collected, though insufficient information has been recorded to confirm (e.g. Potential Diurnal Roost contains attributes and/or evidence to suggest diurnal roosting, though no diurnal roosting has been confirmed). Non-potential caves were confirmed to be used for that purpose and unlikely to be used for any higher purpose. Each cave was classified based on definitions defined in Section 1.4.3 and Section 1.4.4 for each of the respective species.

The categories of significance for Pilbara leaf-nosed bats followed the prioritisation outlined by (TSSC, 2016b). The following cave categories were used (in order of priority for the species) as defined in Section 1.4.3:

- Permanent Diurnal Roosts;
- Non-Permanent Breeding Roosts;
- Transitory Diurnal Roosts; and
- Nocturnal Refuge.

For ghost bats, the five cave categories defined in Section 1.4.4 were used, in increasing order of significance:

- Maternity Roosts;
- Potential Maternity Roosts;
- Day Roosts;
- Potential Day Roosts;
- Night Roosts; and
- Potential Night Roosts.

2.3.3 Significance of Occurrence

For the target species, an assessment was made on the significance of their occurrence based on the most relevant and prescriptive guidance documents relative to each species. For northern quoll the significance of occurrence was based on definitions of the DoE (2016), specifically whether the individuals present in the Study Area were representative of a "population important for the long-term survival of the northern quoll". These are populations that are:

- high density quoll populations, which occur in refuge-rich habitat critical to the survival of the species, including where cane toads are present;
- occurring in habitat that is free of cane toads and unlikely to support cane toads upon arrival i.e. granite habitats in WA, populations surrounded by desert and without permanent water; and/ or
- subject to ongoing conservation or research actions i.e. populations being monitored by government agencies or universities or subject to reintroductions or translocation.

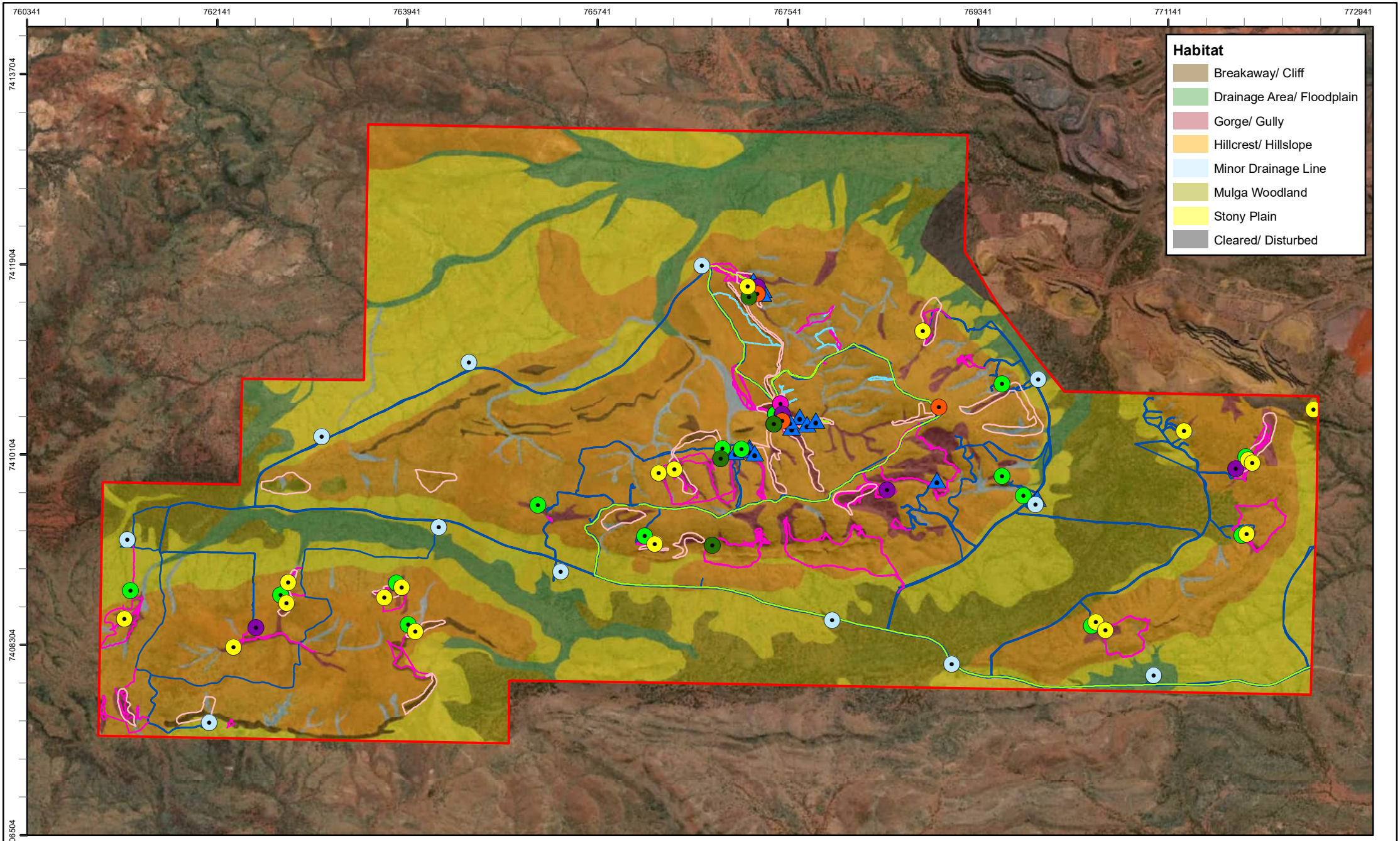
For the greater bilby, ghost bat and Pilbara olive python (species listed as vulnerable under the EPBC Act, but with no specific criteria to assess significance of occurrence), the significance of occurrence was based on criteria defined by DoE (2013), specifically whether their occurrence in the Study Area represented a 'important population'. An 'important population' is a population that is necessary for a species' long-term survival and recovery - this may include populations identified as such in recovery plans, and/or that are DoE (2013):

- key source populations either for breeding or dispersal;
- populations that are necessary for maintaining genetic diversity, and/or
- populations that are near the limit of the species range.

For the Pilbara leaf-nosed bat, the entire Pilbara is suggested to represent an 'important population', thus the significance of occurrence was based on the presence of Priority 1 and 2 refuges (Permanent Diurnal Roosts and Non-permanent Breeding Roosts), as stipulated by TSSC (2016b).

For the night parrot, the significance of occurrence was based on definitions by the DoE (2013), specifically the presence of a 'population'. A 'population of a species' is defined under the EPBC Act as an occurrence of the species in a particular area, including, but are not limited to:

- a geographically distinct regional population, or collection of local populations, or
- a population, or collection of local populations, that occurs within a particular bioregion.



Legend

- Study Area

Sampling Method

- Acoustic Recorder
- eDNA Sampling
- Cave Assessments
- Nocturnal Search
- Camera Transect
- Omni-directional Tower
- Ultrasonic Recorder
- Water Feature Assessment

Searches

- Driving Tracks
- Drone
- Biologic (2011) Targeted Searches
- Spotlighting Tracks
- Targeted Searches

biologic Environmental Survey

N

1:45,000

0 0.5 1 2 km

BHP WAIO

Western Ridge Target Fauna Survey

Figure 2.2: Vertebrate Fauna Sampling Sites

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 14/02/2020

3 RESULTS AND DISCUSSION

3.1 Fauna Habitats

A total of seven broad fauna habitat types were mapped across the Study Area, comprising, in order of occurrence, Hillcrest/ Hillslope, Stony Plain, Mulga Woodland, Drainage Area/ Floodplain, Gorge/ Gully, Minor Drainage Line and Breakaway/ Cliff (Table 3.1, Figure 3.1). Of the seven broad fauna habitats occurring within the Study Area, Hillcrest/ Hillslope was the dominant habitat type covering approximately 40.6 % (1,936.6 ha), followed by Stony Plain (30.3%, 1,444.8 ha), Mulga Woodland (11.7%, 555.5 ha), Drainage Area/ Floodplain (9.8%, 468.8 ha), Gorge/ Gully (3.5%, 165.7 ha), Minor Drainage Line (2.1%, 101.7 ha) and Breakaway/ Cliff (1.1%, 53.1 ha) (Table 3.1; Figure 3.1). The remaining 0.8% (48.8 ha) of the Study Area comprised disturbed areas from current mining and exploration operations (Table 3.1; Figure 3.1).

Table 3.1: Habitat types and descriptions within the Study Area

Habitat type and extent	Detailed habitat description	Critical habitat for target MNES species	Representative photo
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.	• **Northern quoll** –secondary breeding, foraging and/or dispersal (if proximal to primary habitat) • **Pilbara olive python** – secondary denning/shelter habitat, secondary foraging and/or dispersal (if proximal to primary habitat)	
Stony Plain • 1,444.8 ha • 30.3%	Stony Plain habitat comprises flat to low undulating areas with vegetation dominated by *Triodia* hummock grasses of various life stages and scattered patches of various small to medium shrub species on gravelly clay loam substrates. A Turkeys nest is located in this habitat.	• **Night parrot** – secondary roosting/nesting • **Ghost bat** – secondary foraging and dispersal (where proximal to primary roosting and breeding habitat)	

Habitat type and extent	Detailed habitat description	Critical habitat for target MNES species	Representative photo
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.	• **Ghost bat** – primary foraging and/or dispersal	
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.	• **Ghost bat** – primary foraging and dispersal • **Night parrot** – secondary roosting/nesting	

Habitat type and extent	Detailed habitat description	Critical habitat for target MNES species	Representative photo
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.	• **Northern quoll** – primary breeding, foraging and dispersal • **Pilbara leaf-nosed bat** – primary foraging • **Ghost bat** – primary roosting, breeding, and foraging • **Pilbara olive python** – primary breeding and foraging	
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.	• **Northern quoll** – primary foraging and dispersal (if proximal to primary denning habitat) • **Pilbara leaf-nosed bat** – primary foraging and dispersal (if proximal to primary foraging habitat e.g. Gorge/ Gully) • **Ghost Bat** – primary foraging and/or dispersal (if proximal to primary roosting and breeding habitat) • **Pilbara olive python** – primary foraging and/or dispersal (if proximal to primary breeding and other foraging habitat habitat)	

Habitat type and extent	Detailed habitat description	Critical habitat for target MNES species	Representative photo
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.	• **Northern quoll** – primary breeding, foraging and dispersal • **Pilbara leaf-nosed bat** – secondary foraging • **Ghost bat** – primary roosting, breeding, and foraging • **Pilbara olive python** – primary breeding and foraging	
Disturbed/ Cleared • 38.8 ha • 0.8%	Mount Whaleback pit area	N/A	-

3.2 Habitat Features

3.2.1 Caves

Caves can be important features within a landscape, particularly in arid zone systems, often providing stable microclimates, shelter and protection (Medellin *et al.*, 2017). A total of 19 have been recorded within the Study Area, comprising 12 caves discovered during the current survey and seven recorded during previous surveys (Table 3.2). Of the 19 caves recorded within the Study Area, 17 occur within Gorge/ Gully habitat, and two within Breakaway/ Cliff habitat (Table 3.2; Figure 3.1). With consideration of overall cave searching survey effort and the extent of these habitats within the Study Area (Figure 2.2; Figure 3.4; Figure 3.5), it is possible additional caves occur within the Study Area which were not located during the current or past surveys, particularly within Gorge/ Gully habitat.

Ultrasonic recorders were placed at six caves (see section 2.2.3) during the survey. Four ghost bat echolocation calls were detected at one cave (CWER-03) on the night of the 12th of March. These calls likely represent foraging bats as no ghost bat individuals were observed when Biologic personnel inspected the cave that day. However, this cave is a confirmed diurnal roost for the species, as individuals have been observed roosting within the cave during previous surveys (Biologic, 2011, 2017); most recently, one ghost bat was observed within the cave on 12 December 2019. No Pilbara leaf-nosed bats were recorded from ultrasonic recordings during the current survey; however, it should be noted that recorders were not deployed at all caves, so the lack of calls recorded does not indicate species absence.

In total, ghost bat were observed via direct observation or secondary evidence in seven of the 19 caves assessed during the survey (including sampling completed in December 2019) (Table 3.2). The species was recorded from direct observation of a single individual at one cave (CWER-02) and from scats at all seven, with scat abundance per cave ranging from 8 to 500 (Table 3.2). Of the 19 caves recorded within the Study Area, one was considered a maternity roost, one was identified as a potential maternity roost (and confirmed diurnal roost), three as potential diurnal roosts, five as night roosts and five as potential night roosts (Table 3.2; Figure 3.5; Appendix A). The remaining four caves showed no evidence of usage by the ghost bat and are unlikely to be suitable for the species.

The Pilbara leaf-nosed bat has not been recorded at any caves within the Study Area, though all caves were considered possible nocturnal refuges for the species (Table 3.2; Appendix A). It should be noted that one cave (CWER-05) was not accessible in its entirety due to internal structuring of the cave (comprising a small tube at rear which curved around a corner) and bat presence could not be assessed; however, the cave did present an odour consistent with caves utilised by bats (Table 3.2).

Two caves, CWER-01 and CWER-03, form part of a regional ghost bat monitoring program and have recorded continued diurnal roosting activity by ghost bat between 2016 and 2019 (Table 3.2, Table 3.3). Elevated levels of progesterone (>970 ng/g) (Keeley, 2016 found that presumed non-pregnant bats averaged 201.1 ± 127.9 ng/g and presumed pregnant bats averaged 3,330.1 ± 2,314.9 ng/g) indicating presence of pregnant and/or lactating females, was also recorded from scats collected from CWER-01

in 2016 through to 2019, indicating its use as maternity roost (Biologic, 2018, 2020b). This continued use as a diurnal roost and maternity roost highlights the local and regional significance of the cave, particularly given their location relative to the species distribution, most south-eastern extent.

Table 3.2: Summary of caves recorded in Study Area

Cave ID	New/ Revisited	Coordinates		Habitat	Ghost Bat		Pilbara Leaf-nosed Bat	
		Latitude	Longitude		Records	Significance	Records	Significance
CWER-01	Originally OB35 Cave 2	-23.4127	119.5835	Breakaway/ Cliff	**Previous**: Small number of ghost bat scats present. Likely day roost (Biologic, 2011). As part of the South Flank monitoring, 2 Individual ghost bat and a total of 95 scats over two surveys were recorded in 2016 (Biologic, 2018), 2 Individual ghost bat, a total of 1,181 scats over four surveys in 2017 and 2018 (Biologic, 2020a) and a total of 69 scats over six surveys in 2019 (Biologic, 2020b). Elevated levels of progesterone recorded from scats collected during 2016 and 2019 monitoring, indicating use by pregnant and/or lactating females and as a maternity roost (Biologic, 2018, 2020b). **Current**: 14 recent scats (December 2019)	Maternity Monitoring shows continued uses by ghost bats and important local context (Biologic, 2020b)	Nil	Potential Nocturnal Refuge
CWER-02	Originally OB35 Cave 6	-23.3923	119.6663	Breakaway/ Cliff	**Previous**: Five scats present (Biologic, 2011) **Current**: 2 recent scats (December 2019)	Night Roost	N/A	Potential Nocturnal Refuge
CWER-03	Originally OB35 Cave 1	-23.3970	119.6607	Gorge/ Gully	**Previous**: Two ghost bats recorded in second phase. Large pile of ghost bat scats (Biologic, 2011). As part of the South Flank monitoring, 1 Individual ghost bat, 19 scats were recorded in May 2016 (Biologic, 2017) and 10 scats were recorded in October 2016 (Biologic, 2018). **Current**: 1 Individual ghost bat observed, 500 fresh scats (December 2019), four calls in succession at 0345AM (March 2020)	Confirmed Diurnal Roost, Potential Maternity (deep, dark cave with large scat piles stereotypical of maternity caves)	Nil	Potential Nocturnal Refuge
CWER-04	New	-23.3967	119.6603	Gorge/ Gully	Nil	Night Roost	N/A	Potential Nocturnal Refuge
CWER-05	New	-23.4120	119.5566	Gorge/ Gully	Nil	No Usage	N/A	Potential Nocturnal Refuge
CWER-06	Originally OB35 Cave 10	-23.3827	119.6137	Gorge/ Gully	**Current**: 8 old scats	Night Roost	N/A	Potential Nocturnal Refuge

Cave ID	New/ Revisited	Coordinates		Habitat	Ghost Bat		Pilbara Leaf-nosed Bat	
		Latitude	Longitude		Records	Significance	Records	Significance
CWER-07	Originally OB35 Cave 7	-23.4098	119.5806	Gorge/ Gully	Nil	Potential Night Roost (Biologic, 2014b)	N/A	Potential Nocturnal Refuge
CWER-08	New	-23.3862	119.6300	Gorge/ Gully	Nil	No Usage	N/A	Potential Nocturnal Refuge
CWER-09	Originally OB35 Cave 9	-23.4104	119.5716	Gorge/ Gully	Nil	Potential Night Roost (Biologic, 2014b)	N/A	Potential Nocturnal Refuge
CWER-10	New	-23.4030	119.6603	Gorge/ Gully	**Current**: 10 old scats	Potential Diurnal Roost	Nil	Potential Nocturnal Refuge
CWER-11	New	-23.4142	119.5667	Gorge/ Gully	Nil	No Usage	N/A	Potential Nocturnal Refuge
CWER-12	New	-23.4108	119.6465	Gorge/ Gully	Nil	Night Roost	N/A	Potential Nocturnal Refuge
CWER-13	Originally OB35 Cave 8	-23.4089	119.5822	Gorge/ Gully	Nil	Potential Night Roost (Biologic, 2014b)	N/A	Potential Nocturnal Refuge
CWER-14	New	-23.4115	119.6474	Gorge/ Gully	**Current**: 9 old scats	Night Roost	Nil	Potential Nocturnal Refuge
CWER-15	New	-23.3944	119.6543	Gorge/ Gully	Nil	Potential Night Roost	N/A	Potential Nocturnal Refuge
CWER-16	New	-23.4048	119.6056	Gorge/ Gully	**Current**: 50 recent scats	Potential Diurnal Roost	Nil	Potential Nocturnal Refuge
CWER-17	New	-23.4087	119.5717	Gorge/ Gully	Nil	Potential Diurnal Roost	Nil	Potential Nocturnal Refuge
CWER-19	New	-23.3987	119.6058	Gorge/ Gully	Nil	No Usage	N/A	Potential Nocturnal Refuge
CWER-20	New	-23.3984	119.6072	Gorge/ Gully	Nil	Potential Night Roost	N/A	Potential Nocturnal Refuge

Table 3.3: Previous monitoring conducted at CWER-01 and CWER03

Cave ID	Monitoring Year	Date	Total Scats on Sheets	Deposition Rate (scats/day)	Number of Ghost Bats Present	Scats with elevated Progesterone (Pregnant Individuals)	Range of observed elevated progesterone (ng/g)
CWER-01	2016-2017 (Biologic, 2018)	14/10/16	0	0*	2	5%	1,403.0–2,122.5
		13/12/16	60	1	0		
	2017-2018 (Biologic, 2020a)	20/10/17	65	0.21	0	80%	989.6–2,7081.7
		9/01/18	2	0.02	0	N/A	N/A
		23/07/18	60	0.86	0	58%	1,280.0–9,266.4
		14/05/18	1,000	8	2	N/A	N/A
	2018-2019 (Biologic, 2020b).	19/02/19	5	0.02	0	20%	1,768.4
		27/05/19	50	0.52	0	18%	1,645.0–3,207.3
		12/08/19	0	0	0	N/A	N/A
		8/10/19	0	0	0	N/A	N/A
		6/11/19	0	0	0	N/A	N/A
		2/12/19	14	0.54	0	50%	2,451.4–9,454.6
CWER-03	2015-2016 (Biologic, 2017)	13/05/16	19	-	1	N/A	N/A
	2016-2017 (Biologic, 2018)	14/10/16	10	0.1	0		N/A
		13/12/16	0	0	0		N/A

3.2.2 Water Features

Water sources are a limiting factor for many ecosystems (James *et al.*, 1995), particularly within arid-zone ecosystems such as the Pilbara (Burbidge *et al.*, 2010; Doughty *et al.*, 2011) and often represent areas of comparatively high ecological productivity (Murray *et al.*, 2003). These features are highlighted because they may provide important sources of food and water for the target species.

Water features have varying levels of significance to the target species of this assessment (Table 3.4). For northern quolls, they often represent areas of high productivity, and therefore may contain a relatively high abundance of feeding resources (Braithwaite & Griffiths, 1994; Oakwood, 2000), when in suitable habitat - rocky habitats, and to a lesser degree, drainage lines. For Pilbara leaf-nosed bats they can provide significant drinking and foraging sources, and are a key component to 'Gorges with Pools' being recognised as the priority foraging habitat for the species (TSSC, 2016b). For Pilbara olive pythons, these features can often act as primary foraging locations and for that reason the species is more often than not, associated with such features, particularly within rocky habitats, but also, to a lesser degree within drainage habitats (Pearson, 1993). Additionally, some water bodies may provide drinking sources for the night parrot when in close proximity to nesting locations and within suitable foraging habitat, however the dependency of the species to such features is relatively unknown (Kearney *et al.*, 2016; Murphy *et al.*, 2017b).

During the current survey, 14 water features were recorded; two were seeps, two were rock pools fed by a seep and the remaining were surface water rock pools (Table 3.4; Figure 3.1). With the exception of one artificial water feature (Turkeys nest in Stony Plain habitat), all water features occurred within Gorge/ Gully habitat (Table 3.4; Figure 3.1). With consideration of overall survey effort for water features and Study Area coverage (Figure 2.2), it is possible that additional water features occur within the Study Area, particularly within Gorge/ Gully and Minor Drainage Line habitats (Figure 3.1).

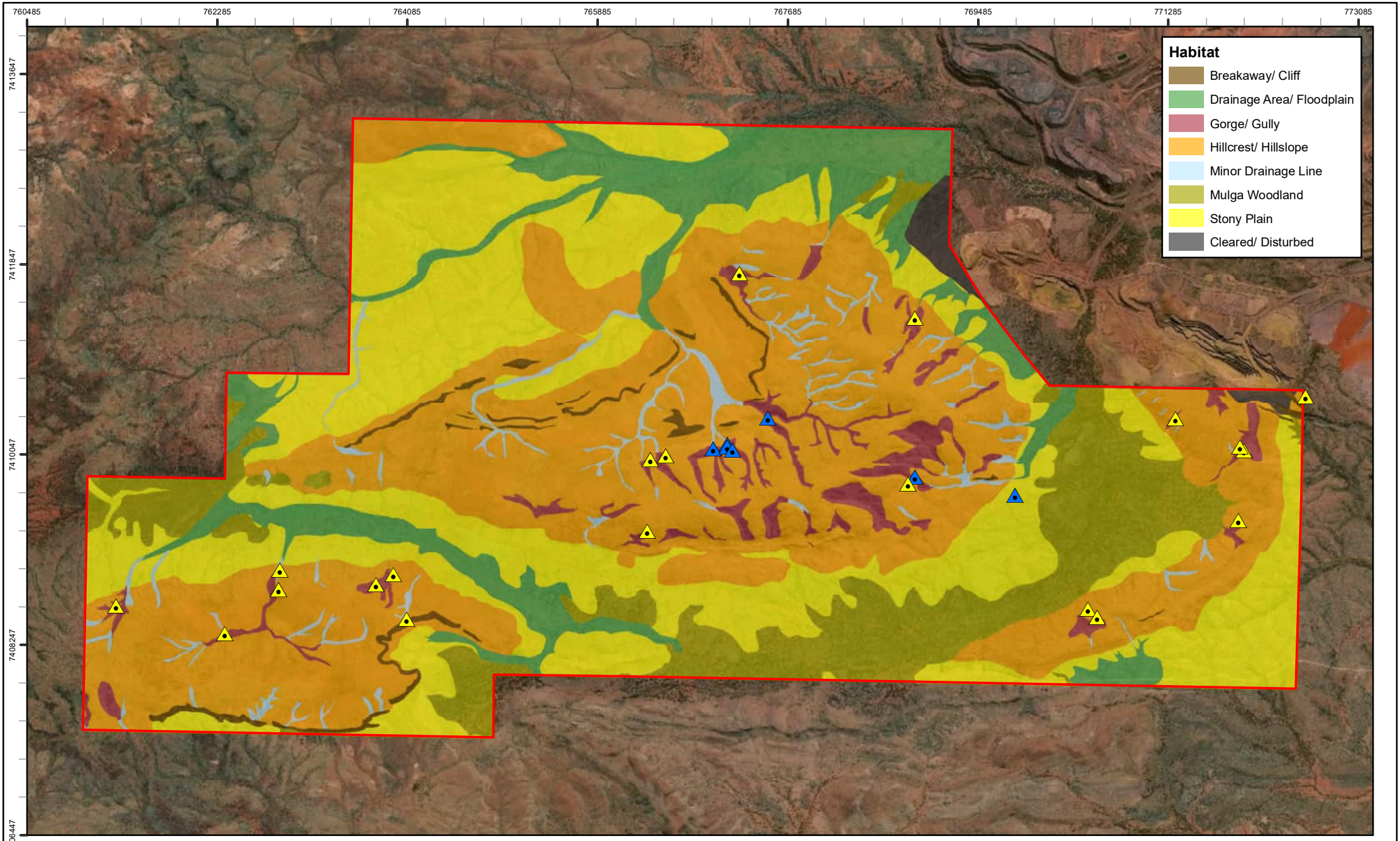
The two seep fed rock pools (WWER-01 and WWER-04) are considered to be of high significance to the northern quoll, ghost bat, Pilbara leaf-nosed bat and Pilbara olive python as they are likely to provide core foraging habitat for all of or for the majority of the year. As no ground water dependant vegetation was observed it is unclear whether these pools are permanent. However, during an opportunistic visit in December 2019 (end of the dry season) water was still observed at these two pools suggesting they may be permanent for most of the year and/or most years. One Pilbara olive python was observed within the gorge containing these two pools during a nocturnal search on the 15th of March. Moreover, eDNA belonging to the species was detected within WWER-04 and within WWER-01.

The remaining 12 water features provide habitat of moderate significance to the northern quoll, ghost bat, Pilbara leaf-nosed bat and Pilbara olive python as they are likely to provide foraging habitat, albeit only for a temporary period. Of these 12 water features, six were sampled for Pilbara olive python eDNA and five contained evidence of the species.

Table 3.4: Water features recorded in the Study Area

Water Feature ID	Description	Coordinates		Habitat	New/ Revisited	Occurrence of MNES Species			
		Latitude	Latitude			Northern Quoll	Pilbara Leaf-Nosed Bat	Ghost Bat	Pilbara Olive Python
WWER-01 (Afghan Pool – downstream of WWER-02)	Seep Fed Rock Pool	-23.3832	119.6145	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not detected	Not detected	Targeted search – not detected eDNA (EnviroDNA) – equivocal eDNA (eDNA Frontiers) – negative
WWER-02 (Afghan Pool - upstream)	Rock Pool	-23.3835	119.6145	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA – not sampled
WWER-04 (Afghan Pool - downstream)	Seep Fed Rock Pool	-23.3825	119.6136	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not sampled	Not sampled	Targeted search - recorded (live individual) eDNA (EnviroDNA) – positive eDNA (eDNA Frontiers) – positive
WWER-05	Rock Pool	-23.3949	119.6174	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA (EnviroDNA) – negative eDNA (eDNA Frontiers) – not sampled
WWER-06	Seep	-23.3940	119.6181	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA – not sampled
WWER-07	Rock Pool	-23.3944	119.6172	Gorge/ Gully	New	Not detected	Not detected	Not detected	Targeted search - recorded (live individual) eDNA (EnviroDNA) – equivocal eDNA (eDNA Frontiers) – positive
WWER-09	Seep	-23.3946	119.6188	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA – not sampled
WWER-10	Rock Pool	-23.3992	119.6309	Gorge/ Gully	New	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA – not sampled
WWER-11	Rock Pool	-23.3943	119.6196	Gorge/ Gully	Revisited (discovered by Biologic, 2011)	Not detected	Not detected	Not detected	Targeted search - not detected eDNA (EnviroDNA) – negative eDNA (eDNA Frontiers) – positive

Water Feature ID	Description	Coordinates		Habitat	New/ Revisited	Occurrence of MNES Species			
		Latitude	Latitude			Northern Quoll	Pilbara Leaf-Nosed Bat	Ghost Bat	Pilbara Olive Python
WWER-12	Artificial/ Turkeys Nest	-23.4006	119.6402	Stony Plain	N/A	Not detected	Not detected	Not detected	Targeted search - not detected eDNA – not sampled
WWER-13	Rock Pool	-23.3971	119.6122	Gorge/ Gully	New	Not detected	Not detected	Not detected	Targeted search - not detected eDNA (EnviroDNA) – positive eDNA (eDNA Frontiers) – not sampled
WWER-14	Rock Pool	-23.3967	119.6135	Gorge/ Gully	New	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA (EnviroDNA) – negative eDNA (eDNA Frontiers) – positive
WWER-15	Rock Pool	-23.3969	119.6135	Gorge/ Gully	New	Not detected	Not sampled	Not sampled	Targeted search - not detected eDNA – not sampled
WWER-16	Rock Pool	-23.3972	119.614	Gorge/ Gully	New	Not detected	Not detected	Not detected	Targeted search - not detected eDNA (EnviroDNA) – equivocal eDNA (eDNA Frontiers) – not sampled



Legend

StudyArea

Habitat Feature

Cave

Water

biologic Environmental Survey

N

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BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.1: Habitat Features Recorded within the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 8/05/2020

3.3 Occurrence of Fauna

Of the six species targeted during this assessment, two have been confirmed as occurring within the Study Area prior to the assessment, ghost bat and Pilbara olive python. Three targeted species were recorded during the current survey; northern quoll, ghost bat and Pilbara olive python. Additionally, the Pilbara leaf-nosed bat was recently recorded 50 m south of the Study Area in December 2019 (Biologic, 2020c) and is deemed highly likely to occur within the Study Area as foraging or transient individuals. The remaining two species, greater bilby, and night parrot are deemed unlikely to occur based on the lack of suitable habitat occurring within the Study Area and absence of any nearby contemporary records.

3.3.1 Northern Quoll

Previous Records

The Study Area falls within the current distribution of the northern quoll, whereby the species or species habitat may occur (DoEE, 2019b). The nearest northern quoll record to the Study Area is located approximately 52 km west of the Study Area, dated 2014 (DBCA, 2020a); however, a 2007 record of a roadkill juvenile individual was reported from the main access bridge into Whaleback, located approximately 5.5 km north east of the Study Area (Onshore & Biologic, 2009a). This roadkill record from Whaleback represents the south-eastern limit of the species occurrence in the Pilbara region (DBCA, 2020a).

Current Survey

Three northern quoll scats were recorded from within two caves in Gorge/ Gully habitat, CWER-10 (located near the eastern edge of the Study Area) and CWER-16 (located centrally in the Study Area, along the southern edge of Western Range), while conducting targeted searches during the current survey (Table 3.5; Figure 3.2; .Appendix F). Scats were sent to Georgeanna Story (Scats About) to confirm identification. One scat collected from Cave CWER- 10 was confirmed as northern quoll and was determined to be greater than 12 months old. The remaining two scats were determined to be probable northern quoll; however, due to their very old age (>24 months) and degraded condition, identification couldn't not be confirmed (Table 3.5). The occurrence of a certain northern quoll scat within the same cave as one of the probable scats provides greater confidence in the probability that the very old scat was also northern quoll.

Camera transects across five sites for a total of 200 sampling nights did not record any northern quoll. With consideration of the limited evidence of northern quoll occurrence within the Study Area and in the vicinity of the Study Area, in addition to the age and condition of scats collected, it's likely that the scats collected during the current survey represent historic occupation, transient individuals or a declining population that no longer or rarely occurs within the Study Area. Some preservation of scats is likely to have occurred due to the stable microclimate occurring within the caves that samples were collected from. Furthermore, scats potentially belonging to a regionally extinct species, the Lesser Stick Nest Rat (*Leporillus apicalis*), were also recorded from one cave (CWER-10), highlighting the potential for scats to be preserved in better condition and retained in these cave environments.

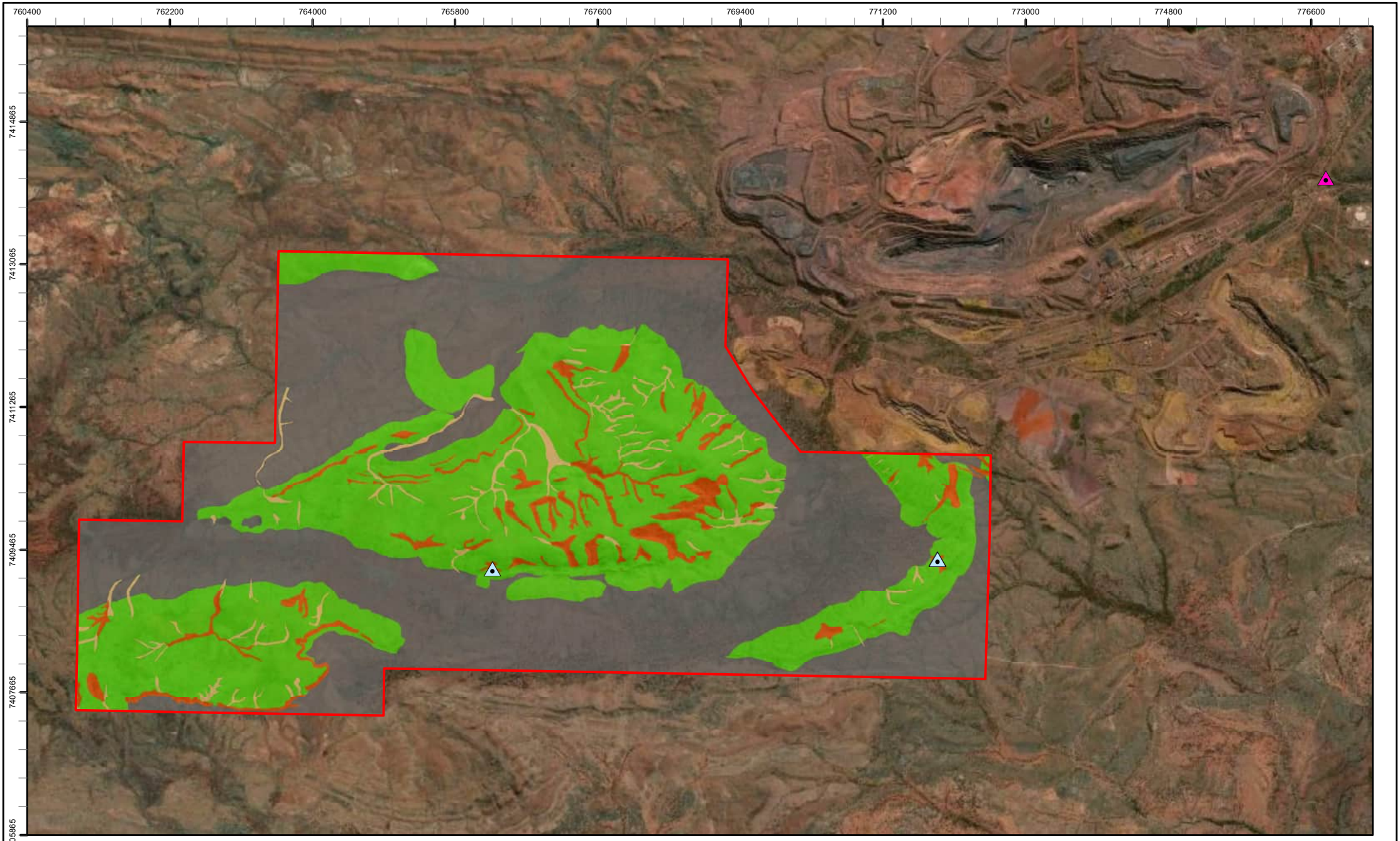
Table 3.5: Northern Quoll recorded in the Study Area

Site	Record Type	Habitat	Latitude	Longitude	Age
VWER-26 (Cave CWER-10)	Scat (certain)	Gorge/ Gully	-23.4030	119.6603	Old (>12 months)
VWER-44 (Cave CWER-16)	Scat (probable)	Gorge/ Gully	-23.4051	119.6055	Very Old
VWER-26 (Cave CWER-10)	Scat (probable)	Gorge/ Gully	-23.4031	119.6604	Very Old

Habitats Within the Study Area

Critical habitat for the northern quoll includes rocky habitats such as ranges, escarpments, mesas, gorges, breakaways, boulder fields, major drainage lines or treed creek lines, and provides shelter for breeding, and refuge from fire or predators (DoE, 2016). Within the Study Area, the Gorge/Gully, Breakaway/ Cliff, Hillcrest/ Hillslope and Minor Drainage Line meet the definition of critical habitat (Figure 3.2). The suitability and significance of these habitats for northern quoll within the Study Areas does however vary (Table 3.1). Rocky habitats tend to support higher densities, as they offer protection from predators and are generally more productive in terms of availability of resources (Braithwaite & Griffiths, 1994; Oakwood, 2000) and in the Pilbara provide a higher abundance of possible denning features (Hernandez-Santin *et al.*, 2016). Gorge/ Gully habitat (3.5%, 165.7 ha) and Breakaway/ Cliff (1.1%, 53.1 ha) within the Study Area, is limited in extent throughout the Pilbara and provides high density denning features and rich foraging areas. As such, the Gorge/ Gully and Breakaway/ Cliff habitat is considered primary breeding and foraging habitat for the northern quoll within the Study Area.

Minor Drainage Line (2.1%, 101.7 ha) and Hillcrest/ Hillslope (40.6 %, 1,936.6 ha) habitats represent secondary breeding habitat (hollow logs, tree hollows, boulders and rock crevices provide suitable denning habitat (Hill & Ward, 2010; Oakwood, 2008)), as well as primary dispersal and foraging habitat for the species (Figure 3.2). However, the presence of northern quoll within these habitats is very likely tied to their occurrence relative to Gorge/ Gully habitat, and they are unlikely to support the species exclusive of this. The Minor Drainage Line is represented as an extension of the Gorge/ Gully habitat and thus provides similar habitat features to this habitat type, although to a much lesser extent (Figure 3.2). Foraging or dispersal habitat is recognised to be any land comprising predominantly native vegetation in the immediate area (i.e. within 1 km) of shelter habitat (DoE, 2016). While individuals may be recorded within the remaining habitats, this is likely to be on a temporary basis only.



Legend

Study Area

Current Records

Scat

Previous Records

Opportunistic

Potential Habitat

Primary breeding habitat - Gorge/ Gully; Breakaway/ Cliff

Primary foraging/ dispersal habitat - Minor Drainage Line

Secondary habitat - Hillcrest/ Hillslope

Nil - Drainage Area Floodplain; Mulga Woodland; Stony Plain; Disturbed

biologic Environmental Survey

N

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0 0.5 1 2 km

BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.2: Potential northern quoll habitat within the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4, Created 8/05/2020

3.3.2 Greater Bilby

Previous Records

The Study Area falls within the current distribution of the greater bilby, whereby the species or species habitat may occur (DoEE, 2019b). No evidence of greater bilby occurrence has previously been recorded within the Study Area; however, six historical records exist within 31 km of the Study Area. The nearest record is located approximately 13.5 km east of the Study Area (1979), with an additional four records located approximately 29 km south west of the Study Area (1970, 1980, 1981 and 1984) (DBCA, 2020a). The nearest contemporary records (<20 years) are located approximately 62 km north (2013) and 74 km east (2018) (DBCA, 2020a). During a previous survey, a trapping site was established within Mulga Woodland habitat. However, no greater bilby was observed.

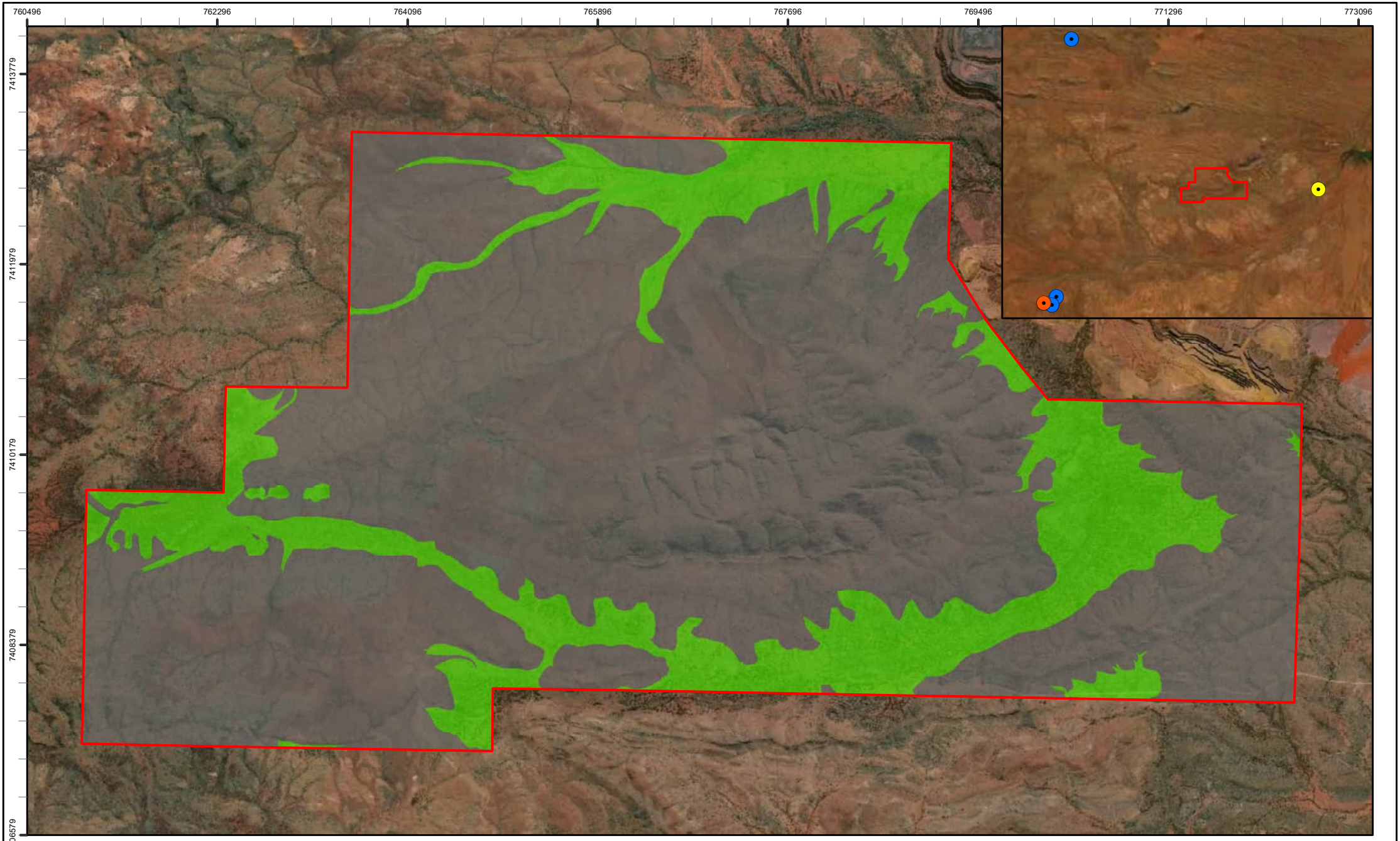
Current Survey

During the current survey, no greater bilby signs, tracks, scats, diggings, or burrows, were recorded within the Study Area, nor was any highly suitable habitat recorded.

Habitats within the Study Area

Extant populations of the greater bilby occur in a variety of habitats, usually on landforms with level to low slope topography and light to medium soils (Southgate, 1990b). Within the Pilbara region, the species is recorded within spinifex sandplains associated with paleo-drainage lines and perched drainage lines where the substrate of sand, soil, sandy clay, or sandy gravel is suitable for burrowing (Dziminski & Carpenter, 2017). Within these sandplain habitats, there is also an association with particular *Acacia* spp. containing root dwelling larvae that the species use for food resources (Dziminski & Carpenter, 2017). Outside of the Pilbara, the species has also been recorded within Mulga Woodland habitat (Southgate, 1990b).

The Mulga Woodland (11.7%, 555.5 ha) and Drainage Area/ Floodplain (9.8%, 468.8 ha) habitat types within the Study Area are both considered marginal habitat types for the species (containing heavy soils which provide low burrowing suitability for larger burrowing species), and therefore regarded as secondary habitat for the species (Figure 3.3). Due to the absence of any primary habitat within or in the vicinity of the Study Area, neither habitats are considered likely to support the species. Due to the lack of contemporary records and the absence of primary habitat, it is considered unlikely that the greater bilby occurs within the Study Area.



Legend

Study Area

Previous Records

- Caught or trapped
- Secondary sign
- Unknown

Potential Habitat

- Secondary habitat - Drainage Area Floodplain; Mulga Woodland
- Nil - Disturbed; Breakaway/ Cliff; Gorge/ Gully; Hillcrest/ Hillslope; Minor Drainage Line; Stony Plain

biologic Environmental Survey

N

1:45,000

0 0.5 1 2 km

BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.3: Potential greater bilby habitat within the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4, Created 8/05/2020

3.3.3 Pilbara Leaf-nosed Bat

Previous records

The Study Area is located at the southern extent of the species current distribution, whereby the species or species habitat may occur (DoEE, 2019b). The desktop assessment returned 156 records of Pilbara leaf-nosed bat within 26 km of the Study Area (BHP, 2020; DBCA, 2020b). The nearest record of the species is located approximately 50 m south of the Study Area from November 2019 (Biologic, 2020c), followed by multiple records from Cathedral Gorge, approximately 11 km north of the Study Area in 2015 (Biologic, 2016a). The remaining records occur between 20–26 km north of the Study Area, primarily along Kalgan Creek and the Ophthalmia Range, from 2013–2017 (DBCA, 2020b).

The recent record of the species approximately 50 m to the south of the Study Area was from a single call recording at 21:03 within Mulga Woodland habitat on 30 November 2019 (Biologic, 2020c). Based on the late timing of the call, it is likely to be representative of a foraging individual; however, the origin (i.e. where it may be roosting) of the individual could not be determined. The nearest known roost of the species is located at Kalgan Creek, approximately 21 km north of the Study Area; however, sampling within the intervening area is sparse and additional roost sites may also occur closer to the Study Area. The scarcity of records in the broader vicinity of the Study Area suggests the species is relatively uncommon in the area.

Current Survey

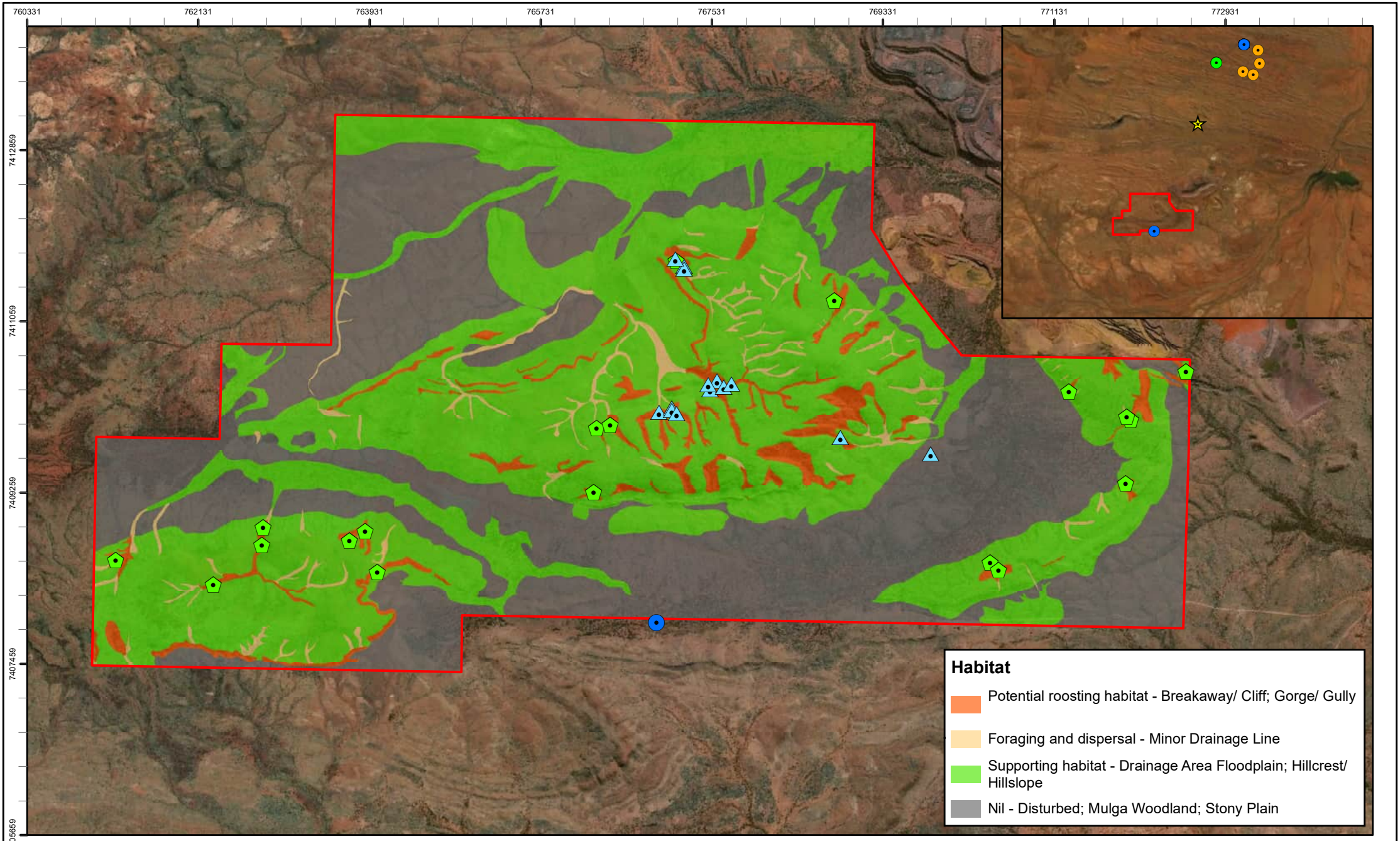
No evidence of Pilbara leaf-nosed bat occurrence was recorded within the Study Area during the current survey. A total of 19 caves have been recorded within the Study Area, which represent potential nocturnal refuges for the species (Priority 4 refuges as defined by TSSC, 2016b) (Table 3.2). Ultrasonic recordings were collected from six caves deemed potential nocturnal refuges, in addition to 11 other sampling locations, including six water features and five areas of potential foraging habitat; however, no calls of the species were recorded. It should be noted that not all caves in the Study Area were located and sampled, therefore it is possible other potential roost sites may occur within the Study Area and/ or that un-sampled caves were utilised by the species during the survey. The lack of any call recordings of the species during the current or previous surveys within the Study Area, in addition to the scarcity of records in the broader vicinity, suggests the species' occurrence within the Study Area is likely to be limited to occasional and temporary visitation by foraging and dispersing individuals only. Potential nocturnal roost caves recorded within the Study Area are likely to be intermittently used by foraging and dispersing individuals from areas outside the Study Area.

Habitats within the Study Area

Pilbara leaf-nosed bats roost in undisturbed caves, deep fissures or abandoned mine shafts (TSSC, 2016b). Nineteen caves are known from the Study Area. Of the caves that were able to be accessed and assessed, none were deemed likely to provide suitable diurnal roosting habitat for Pilbara leaf-nosed bat due to the lack of a unique microclimate. Additionally, no Pilbara leaf-nosed bat evidence has been recorded within the Study Area to date, suggesting the species is unlikely to permanently reside in the Study Area, and presence is likely restricted to transient or dispersing individuals. However, all 19 caves recorded may represent nocturnal refuges for the species (occupied or entered at night for

resting, feeding or other purposes but are not considered critical for persistence in a local area; TSSC, 2016b). Due to the size of the Study Area and access limitations, it was not feasible to search the entire extent of suitable habitat, and therefore there is possibly additional undiscovered nocturnal refuges occur within the Study Area.

Approximately 3.5% (165.7 ha) of the Study Area is represented by the Gorge/Gully habitat and 1.1% (53.1 ha) is represented by Breakaway/ Cliff habitat, which is prone to forming important habitat features for the species, such as nocturnal refuges. Moreover, Gorge/ Gully habitat is prone to forming water features. Furthermore, this habitat type represents Priority 1 (gorges with water pools) and Priority 2 (gullies) foraging habitats as defined by TSSC (2016b). As such, the Gorge/ Gully habitat represents primary foraging habitat for the species. Breakaway/ Cliff (1.1%, 53.1 ha) and limited instances where outcropping occurs within the Hillcrest/ Hillslope (40.6 %, 1,936.6 ha) are regarded as Priority 3 foraging habitat by the TSSC (2016b). The Minor Drainage Line habitat (2.1%, 101.7 ha; particularly those with water features) is regarded as Priority 4 foraging habitat by the TSSC (2016b) and also categorised as primary foraging habitat for the species. Finally, open grasslands and woodlands contained within the remaining habitats; Stony Plain (30.3%, 1,444.8 ha), Mulga Woodland (11.7%, 555.5 ha) and Drainage Area/ Floodplain (9.8%, 468.8 ha); are considered Priority 5, secondary foraging habitat for the species (TSSC, 2016b - refer to Section 2.3) (Figure 3.4).



Legend

- Study Area
- **Previous Records**
  - Anabat
  - Caught or trapped
  - Echolocation recording
  - Unknown
- **Habitat Feature**
  - Cave
  - Waterhole

biologic Environmental Survey

N

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BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.4: PLNB records, cave locations and potential habitats

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4, Created 8/05/2020

3.3.4 Ghost Bat

Previous Records

The Study Area is located at the southern extent of the species current distribution, whereby the species or species habitat may occur in the Pilbara region (DoEE, 2019b). The desktop assessment returned 37 records of ghost bat within 24 km of the Study Area. The species has been recorded on eight occasions from four main locations within the Study Area. Three records were documented in 2010 by Biologic (2011), at three cave locations (see Section 3.2.1) via direct observation and secondary evidence. Additionally, one record was documented in 2013 (Ecologia, 2006) and three records were documented in 2016 (DBCA, 2020b). Outside the Study Area, the nearest record of the species is located approximately 4.5 km east (2012), with few other records within 50 km of the Study Area (DBCA, 2020a). There are no contemporary records (<20 years) of the species south of the Study Area (DBCA, 2020a), indicating the species occurrence within and in the vicinity of the Study Area likely represents the south-eastern extent of the species occurrence in the Pilbara region.

Current Survey

A total of 19 caves have been recorded within the Study Area, of which ghost bats have been observed via direct and/or secondary evidence at seven (Table 3.2; Table 3.6). The species was recorded from direct observation of a single individual at one cave (CWER-02) and from scats at all seven, with scat abundance ranging from 8 to 500 (Table 3.2; Figure 3.5). Of the 19 caves, 15 represent habitat for the ghost bat, comprising one maternity roost, one potential maternity roost (and confirmed diurnal roost), three potential diurnal roosts, five night roosts and five potential night roosts (Table 3.2; Figure 3.5; Appendix A). The remaining four caves showed no evidence of usage by the ghost bat and are unlikely to be suitable for the species.

Ultrasonic recorders were placed in 17 locations during the field survey, including at six caves and six water features. Four ghost bat echolocation calls in succession were detected at one cave (CWER-03) on the night of the 12th of March at 3:45am. These calls likely represent foraging bats as no ghost bat individuals were observed when Biologic personnel inspected the cave that day. Unlike the majority of microbats, ghost bats are proficient in navigating and hunting visually without needing to constantly echolocate (Strahan, 2004). For this reason, it is difficult and inaccurate to rely on ultrasonic and acoustic recordings of the species to infer absence and/or activity, and therefore very possible the species went undetected at other sampling sites during the survey.

Two caves, CWER-01 and CWER-03, form part of a regional ghost bat monitoring program and have recorded continued diurnal roosting activity by ghost bat between 2016 and 2019 (Table 3.2, Table 3.3). During the visitation in December 2019, 14 scats were observed on sheet at CWER-01. This equated to a deposition rate of 0.5 scats per day (since the cave was last visited in November 2019). CWER-03 was last visited in December 2016. Given that the cave was last visited ~3 years ago, scat monitoring sheets were worn and therefore could not be used to accurately determine the number of scats and consequently the deposition rates. However, ~500 scat observed in December 2019 were considered

fresh and therefore deposited within the last month. Additionally, one ghost bat individual was observed roosting within the caves during this pre-survey visitation.

Elevated levels of progesterone (>970 ng/g) indicating presence of pregnant and/or lactating females, was also recorded from scats collected from CWER-01 in 2016 through to 2019, indicating its use as maternity roost (Biologic, 2018, 2020b). This continued use as a diurnal roost and maternity roost highlights the local and regional significance of the cave, particularly given their location relative to the species distribution, most south-eastern extent.

Table 3.6: Ghost Bats Recorded during the Current Survey

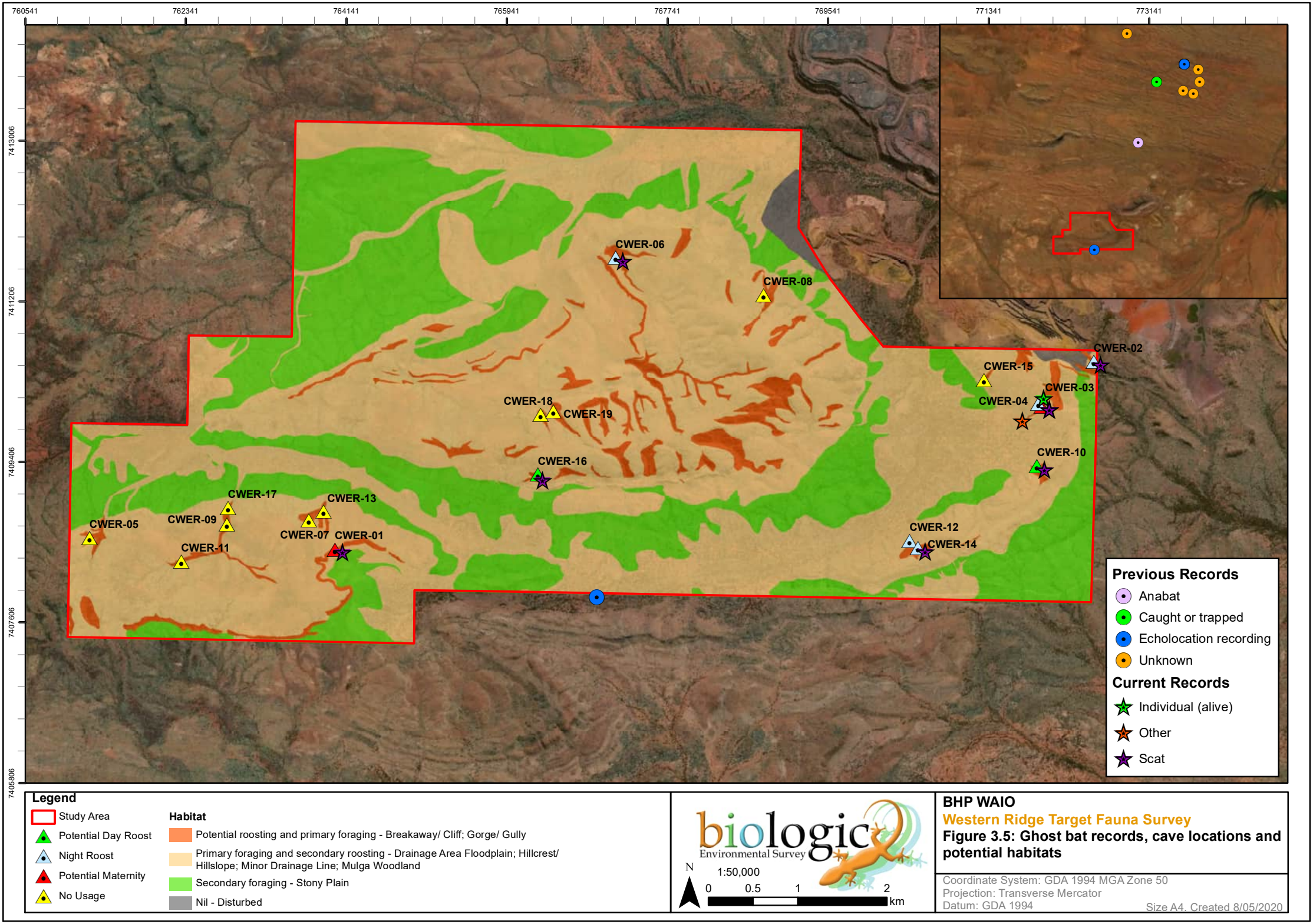
Cave ID	Habitat	Coordinates		Ghost Bat	
		Latitude	Longitude	Records	Significance
CWER-01	Breakaway/ Cliff	-23.4127	119.5835	**December 2019**: 14 recent scats	Maternity
CWER-02	Breakaway/ Cliff	-23.3923	119.6663	**December 2019**: 2 recent scats	Night Roost
CWER-03	Gorge/ Gully	-23.3970	119.6607	**December 2019**: 1 Individual ghost bat observed, 500 fresh scats **March 2020:** four calls in succession at 0345AM (March 2020)	Confirmed Diurnal Roost, Potential Maternity
CWER-06	Gorge/ Gully	-23.3827	119.6137	**March 2020:** 8 old scats	Night Roost (Biologic, 2014b)
CWER-10	Gorge/ Gully	-23.4030	119.6603	**March 2020:** 10 old scats	Potential Diurnal Roost
CWER-14	Gorge/ Gully	-23.4115	119.6474	**March 2020:** 9 old scats	Night Roost
CWER-16	Gorge/ Gully	-23.4048	119.6056	**March 2020:** 50 recent scats	Potential Diurnal Roost

Habitats within the Study Area

Of the 15 caves which provide or potentially provide habitat for the species, thirteen occur within Gorge/ Gully habitat, two within Breakaway/ Cliff habitat (Table 3.2; Figure 3.5). Within the Study Area, Gorge/ Gully habitat (3.5%, 165.7 ha) and Breakaway/ Cliff (1.1%, 53.1 ha), is prone to forming important habitat features such as overhangs and caves. Moreover, Gorge/ Gully habitat is prone to forming water features. Due to the size of the Study Area and access limitations, it was not feasible to search the entire extent of this habitat, and therefore there is possibly additional undiscovered caves occurring within the Study Area. The Gorge/ Gully and Breakaway/ Cliff habitat is considered primary breeding and roosting habitat to the species within the Study Area (Figure 3.5).

The ghost bat is a generalist feeder. It relies on a large array of prey items from invertebrates to small vertebrates, some of which are strongly associated with specific habitats and soil types (Claramunt *et al.*, 2018). Ghost bats have a 'sit and inspect' foraging strategy; they hang on a perch (typically small branches or the main trunk in the mid-to-upper canopy of *eucalypts*; Tidemann *et al.*, 1985) where they

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). Recent studies of ghost bat home range and foraging behaviour in the Pilbara region have identified Drainage Area/ Floodplain (9.8%, 468.8 ha), Gorge/ Gully, Minor Drainage Line (2.1%, 101.7 ha) and Mulga Woodland (11.7%, 555.5 ha) as primary foraging habitats for the species, followed by Stony Plain (30.3%, 1,444.8 ha) as secondary suited foraging habitat (Biologic, 2020d; unpublished data). The suitability of Stony Plain, however, is variable depending on particular characteristics of the habitat, including the abundance of foraging structures (tree perches) and density of understory vegetation present. Where these habitat are present, their suitability for Ghost Bat is dependent on the abundance of foraging structures and an open understory (Biologic, 2020d; unpublished data). While it is likely that all instances of these habitat types will be used for foraging by the species, those instances in closer proximity to roosting caves (night roosting, day roosting and maternity) should be considered of greater significance.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CWER-06
CWER-08
CWER-02
CWER-15
CWER-03
CWER-04
CWER-18
CWER-19
CWER-10
CWER-16
CWER-17
CWER-13
CWER-05
CWER-09
CWER-07
CWER-01
CWER-11
CWER-12
CWER-14
Previous Records
Anabat
Caught or trapped
Echolocation recording
Unknown
Current Records
Individual (alive)
Other
Scat
Legend
Study Area
Potential Day Roost
Night Roost
Potential Maternity
No Usage
Habitat
Potential roosting and primary foraging - Breakaway/ Cliff; Gorge/ Gully
Primary foraging and secondary roosting - Drainage Area Floodplain; Hillcrest/ Hillslope; Minor Drainage Line; Mulga Woodland
Secondary foraging - Stony Plain
Nil - Disturbed
biologic
Environmental Survey
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BHP WAIO
Western Ridge Target Fauna Survey
Figure 3.5: Ghost bat records, cave locations and potential habitats
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Size A4. Created 8/05/2020

3.3.5 Night Parrot

Previous Records

The distribution of the night parrot is very poorly understood in Western Australia. The Study Area falls within the current distribution of the night parrot, whereby the species or species habitat is likely to occur (DoEE, 2019b). The Study Area also falls within a high priority area for survey as defined in survey guidelines for the species (DPaW, 2017). Records of the Night Parrot within the Pilbara region are scarce, with the nearest contemporary record of the species located approximately 126 km northwest of the Study Area from April 2005 (Davis & Metcalf, 2008). Three individuals of the species were purportedly observed at Minga Well, a station bore and livestock watering point with large pools of water (Davis & Metcalf, 2008). The site is heavily degraded from cattle and lacks understory within a larger area; however, larger patches of old-growth *Triodia* grasslands occur in the vicinity along the peripherals of the Fortescue Marsh and chenopod shrublands occur throughout the marsh itself. Despite this observation, subsequent targeted survey for the species at the location and in the vicinity have failed to record the species again. An additional record is known to occur within 100 km of the Study Area, though further information is unavailability for sensitivity reasons (K. Rick, DBCA, *pers. comms.*).

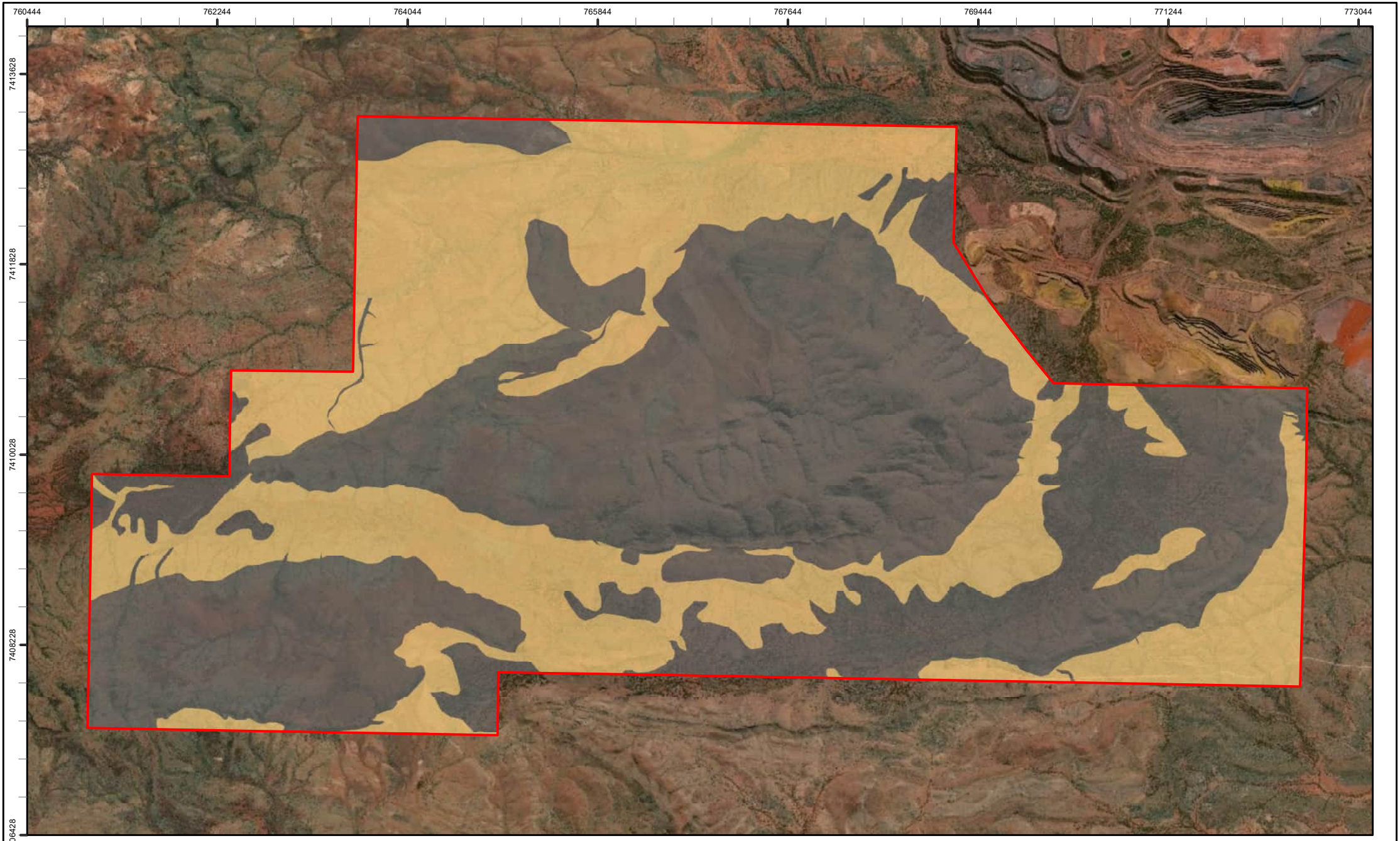
Current Survey

No evidence of the night parrot was recorded within the Study Area, nor was any highly suitable habitat recorded.

Habitats Within the Study Area

The preferred habitat for the night parrot is thought to consist of *Triodia* grasslands in stony or sandy environments (McGilp, 1931; North, 1898; Whitlock, 1924; Wilson, 1937) and of samphire and chenopod shrublands on floodplains and claypans, as well as margins of salt lakes, creeks or other sources of water (McGilp, 1931; Wilson, 1937). Given the ambiguity of the species-specific habitat requirements, it is considered possible that the species can occur in most habitats dominated by *Triodia* (spinifex) hummock grasses, more specifically old-growth spinifex (DPaW, 2017). Though instances of suitably sized (instance appear long unburnt however, their age is unknown) *Triodia* hummock grasses for breeding and roosting were present in the Drainage Area/ Floodplain (9.8%, 468.8 ha) and Stony Plain (30.3%, 1,444.8 ha) habitats, these were sparsely distributed, not associated with known habitat preferences of the species and were therefore considered to be of marginal suitability. It is also believed that a key to the species presence is the occurrence of nesting habitat in proximity to primary foraging habitat, defined as low, treeless chenopod shrublands or herb lands with high abundance and diversity of annual grasses and herbs (Jackett *et al.*, 2017; Murphy *et al.*, 2017b). Whilst the Drainage Area/ Floodplain (9.8%, 468.8 ha) habitat contained some herbaceous plants, this is considered to be of marginal suitability when compared with known populations (Harewood, 2018; Jackett *et al.*, 2017; Murphy *et al.*, 2017b). Furthermore, no primary suitable habitat is known to occur within 10 km of the Study Area (furthest distance recorded for a foraging individual; Murphy *et al.*, 2017b).

Due to the lack of records within the Pilbara region, and the lack of quality habitat, it is deemed unlikely that the species occurs within the Study Area.



Legend

Study Area

Habitat Type

Low quality nesting/foraging habitat - Drainage Area Floodplain; Stony Plain

Nil - Breakaway/ Cliff; Disturbed; Gorge/ Gully; Hillcrest/ Hillslope; Minor Drainage Line; Mulga Woodland

biologic Environmental Survey

N

1:45,000

0 0.5 1 2 km

BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.6: Night Parrot records, cave locations and potential habitat

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4, Created 8/05/2020

3.3.6 Pilbara Olive Python

Previous Records

The Study Area is located at the south-eastern extent of the species current distribution, whereby the species or species habitat may occur (DoEE, 2019b). Pilbara olive pythons are known to occur across the Pilbara bioregion and in the Hamersley subregion, and are most often encountered in the vicinity of permanent waterholes in rocky ranges or among riverine vegetation (DSEWPaC, 2011b; Pearson, 1993). The desktop assessment returned 14 records of the Pilbara olive python within 33 km of the Study Area. The species has previously been recorded within the Study Area on three occasions, comprising an individual observed in a small cave, accumulated scats and sloughs at another location in the same gorge and a slough recorded approximately 1 km north of these records at Afghan pool (near water feature WWER-01) (Biologic, 2011). Outside the Study Area, the nearest record of the species is located approximately 7 km north (1990), with few other records within 20 km of the Study Area (DBCA, 2020a). With exception of a 2014 record approximately 50 km to the east, that is slightly further south than the Study Area, and the isolated records at Mount Augustus approximately 300 km west-southwest of the Study Area, no further records of the species occur south of the Study Area (DBCA, 2020a) likely because the Study Area falls within the southern extent of the Hamersley subregion and consequently the southern extent of suitable habitat for the species.

Current Survey

The Pilbara olive python was recorded on 12 occasions during the current survey, comprising two records of live individuals (one adult and one juvenile), four records of scats and six positive eDNA results from water sampled at selected water features (Table 3.7; Figure 3.7; Appendix F). Four scats and two live individuals were recorded. One juvenile individual was recorded in WWER-07 (rock pool) on 12th March (Plate 3.1) and one adult individual was recorded approximately 500 m away from WWER-04 during a nocturnal search on 15th March 2020 (Table 3.7).

Plate 3.1: Pilbara olive python observed in WWER-07

Table 3.7: Pilbara olive python recorded during the current survey

Site ID	Record Type	Latitude	Longitude	Habitat	Date	Specimen Information					
						Age	Sex	Total Length	Weight	Condition	Microchip Number
VWER-17 (Water feature WWER-07)	Individual (alive)	-23.3944	119.6172	Gorge/ Gully	12/03/2020	Juvenile	Female	990 mm	275 g	Excellent	990000003690222
VWER-17	Scat	-23.3939	119.6181	Gorge/ Gully	13/03/2020	N/A					
VWER-10 (Water feature WWER-04)	Individual (alive) ~500 m from water feature WWER-04	-23.3821	119.6134	Gorge/ Gully	15/03/2020	Adult	Undetermined	2.5 m	6.18 kg	Excellent	900193003604512
VWER-17	Scat	-23.3944	119.6187	Gorge/ Gully	15/03/2020	N/A					
VWER-40	Scat	-23.4047	119.6142	Hillcrest/ Hillslope	15/03/2020	N/A					
Opp	Scat	-23.4051	119.6055	Gorge/ Gully	16/03/2020	N/A					

Five water features were sampled by two separate eDNA analysis providers, of which two water features (WWER-04 and WWER-07) tested positive for Pilbara olive python eDNA by both analyses (Table 3.8). It should be noted that where an equivocal result was returned by qPCR, result of PCR + DNA metabarcoding analysis were used to weight the likelihood of the result representing a positive or negative result (e.g. where qPCR returned an equivocal result for WWER-07 (Day 0) but PCR returned a positive, the result was treated as a positive). The equivocal results herein are considered positive as in two instances, individuals were recorded using the pools and or area of WWER-07. Although no Pilbara olive python were observed directly using the water feature WWER-04, one adult individual was recorded approximately 500 m away during a nocturnal search on the 15 March 2020, which supported the positive result returned by both eDNA sampling and analysis methods (Table 3.8).

A further two water features returned a positive PCR + DNA metabarcoding result (WWER-11, WWER-14) and four returned positive (WWER-13) or equivocal (WWER-01, WWER-07 (Day 3) and WWER-16) qPCR result. These three equivocal results are treated herein as positive results. eDNA is likely present in low concentrations (due to minimal shedding by the species) or degradation (see Section 2.2.3 Quantitative polymerase chain reaction analysis: EnviroDNA); though cross contamination through sampling cannot be ruled out confidently (Table 2.7; Table 3.8). Moreover, the Pilbara Olive Python was observed within the same gorge containing WWER-01 during the current and previous surveys. This, and the fact that WWER-01 contains flowing water (likely a source of dilution), further supports the fact that eDNA may be present in low concentrations. Finally, no Pilbara olive python eDNA was detected at WWER-05.

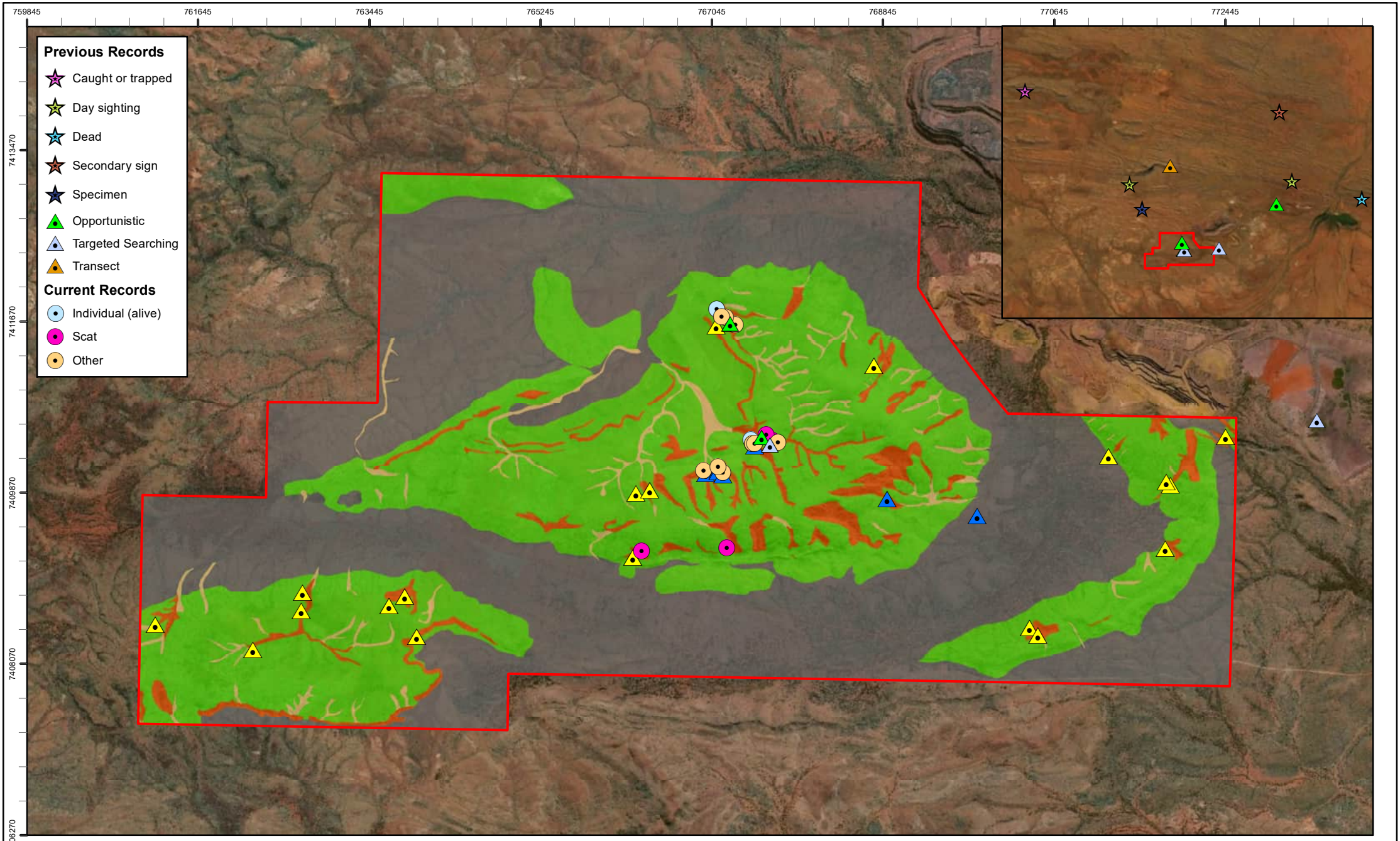
Table 3.8: Pilbara olive python eDNA results from the current survey

Water Feature ID	Date	EnviroDNA (qPCR)	eDNA Frontiers (PCR + metabarcoding)
WWER-01	15/03/2020	Equivocal	Negative
WWER-04	15/03/2020	Positive	Positive
WWER-05	13/03/2020	Negative	N/A
WWER-07 (Day 0)	13/03/2020	Equivocal	Positive
WWER-07 (Day 3)	16/03/2020	Equivocal	N/A
WWER-11	13/03/2020	Negative	Positive
WWER-13	15/03/2020	Positive	N/A
WWER-14	15/03/2020	Negative	Positive
WWER-16	15/03/2020	Equivocal	N/A

Habitats within the Study Area

Pilbara olive python is most often encountered in the vicinity of permanent water features in rocky ranges or among riverine vegetation (DSEWPaC, 2011b; Pearson, 1993). Gorge/ Gully habitat (3.5%, 165.7 ha) within the Study Area provides primary breeding habitat for Pilbara olive python (Figure 3.7; Figure 3.1; Appendix B). Additionally, this habitat type is prone to pooling and ponding, therefore providing primary foraging habitat for the species. Overall, 14 water features are known from the Study

Area (refer to Appendix D - Biologic, 2013a, current survey; 2016b). Two of these water features (located in Gorge/ Gully habitat) are fed by a seep and appear to be potentially permanent or semi-permanent based on a high volume of water observed on visits in December 2019 and the current other visitations. Hillcrest/ Hillslope habitat (40.6 %, 1,936.6 ha) and Breakaway/ Cliff (1.1%, 53.1 ha) within the Study Area also provides secondary breeding and foraging habitat for the species (Figure 3.7), particularly in areas where it provides connectivity between areas of primary Gorge/ Gully habitat. Primary foraging and dispersal habitats are provided by Minor Drainage Line habitat (2.1%, 101.7 ha) (Figure 3.7). The Pilbara olive python is expected to occur throughout the Study Area in these habitats, particularly where they facilitate connectivity between Gorge/ Gully habitat.



Legend

Study Area

Habitat Feature

Caves

Water

Habitat

Potential roosting and primary foraging - Breakaway/ Cliff; Gorge/ Gully

Foraging and dispersal - Minor Drainage Line

Supporting habitat - Hillcrest/ Hillslope

Nil - Drainage Area Floodplain; Mulga Woodland; Stony Plain; Disturbed

biologic Environmental Survey

N

1:50,000

0 0.5 1 2 km

BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.7: Pilbara Olive Python records, cave locations and potential habitat

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 8/05/2020

3.4 Other Fauna of Conservation Significance

A total of 31 species of conservation significance (not including the target species) were recorded during the desktop assessment (see Section 2.1.2), comprising four mammals, 24 birds and three reptiles (Table 3.9). Of the 31 species, three species have been recorded within the Study Area during previous surveys: peregrine falcon (*Falco peregrinus*), western pebble-mound mouse (*Pseudomys chapmani*) and *Anilios ganei*.

Table 3.9: Species of conservation significance with the potential to occur over the Study Area

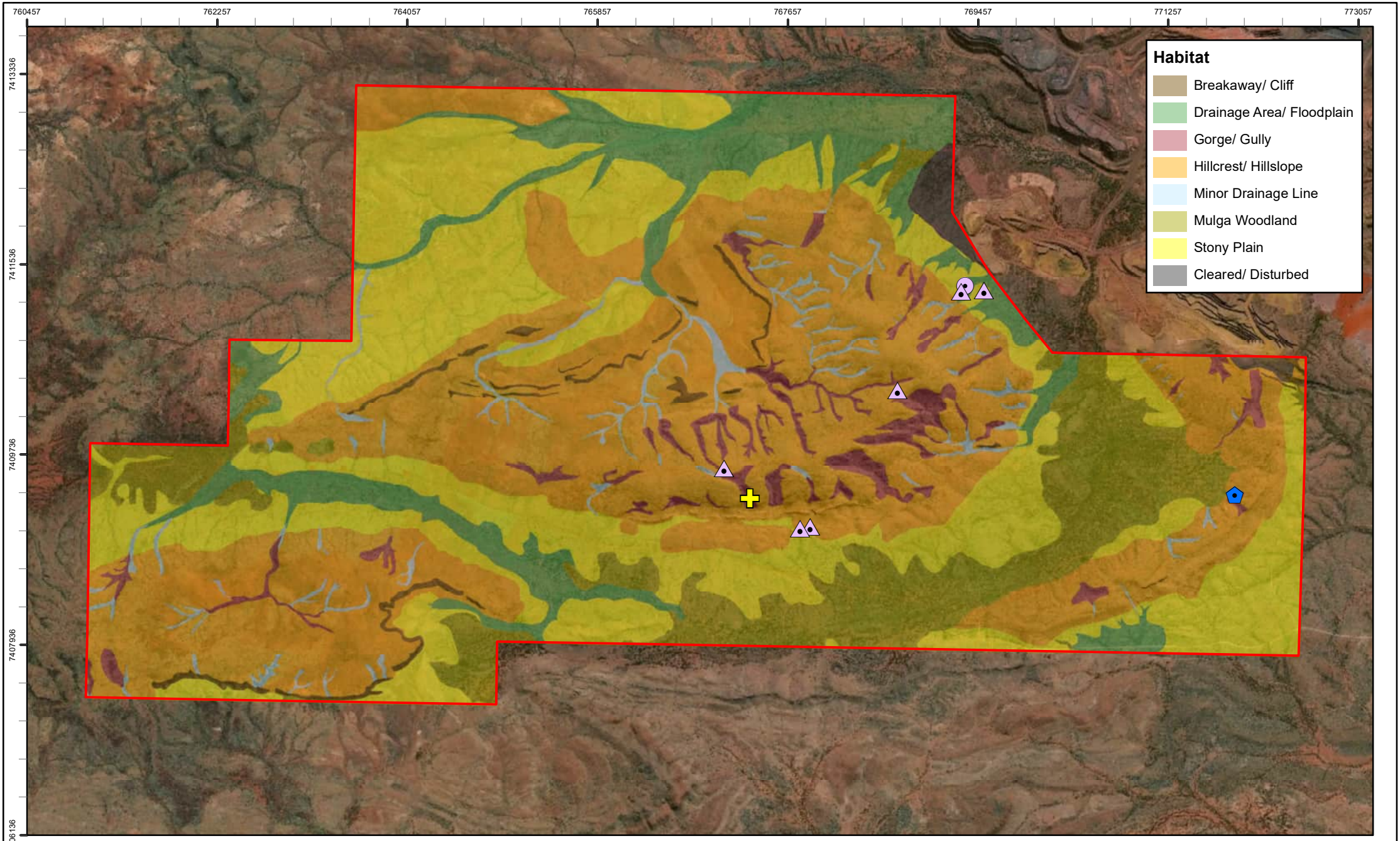
Scientific Name	Common name	Conservation Status				Recorded within the Study Area	
		EPBC	BC	DBCA	IUCN	BHP (2020)	DBCA (2020b)
Mammals							
Petrogale lateralis subsp. *lateralis*	Black-flanked Rock-wallaby	EN	EN		NT		
Dasycercus blythi	Brush-tailed Mulgara			P4			
Sminthopsis longicaudata	Long-tailed Dunnart			P4			
Pseudomys chapmani	Western Pebble-mound Mouse			P4		Yes	Yes
Reptiles							
Anilios ganei	Pilbara Flat-headed Blind-snake			P1		Yes	Yes
Ctenotus uber subsp. *johnstonei*	Spotted Ctenotus			P2			
Lerista macropisthopus remota				P2			
Birds							
Calidris ferruginea	Curlew Sandpiper	CR/MG	CR/MG		NT		
Rostratula benghalensis subsp. *australis*	Australian Painted Snipe	EN	EN		EN		
Polytelis alexandrae	Princess Parrot	VU		P4	NT		
Charadrius leschenaultii	Greater Sand Plover	VU/MG	VU/MG				
Falco hypoleucos	Grey Falcon		VU		VU		
Apus pacificus	Fork-tailed Swift	MG	MG				
Charadrius veredus	Oriental Plover	MG	MG				
Hirundo rustica	Barn Swallow	MG	MG				
Sterna caspia	Caspian Tern	MG	MG				
Gelochelidon nilotica	Gull-billed Tern	MG	MG				
Motacilla cinerea	Grey Wagtail	MG	MG				
Motacilla flava	Yellow Wagtail	MG	MG				
Calidris acuminata	Sharp-tailed Sandpiper	MG	MG				
Calidris melanotos	Pectoral Sandpiper	MG	MG				
Calidris ruficollis	Red-necked Stint	MG	MG		NT		

Scientific Name	Common name	Conservation Status				Recorded within the Study Area	
		EPBC	BC	DBCA	IUCN	BHP (2020)	DBCA (2020b)
Calidris subminuta	Long-toed Stint	MG	MG				
Tringa glareola	Wood Sandpiper	MG	MG				
Tringa hypoleucos	Common Sandpiper	MG	MG				
Tringa nebularia	Common Greenshank	MG	MG				
Tringa stagnatilis	Marsh Sandpiper	MG	MG				
Tringa totanus	Common Redshank	MG	MG				
Plegadis falcinellus	Glossy Ibis	MG	MG				
Falco peregrinus	Peregrine Falcon		OS			Yes	
Ephippiorhynchus asiaticus	Black-necked Stork				NT		

Two non-target species of conservation significance were identified during the current survey: the peregrine falcon (*Falco peregrinus*) and the Western pebble mound mouse (*Pseudomys chapmani*) (Table 3.10; Figure 3.8). These species were also identified in the desktop assessment. Seven mounds belonging to the western pebble mound mouse were identified during the survey including six inactive mounds and one recently inactive mound. Furthermore, potential scats of the regionally extinct Lesser Stick Nest Rat (*Leporillus apicalis*), were also recorded from one cave (CWER-10). Given that the scats were recorded within a cave where they are protected from weathering, and there was evidence of amberat (crystallised urine), it is possible that they are remnant scats from Lesser Stick-nest Rat. However, the scats were in a degraded state and therefore, cannot be confidently identified. Moreover, no reference samples are available for the species.

Table 3.10: Non-target species of conservation significance observed during the current field survey.

Species	Habitat	Latitude	Longitude	Date	Record Type
Pseudomys chapmani	Stony Plain	-23.3860	119.6368	13/03/2020	Mound (inactive)
Pseudomys chapmani	Hillcrest/ Hillslope	-23.3946	119.6289	13/03/2020	Mound (inactive)
Pseudomys chapmani	Drainage Area/ Floodplain	-23.3859	119.6347	13/03/2020	Mound (recently inactive)
Pseudomys chapmani	Drainage Area/ Floodplain	-23.3861	119.6347	13/03/2020	Mound (inactive)
Pseudomys chapmani	Hillcrest/ Hillslope	-23.4064	119.6211	14/03/2020	Mound (inactive)
Pseudomys chapmani	Hillcrest/ Hillslope	-23.4066	119.6202	14/03/2020	Mound (inactive)
Pseudomys chapmani	Hillcrest/ Hillslope	-23.4016	119.6131	13/03/2020	Mound (inactive)
Falco peregrinus	Gorge/ Gully	-23.4041	119.6155	15/03/2020	Individual (alive)
Leporillus apicalis	Gorge/ Gully	-23.4030	119.6603	14/03/2020	Scat



Legend

Study Area

Lesser Stick-nest Rat

Scat

Peregrine Falcon

Individual (alive)

Western Pebble-mound Mouse

Mound (inactive)

Mound (recently inactive)

biologic Environmental Survey

N

1:45,000

0 0.5 1 2 km

BHP WAIO

Western Ridge Target Fauna Survey

Figure 3.8: Other fauna of conservation significance recorded during the Assessment

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4, Created 8/05/2020

3.5 Constraints and Limitations

The EPA (2016b) outlines several potential limitations to vertebrate fauna surveys. These aspects are assessed and discussed in Table 3.11 below. No major limitations or constraints were identified for the survey.

Table 3.11: Survey constraints and limitations

Potential limitation or constraint	Constraint	Applicability to this survey
Experience of personnel	No	The field personnel involved in the survey (Chris Knuckey, Andrew Hide, Brighton Downing and Ashleigh Jenkins) are experienced in undertaking fauna surveys of similar nature, including with conservation significant fauna targeted during the survey. Technical personnel with relevant expertise assisted with analysis of acoustic recordings (Nigel Jackett) and ultrasonic recordings (Bob Bullen).
Scope (faunal groups sampled and whether any constraints affect this)	No	The scope was a targeted fauna survey and was conducted within that framework (EPA, 2016b).
		Northern quoll –The species was sampled following survey guidelines in relation to survey design and effort, site coverage, and detectability (DoE, 2016). Motion camera lines were set during the current survey; 200 sampling nights. Searches were undertaken for secondary evidence (e.g. scats).
		Greater bilby – Greater bilby sampling in the Study Area was restricted to opportunistic records. No greater bilby habitat was recorded, and the species was assessed as unlikely to occur - thus no targeted sampling was undertaken
		Pilbara leaf-nosed bat- The species has been sampled through targeted surveys (ultrasonic recording) and searches (cave searches). Bat detectors were placed at known caves, new caves and at significant habitat areas. Not all caves located have been sampled by SM recorder. Sampling was undertaken during the wet season, when bats are likely to be dispersing, and there is a greater likelihood of detection.
		Ghost bat- The species has been sampled through targeted surveys (ultrasonic recording) and searches (cave searches). Caves have been searched for scats and sheeted for follow up monitoring. Bat detectors were placed at known caves, new caves, or significant habitat areas. Not all caves located have been sampled by SM recorder.
		Pilbara olive python- Potential habitat areas were searched for individuals, scats, and water features. eDNA sampling was also conducted to increase the detectability of the species.
		Night parrot – Sampling has been conducted throughout the Study Area. The acoustic detectors range is only ~300 metres (DPaW, 2017), but due to the large number of sites within the area, it is considered adequate coverage. SM4 recorders were deployed for between five and six nights each (66 sampling nights). Conditions during the recording period was generally good, with no rain and low winds recorded.
Proportion of fauna identified	No	All fauna recorded via motion camera and SM recorders were able to be accurately identified.

Potential limitation or constraint	Constraint	Applicability to this survey
Sources of information (recent or historic) and availability of contextual information	No	A significant amount of survey work has been undertaken in the wider local area and the surrounding region, and most these previous survey results were available for review. These reports were available at the time of reporting.
Proportion of the task achieved	No	A targeted fauna survey of the Study Area was completed and related to the results of surveys in the broader area.
Disturbances (e.g. fire or flood)	No	No temporary disturbance impinged on the results of the current survey. Part of a mining pit intersecting a small portion of the north-eastern edge of the Study Area; however, is unlikely to have impacted results of the current survey.
Intensity of survey	No	A targeted survey was undertaken across the Study Area to assist with decisions on future environmental approvals. The survey intensity was high and focussed on the species of interest.
Completeness of survey	No	The survey was adequately completed to meet the requirements of a targeted survey.
Resources (e.g. degree of expertise available)	No	All resources required to complete the survey were available. Experts were consulted for night parrot- Nigel Jackett and for bats- Bob Bullen
Remoteness or access issues	Yes	With the exception of a portion of the range, the majority of the Study Area was accessible either by vehicle or on foot, thus the sampling techniques used in these areas during this survey were unconstrained by accessibility or remoteness. Due to access constraints, parts of the north-eastern part of the range could not be access in its entirety and therefore some areas were subjected to reduced or no sampling effort.

4 CONCLUSION

The overarching objective of the current survey was to assess the likelihood of occurrence and determine the spatial and quantitative extent of occurrence for six target species considered MNES. The targeted MNES species for the survey comprised the northern quoll, greater bilby, Pilbara leaf-nosed bat, ghost bat, night parrot and Pilbara olive python and night parrot.

4.1 Northern Quoll

During the current survey, northern quoll was confirmed as occurring within the Study Area by the presence of three scat records. Based on the paucity of records within the Study Area, and the scarcity of records in the broader vicinity of the Study Area, it's very likely that the northern quoll occurs in the Study Area on an infrequent basis only. Any records of the species in the Study Area are likely to be representative of individuals on the periphery of a permanent population (as it expands and contracts over time) and/or dispersing from a permanent population elsewhere. Approximately 3.5% (165.7 ha) of the Study Area is represented by Gorge/ Gully habitat and 1.1% (53.1 ha) is represented by Breakaway/ Cliff habitat. Both are considered primary breeding habitat for the species. Minor Drainage Line (2.1%, 101.7 ha) and Hillcrest/ Hillslope (40.6 %, 1,936.6 ha) habitats represent secondary breeding habitat, as well as primary dispersal and foraging habitat for the species, particularly in areas that are located nearby to Gorge/ Gully habitat.

While the species may occur within the Study Area on an infrequent basis, the population is not likely to meet the definition of a "population important for the long-term survival of the northern quoll", as defined by DoE (2016).

4.2 Greater Bilby

The Study Area falls within the current distribution of the greater bilby, whereby the species or species habitat may occur. However, there is a lack of contemporary records in the vicinity of the Study Area. Furthermore, no evidence of the greater bilby was recorded within the Study Area, nor was any suitable primary habitat recorded. The Mulga Woodland (11.7%, 555.5 ha) and Drainage Area/ Floodplain (9.8%, 468.8 ha) habitats are both considered marginal habitat types for the species, when adjacent to primary habitat. However, due to the lack of contemporary records and the absence of primary habitat, it is considered unlikely that these habitats support the greater bilby and that the species occurs within the Study Area.

Due to the lack of contemporary records and the absence of quality habitat, it is unlikely that the greater bilby occurs within the Study Area or that the Study Area is capable of providing for an important population, as defined by DoE (2013).

4.3 Pilbara Leaf-nosed Bat

The Study Area is located at the southern extent of the species distribution. A total of 19 caves were regarded as potential nocturnal refuges for the species. A total of 14 water features were recorded

within the Study Area and are likely to provide high quality foraging and drinking sources for the species. The species has not been recorded within the Study Area, nor is it likely that the species resides (roosts) within the Study Area. However, the presence of a nearby (50 m south), contemporary record suggests that the species may occasionally forage within the Study Area. Approximately 3.5% (165.7 ha) of the Study Area is represented by the Gorge/Gully habitat, which represents primary foraging habitat for the species in the Study Area. Breakaway/ Cliff (1.1%, 53.1 ha), limited instances where outcropping occurs within the Hillcrest/ Hillslope (40.6 %, 1,936.6 ha) the Minor Drainage Line habitat (2.1%, 101.7 ha) is also categorised as primary foraging habitat for the species. Finally, open grasslands and woodlands contained within the remaining habitats; Stony Plain (30.3%, 1,444.8 ha), Mulga Woodland (11.7%, 555.5 ha) and Drainage Area/ Floodplain (9.8%, 468.8 ha); are considered Priority 5, secondary foraging habitat for the species.

According to definition prescribed by the TSSC (2016b), the entire Pilbara represents one interbreeding population, meeting the requirements of an 'important population' as defined by DoE (2013) (TSSC, 2016b). However, the Study Area is unlikely to contain any Priority 1 or Priority 2 diurnal roosts for the species, nor are any indicated to be nearby, and therefore the Study Area is unlikely to represent a significant area for the species

4.4 Ghost Bat

During the current survey, the ghost bat was recorded from seven caves. A total of 15 caves are deemed significant to the species, comprising one maternity roost, one potential maternity roost (and confirmed diurnal roost), three potential diurnal roosts, five night roosts and five potential night roosts. The maternity roost (CWER-01) and potential maternity roost (CWER-03) are considered to be of high local and regional significance for the species, evident by continued use over the past four years. Elevated levels of progesterone hormone have also been recorded from scats collected at cave CWER-01 indicating use as maternity roost during this period. Within the Study Area, Gorge/ Gully habitat (3.5%, 165.7 ha) and Breakaway/ Cliff (1.1%, 53.1 ha), is regarded as primary breeding, roosting and foraging habitat for the species within the Study Area. Mulga Woodland (11.7%, 555.5 ha), Drainage Area/ Floodplain (9.8%, 468.8 ha) and Minor Drainage Line (2.1%, 101.7 ha) habitats provide primary foraging habitat and Stony Plain (30.3%, 1,444.8 ha) provides secondary foraging habitat for the species, particularly when adjacent to roosting caves.

The presence of one maternity roost (CWER-01) and one potential maternity roost (CWER-03) within the Study Area, indicates that individuals from the Study Area form part of a 'key source population either for breeding or dispersal' as defined by DoE (2013). Additionally, records from within the Study Area represent the south-eastern extent of the species distribution in the Pilbara region, therefore forming part of a 'population that [is] near the limit of the species range' as defined by DoE (2013). Together these definitions suggest the Ghost Bat's occurring within the Study Area form part of a 'important population' as defined by DoE (2013).

4.5 Night Parrot

The distribution of the night parrot is very poorly understood in Western Australia; however, the Study Area does fall within the potential distribution as currently mapped by DPaW (2017) and (DoEE, 2019a). No evidence of the species was recorded during the survey or has been recorded within or within the close vicinity of the Study Area previously.

Though instances of suitably sized *Triodia* hummock grasses for breeding were present in the Drainage Area/ Floodplain (9.8%, 468.8 ha) and Stony Plain (30.3%, 1,444.8 ha) habitats, these were sparsely distributed, not associated with known habitat preferences of the species and were therefore considered to be of marginal suitability. Furthermore, there is an absence of high-quality foraging habitat within or within 10 km of the Study Area.

Due to the lack of contemporary records in the region and the absence of high quality habitat in the Study Area, it is unlikely that the night parrot occurs within the Study Area, or that the Study Area may support a population of the species, as defined by DoE (2013).

4.6 Pilbara Olive Python

The Pilbara olive python was recorded on 14 occasions during the current survey, comprising two records of live individuals (one adult and one juvenile), four records of scats and six positive eDNA results from water sampled at selected water features. The Gorge/ Gully habitat (3.5%, 165.7 ha) was the most significant habitat for the Pilbara olive python within the Study Area as it represents primary breeding and foraging habitat. Instances of the Breakaway/ Cliff (1.1%, 53.1 ha), Minor Drainage Line (2.1%, 101.7 ha) and Hillcrest/ Hillslope (40.6 %, 1,936.6 ha) habitats also provide secondary breeding opportunities. The Minor Drainage Line habitat also represents primary foraging and dispersal habitat, particularly where it facilitates connectivity between areas of primary Gorge/ Gully habitat and/or where water features are present.

The Pilbara olive python population occurring within the Study Area is likely to represent a permanently residing and breeding population, and therefore a ‘key source population either for breeding or dispersal’, as defined by DoE (2013). Additionally, individuals from within the Study Area represent the south-eastern extent of the species distribution, therefore forming part of a ‘population that [is] near the limit of the species range’, as defined by DoE (2013) . Together these definitions suggest the Pilbara olive python’s occurrence within the Study Area forms part of an ‘important population’, as defined by DoE (2013).

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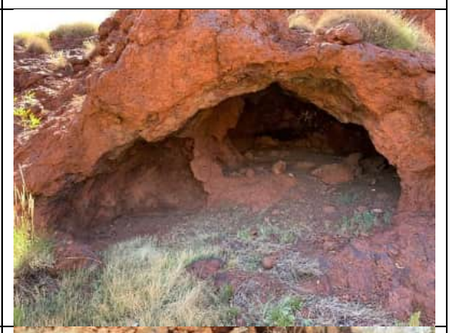
6 APPENDICES

Appendix A – Cave details of the Western Ridge Study Area

Cave ID	Coordinates	Date Assessed	Roost Type	Cave Position	Floor Slope	Aspect	Cave Exposure	Entrance Type	Entrance Shape	Entrance Width (m)	Entrance Height (m)	Cave Depth (m)	No Cham	Cham Height (m)	Water Present	Number of Ghost Bat Scats	Scat Count or Scat Estimate	Scat Age	Bats in cave	Photo
CWER-01	-23.41266, 119.5835298	2/12/2019	Maternity	Upper Slope	Incline	South/ East	Sheltered	Overhang	Round/ Oval	15	5	35	2	1.5	None	14	Count	Recent (1 to 6mths)	*Vespadelus finlaysoni*	
CWER-02	-23.39790724, 119.6662811	3/12/2019	Night Roost	Upper Slope	Incline	North/ West	Sheltered	Overhang	Round/ Oval	2	1	7	1	3	None	2	Count	Recent (1 to 6mths)	Nil	
CWER-03	-23.3969627, 119.6607191	3/12/2019	Potential Maternity	Mid Slope	Incline	North	Semi Exposed	Cavern	Vertical	4	1.5	32	3	4	None	500	Count	Fresh (<1mth)	*Macroderma gigas, Vespadelus finlaysoni*	
CWER-04	-23.3967241, 119.6603346	12/03/2020	Night Roost	Upper Slope	Flat	West	Exposed	Overhang	Round/ Oval	6	1.5	11	1	1.5	Internal rear cave	0	Count	-	*Taphozous georgianus, Vespadelus finlaysoni*	

Cave ID	Coordinates	Date Assessed	Roost Type	Cave Position	Floor Slope	Aspect	Cave Exposure	Entrance Type	Entrance Shape	Entrance Width (m)	Entrance Height (m)	Cave Depth (m)	No Cham	Cham Height (m)	Water Present	Number of Ghost Bat Scats	Scat Count or Scat Estimate	Scat Age	Bats in cave	Photo
CWER-05	-23.41200373, 119.5566157	13/03/2020	No Usage	Lower Slope	Incline	North/ West	Sheltered	Overhang	Horizontal	3	1	15	2	1	None	0	Estimate	-	Nil	
CWER-06	-23.38269553, 119.6137095	12/03/2020	Night Roost	Mid Slope	Flat	South	Sheltered	Cavity	Round/ Oval	2	1	5	1	1.2	External within 50m	8	Count	Old (6mths to 3yrs)	*Vespadelus finlaysoni*	
CWER-07	-23.409809, 119.580604	13/03/2020	No Usage	Upper Slope	Flat	North	Semi Exposed	Cavern	Round/ Oval	3	1.5	10	1	4	None	0	Count	-	*Taphozous georgianus*	
CWER-08	-23.38624945, 119.6299859	13/03/2020	No Usage	Upper Slope		South	Sheltered	Cavity	Horizontal	2	1				None	0	Count	-	*Vespadelus finlaysoni*	
CWER-09	-23.410412, 119.571597	14/03/2020	No Usage	Mid Slope	Flat	West	Semi Exposed	Overhang	Horizontal	10	1.5	15	4	3	None	0	Count	-	*Taphozous georgianus*	

Cave ID	Coordinates	Date Assessed	Roost Type	Cave Position	Floor Slope	Aspect	Cave Exposure	Entrance Type	Entrance Shape	Entrance Width (m)	Entrance Height (m)	Cave Depth (m)	No Cham	Cham Height (m)	Water Present	Number of Ghost Bat Scats	Scat Count or Scat Estimate	Scat Age	Bats in cave	Photo
CWER-10	-23.40302514, 119.6603083	14/03/2020	Potential Day Roost	Mid Slope	Flat	South	Semi Exposed	Overhang	Round/ Oval	7	3	12	2	2	None	10	Count	Old (6mths to 3yrs)	*Taphozous georgianus*	
CWER-11	-23.41423373, 119.5667266	12/03/2020	No Usage	Upper Slope		North	Semi Exposed	Cavity	Round/ Oval	1	0.5				None	0	Estimate	-	Nil	
CWER-12	-23.4107995, 119.6465072	13/03/2020	Night Roost	Mid Slope	Flat	West	Semi Exposed	Cavern	Round/ Oval	3.5	1.8	15	1	1.5	None	0	Count	-	*Taphozous georgianus*	
CWER-13	-23.408903, 119.582201	13/03/2020	No Usage	Lower Slope	Incline	North/ West	Semi Exposed	Cavern	Round/ Oval	3.77	1.7	12.8	1	1.9	None	0	Count	-	*Taphozous georgianus*	

Cave ID	Coordinates	Date Assessed	Roost Type	Cave Position	Floor Slope	Aspect	Cave Exposure	Entrance Type	Entrance Shape	Entrance Width (m)	Entrance Height (m)	Cave Depth (m)	No Cham	Cham Height (m)	Water Present	Number of Ghost Bat Scats	Scat Count or Scat Estimate	Scat Age	Bats in cave	Photo
CWER-14	-23.41150778, 119.6474047	14/03/2020	Night Roost	Mid Slope	Flat	South	Semi Exposed	Cavern	Horizontal	12	3	10	1	2.5	None	9	Count	Old (6mths to 3yrs)	*Taphozous georgianus*	
CWER-15	-23.394355, 119.6543293	14/03/2020	No Usage	Lower Slope	Flat	South/ East	Semi Exposed	Overhang	Round/ Oval	6	1.5	4	1	2.5	None	0	Count	-	Nil	
CWER-16	-23.4047966, 119.6055616	15/03/2020	Potential Day Roost	Lower Slope	Decline	West	Sheltered	Cavern	Round/ Oval	1	1	12	1	15	None	50	Estimate	Recent (1 to 6mths)	*Vespadelus finlaysoni, Taphozous georgianus*	
CWER-17	-23.4086796, 119.5716957	14/03/2020	No Usage	Mid Slope	Incline	South/ West	Semi Exposed	Cavern	Horizontal	3.5	0.5	20	3	4	None	0	Count	-	*Vespadelus finlaysoni, Taphozous georgianus*	

Cave ID	Coordinates	Date Assessed	Roost Type	Cave Position	Floor Slope	Aspect	Cave Exposure	Entrance Type	Entrance Shape	Entrance Width (m)	Entrance Height (m)	Cave Depth (m)	No Cham	Cham Height (m)	Water Present	Number of Ghost Bat Scats	Scat Count or Scat Estimate	Scat Age	Bats in cave	Photo
CWER-19	-23.3987433, 119.6058224	14/03/2020	No Usage	Upper Slope		East	Semi Exposed	Cavity	Round/ Oval	0.6	0.6				None	0	Count	-	Nil	
CWER-20	-23.3984067, 119.6072396	14/03/2020	No Usage	Lower Slope	Incline	North/ East	Sheltered	Overhang	Horizontal	5.5	1.3	9	1	1	None	0	Count	-	Nil	

Appendix B – Water features in the Western Ridge Study Area

Water feature ID	Latitude	Longitude	Date Assessed	Length (m)	Width (m)	Water present above surface	Depth (m)	Water present in intermediate	Emergent macrophyte present	Aquatic vegetation	Fauna present	Notes	Photo
WWER-01	-23.3832	119.6145	12/03/2020	4	2.5	Yes	0.5	Yes	Yes	No	Litoria rubella	eDNA sampling conducted 15/03/2020	
WWER-02	-23.3835	119.6145	16/03/2020	5	5	Yes	2	No	No	No	No		

Water feature ID	Latitude	Longitude	Date Assessed	Length (m)	Width (m)	Water present above surface	Depth (m)	Water present in intermediate	Emergent macrophyte present	Aquatic vegetation	Fauna present	Notes	Photo
WWER-04	-23.3825	119.6136	15/03/2020	1.5	0.7	Yes	0.2	Yes	No	No	Pilbara olive python spotted very close by during nocturnal survey	eDNA sampling conducted 15/03/2020	
WWER-05	-23.3949	119.6174	12/03/2020	3	1	Yes	0.5	No	No	No	*Litoria rubella*	eDNA sampling conducted 13/03/2021	

Water feature ID	Latitude	Longitude	Date Assessed	Length (m)	Width (m)	Water present above surface	Depth (m)	Water present in intermediate pools	Emergent macrophyte present	Aquatic vegetation	Fauna present	Notes	Photo
WWER-06	-23.3940	119.6181	13/03/2020	0	1	No		Yes	No	No	No		
WWER-07	-23.3944	119.6172	12/03/2020	4	1	Yes	0.5	No	No	No	Pilbara olive python	eDNA sampling conducted 13/03/2020 and 16/03/2020	

Water feature ID	Latitude	Longitude	Date Assessed	Length (m)	Width (m)	Water present above surface	Depth (m)	Water present in intermediate soil	Emergent macrophyte present	Aquatic vegetation	Fauna present	Notes	Photo
WWER-09	-23.3946	119.6188	12/03/2020	0.5	0.2	Yes	0.01	No	No	No	No		
WWER-10	-23.3992	119.6309	13/03/2020	1	1	Yes	0.2	Yes	No	No	No		
WWER-11	-23.3943	119.6196	12/03/2020	13	6	Yes	1.5	No	No	No	*Cyclorana maini, Litoria rubella*	eDNA sampling conducted 13/03/2020	

Water feature ID	Latitude	Longitude	Date Assessed	Length (m)	Width (m)	Water present above surface	Depth (m)	Water present in intermediate soil	Emergent macrophyte present	Aquatic vegetation	Fauna present	Notes	Photo
WWER-12	-23.4006	119.6402	14/03/2020	12	12	Yes	1	No	No	No	No	Artificial	
WWER-13	-23.3971	119.6122	14/03/2020	0.4	0.2	Yes	0.1	No	No	No	*Cyclorana maini, Litoria rubella*	eDNA sampling conducted 15/03/2020	
WWER-14	-23.3967	119.6135	15/03/2020	1.5	2	Yes	1.2	No	No	No	*Litoria rubella*	eDNA sampling conducted 15/03/2020	

Water feature ID	Latitude	Longitude	Date Assessed	Length (m)	Width (m)	Water present above surface	Depth (m)	Water present in intermediate	Emergent macrophyte present	Aquatic vegetation	Fauna present	Notes	Photo
WWER-15	-23.3969	119.6135	15/03/2020	2	0.6	Yes	1	No	No	No	No		
WWER-16	-23.3972	119.614	15/03/2020	2	0.6	Yes	0.3	No	No	No	No	eDNA sampling conducted 15/03/2020	

Appendix C – EnviroDNA - Results

Project number 2005CR1
April 9, 2020

Investigating the occurrence of the Pilbara olive python using environmental DNA.

Prepared for:
Brighton Downing

Biologic Environmental
24-26 Wickham St,
East Perth 6004
Australia

Prepared by:
Sarah Licul, Josh Griffiths,
and Dr Andrew Weeks

EnviroDNA
293 Royal Parade
Parkville, VIC 3052
Australia

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EnviroDNA Pty Ltd
+61 3 9028 8753
envirodna.com

Summary

A key challenge for biodiversity conservation is the ability to detect species. Determining the presence or absence of a species is integral to making informed management decisions. Unfortunately, detecting species, particularly in an aquatic environment, can be difficult, time consuming, expensive, and often highly invasive. Analysis of environmental DNA (eDNA) is a relatively new, cheap, quick and non-invasive method for detecting species (Rees *et al.* 2014; McColl-Gausden *et al.* 2019; Thomsen and Willerslev 2015). As the name suggests, eDNA refers to the genetic material that an organism leaves behind in its environment. Quantitative comparisons with traditional sampling methods indicate that eDNA methods can be superior in terms of sensitivity and cost efficiency, particularly for scarce, elusive or cryptic species (Biggs *et al.* 2015; Lugg *et al.* 2018; Smart *et al.* 2015; Thomsen *et al.* 2012; Valentini *et al.* 2016), enabling effective detection of species at low densities.

As a positive control, several samples were collected from a captive facility. In March 2020, water samples were collected from 9 sites by Biologic Environmental staff following sampling protocols developed by EnviroDNA. At each site, 3 samples were collected by passing up to 560 ml water (range 40-560 ml, average 157 ml) through a 0.22 μm filter (Sterivex). These filters have been shown to have very high DNA retention capacity (Spens *et al.* 2017). Filtration was undertaken on site to reduce DNA degradation during transport of water (Yamanaka *et al.* 2016). After water filtration, up to 50 ml of ethanol (100%) was passed through the filter to aid in eDNA preservation. Clean sampling protocols were employed to minimise contamination including new sampling equipment at each site, not entering water, and taking care not to transfer soil, water or vegetation between sites. Filters were frozen prior to postage back to EnviroDNA as an added measure for DNA preservation.

DNA was extracted from the filters using a commercially available DNA extraction kit (Qiagen DNeasy Blood and Tissue Kit). Real-time quantitative Polymerase Chain Reaction (qPCR) assays were used to amplify the target DNA, using a species-specific probe targeting a small region of the mitochondrial DNA (cytochrome B) of the target species. Available gene sequences were compared between related taxa (including humans) using Geneious© software and a probe sequence selected to only detect the target species. Where possible, further in-vitro (tissue samples) testing was undertaken on the target species and closely related co-occurring species to ensure no cross-amplification of non-target DNA.

Assays were performed in triplicate on each sample. Positive and negative controls were included for all assays as well as an Internal Positive Control (IPC) to detect inhibition (Goldberg *et al.* 2016). At least three positive PCR's (out of nine assays undertaken for each site) were required to classify the site as positive for the presence of target species. To minimize false positives, sites were considered equivocal if only 1 or 2 PCR's returned positive results, indicating very low levels of target DNA. While trace amounts of DNA may indicate the target species is actually present in low abundance, it may also arise from sample contamination through the sampling or laboratory screening process, facilitated movement of DNA between waterbodies (i.e. water birds, recreational anglers, water transfers, predator scats), or dispersal from further upstream. If greater confidence is required, further sampling is recommended at equivocal sites to confirm the presence or absence of the target species. Repeat sampling is also recommended to help determine the tenure of the species at a site (i.e. resident or transient).

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Pilbara olive python eDNA was detected in all positive control samples. Pilbara olive python eDNA was also confirmed at 2 of the 9 wild sites sampled, with a further 4 sites returning equivocal results. No Pilbara olive python eDNA was detected at 2 sites. In this instance, it is likely that equivocal sites are true positives due to the isolated nature of the pools sampled and low probability of contamination between pools. Low qPCR results (low DNA) may indicate low abundance of the target species or presence of the species in recent days but not at the time of sampling.

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EnviroDNA Pty Ltd
+61 3 9028 8753
envirodna.com

Research consultant:	**Sarah Licul**
Project Manager:	**Josh Griffiths**
Species:	**Pilbara Olive Python *(Liasis olivaceus)***
Environmental sample:	**Water**
Receipt of samples:	**24th March 2020**
Finalisation of analysis:	**27th March 2020**

Site ID	Waterway	Latitude	Longitude	Date sampled	qPCRs +ve (out of 9)	Test Result
WWER-01	Seep fed rock pool	-23.3832	119.615	15/3/20	1	Equivocal
WWER-04	Seep fed rock pool	-23.38243	119.614	15/3/20	7	**Positive**
WWER-05	Small rock pool	-23.3949	119.617	13/3/20	0	Negative
WWER-07 (Day 0)	Small rock pool	-23.3944	119.617	13/3/20	2	Equivocal
WWER-07 (Day 3)	Small rock pool	-23.3944	119.617	16/3/20	2	Equivocal
WWER-11	Small rock pool	-23.3943	119.62	13/3/20	0	Negative
WWER-13	Small rock pool	-23.39699	119.612	15/3/20	9	**Positive**
WWER-14	Small rock pool	-23.39679	119.614	15/3/20	0	Negative
WWER-16	Small rock pool	-23.39719	119.614	15/3/20	2	Equivocal

Trial Samples	Waterway	Latitude	Longitude	Date sampled	qPCRs +ve (out of 3)	Test Result
1	Perth - Captive	Unknown	Unknown	22/2/20	3	**Positive**
2	Perth - Captive	Unknown	Unknown	23/2/20	3	**Positive**
3	Perth - Captive	Unknown	Unknown	23/2/20	3	**Positive**

Appendix D – eDNA Frontiers - Results

eDNA frontiers
Curtin University
Office: 303.194, Kent Street, Bentley, Perth, WA 6102
Postal: GPO Box U1987, Perth WA 6845
T: +61 8 9266 4119 | E: ednafrontiers@curtin.edu.au
W: https://scieng.curtin.edu.au/edna-frontiers/

REPORT OF eDNA ANALYSIS

Scope of Work:	EF-057		
Project Title:	eDNA biodiversity audit targeting reptile presence/absence for 3-5 pools of water in the Pilbara using eDNA metabarcoding.		
Client:	Biologic Environmental Survey Pty Ltd (ABN: 55 133 116 131) 24-26 Wickham St, East Perth 6004 Postal: PO Box 179, Floreat 6014		
Contact Details:	Brighton Downing Zoologist E: brighton@biologicenv.com.au | P: +61 437 700 867		
Test Facility	eDNA frontiers Curtin University (ABN: 99 143 842 569) 303.194 Kent Street Bentley WA 6102 Phone: +61 8 9266 4119 Email: ednafrontiers@curtin.edu.au		
Study Director:	Dr Rose Lines eDNA frontiers | Curtin University Email: rose.lines@curtin.edu.au Phone: +61 8 9266 5263		
Curtin Office Contact:	Director, Research Services and Systems Research Office at Curtin Building 100 Kent Street, Bentley WA 6102 E: director.research@curtin.edu.au		
Report Reference:	EF-057_Biologic_Final Report		
Laboratory Start Date:	20/04/2020	**Laboratory End Date:**	24/04/2020
Report Issue Date:	12/06/2020		

APPROVALS

	Name	Signature	Date (DD/MM/YYYY)
Author	Dr Rose Lines		12/06/2020
Author	Dr. Tiffany Simpson		12/06/2020

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The eDNA frontiers laboratory offers DNA services across a number of biological applications. While eDNA frontiers stands by the validity of its methodology and the science that underpins it, stakeholders use the information contained within the report at their own risk. DNA results should be regarded as only one line of evidence in decision making processes and it may be necessary or advisable to repeat results, re-sample at sites, corroborate data using other DNA markers or use other non-molecular methods. eDNA frontiers accordingly accepts no liability or responsibility in respect of any use of or reliance upon this report. Copying this report without prior written consent of eDNA frontiers is not permitted.

NOTE: If this eDNA report has specific parts reproduced and cited within a wider report on field work, results displayed should be attributed to eDNA frontiers (Curtin University) and the report included in an appendix in its entirety for referencing purposes.

1.0 OBJECTIVE

The objective of the study was to detect the vulnerable *Liasis olivaceus barroni* (Pilbara Olive python) from water samples collected in the Pilbara.

Study Scope:
Using environmental DNA (eDNA) testing, eDNA frontiers was tasked with analysing water samples from a controlled environment that had a captive *Liasis olivaceus* present in the water for 1 hour, 6 hours or 12 hours. This *L. olivaceus* was a confiscated snake of uncertain origin that had morphological characteristics of the Kimberley population of *L. olivaceus*.

The second part of the study was to analyse water samples collected from five pools in the Pilbara for the presence of *L. olivaceus barroni*.

2.0 SAMPLE DETAILS

Table 1: Sample receipt details

Date received:	23/03/2020
Transport:	frozen
Number of samples:	36
Storage:	All samples were stored at -20ºC prior to analysis.

Table 2: Supplied sample details

eDNA frontiers ID	Client Sample ID	Sample Type	Collection Date
E-057-01	WWER-14 Sample #1	Water - filtered to 0.45uM	16/3/20
E-057-02	WWER-14 Sample #2	Water - filtered to 0.45uM	16/3/20
E-057-03	WWER-14 Sample #3	Water - filtered to 0.45uM	16/3/20
E-057-04	WWER-14 Sample #4	Water - filtered to 0.45uM	16/3/20
E-057-05	WWER-14 Sample #5	Water - filtered to 0.45uM	16/3/20
E-057-06	WWER-07 Sample #1	Water - filtered to 0.45uM	13/3/20
E-057-07	WWER-07 Sample #2	Water - filtered to 0.45uM	13/3/20
E-057-08	WWER-07 Sample #3	Water - filtered to 0.45uM	13/3/20
E-057-09	WWER-07 Sample #4	Water - filtered to 0.45uM	13/3/20
E-057-10	WWER-07 Sample #5	Water - filtered to 0.45uM	13/3/20
E-057-11	WWER-04 Sample #1	Water - filtered to 0.45uM	15/3/20
E-057-12	WWER-04 Sample #2	Water - filtered to 0.45uM	15/3/20
E-057-13	WWER-04 Sample #3	Water - filtered to 0.45uM	15/3/20
E-057-14	WWER-04 Sample #4	Water - filtered to 0.45uM	15/3/20
E-057-15	WWER-04 Sample #5	Water - filtered to 0.45uM	15/3/20
E-057-16	WWER-01 Sample #1	Water - filtered to 0.45uM	15/3/20
E-057-17	WWER-01 Sample #2	Water - filtered to 0.45uM	15/3/20

eDNA frontiers ID	Client Sample ID	Sample Type	Collection Date
E-057-18	WWER-01 Sample #3	Water - filtered to 0.45uM	15/3/20
E-057-19	WWER-01 Sample #4	Water - filtered to 0.45uM	15/3/20
E-057-20	WWER-01 Sample #5	Water - filtered to 0.45uM	15/3/20
E-057-21	WWER-11 Sample #1	Water - filtered to 0.45uM	13/3/20
E-057-22	WWER-11 Sample #2	Water - filtered to 0.45uM	13/3/20
E-057-23	WWER-11 Sample #3	Water - filtered to 0.45uM	13/3/20
E-057-24	WWER-11 Sample #4	Water - filtered to 0.45uM	13/3/20
E-057-25	WWER-11 Sample #5	Water - filtered to 0.45uM	13/3/20
E-057-26	Controlled Environment Trial Slough center	Water - filtered to 0.45uM	23/2/20
E-057-27	Controlled Environment Trial Scat center	Scat	23/2/20
E-057-28	Controlled Environment Trial 12 hr submerge (1)	Water - filtered to 0.45uM	23/2/20
E-057-29	Controlled Environment Trial 12 hr submerge (2)	Water - filtered to 0.45uM	23/2/20
E-057-30	Controlled Environment Trial 6 hr submerge	Water - filtered to 0.45uM	22/2/20
E-057-31	Controlled Environment Trial 1 hr submerge	Water - filtered to 0.45uM	22/2/20
E-057-32	Controlled Environment Trial Control	Water - filtered to 0.45uM	22/2/20
E-057-33	Controlled Environment Trial Slough	Sloughed tissue	23/2/20
E-057-34	Control water Used for WWER-07 and WWER-011	Water - filtered to 0.45uM	15/3/20
E-057-35	Control water Used for WWER-01 and WWER-04	Water - filtered to 0.45uM	15/3/20
E-057-36	Control water Used for WWER-14	Water - filtered to 0.45uM	18/3/20

3.0 METHODS

3.1 Sampling Locations

3.1.1 *Controlled Environment samples*

Tissue and scat samples were collected from a captive *L. olivaceus.* A subsample was taken from the centre of the scat. Sloughed tissue was collected from the python's enclosure and submerged in 1L of water for 12-24 hours. The water was then filtered onto a filter membrane. A second sloughed tissue sample was submitted to be used as a reference sample for the controlled environment water samples.

Water samples of 1L were collected by Biologic Environmental staff from a 30L tub that had an olive python present for 1 hour, 6 hours and 12 hours (2 replicates) on 23rd February 2020. A control water sample was collected prior to placing the olive python in the tub.

3.1.2 *Pilbara samples*

Water was collected from 5 pools in the Pilbara by Biologic staff between 13th March and 16th March 2020. Five replicates were taken from each pool in the Pilbara.

3.2 Water Sample Filtration

Water samples consisting of 1L were collected and filtered to capture eDNA present in the water using 0.45μm polyethersulfone membranes (PES) with a peristaltic Sentino pump. All filtering was carried out by Biologic Environmental staff. Three control samples were included from each rinse water used to clean filtration equipment for the Pilbara study. Filter membranes were transported frozen to Curtin University and stored at -20°C on arrival.

3.3 eDNA Extraction and Analysis

DNA was extracted from half of each filter paper, the tissue sample and the scat using a Qiagen DNeasy blood and tissue kit, following the eDNA frontier lab's SOPs and detailed in Koziol *et al.,* (2018), Stat *et al.,* (2017), Stat *et al.,* (2018). Each sample was assigned an individual barcode tag and amplified by PCR using an in-house 16S assay that detects reptiles. A library was generated and sequenced using the Illumina MiSeq. Field controls (N=3) as well as laboratory extraction and PCR controls were included to test for contamination.

Subsequent to the study, positive control DNA from two *L. olivaceus barroni* samples (Ref ID 216, and Ref ID 333) obtained from the Department of Biodiversity, Conservation and Attractions (DBCA) were processed to obtain a reference sequence for *L. olivaceus barroni*.

3.4 Bioinformatics and Taxonomic assignments

Bioinformatic tools were used to analyse raw sequence data. Results were demultiplexed and trimmed using Obitools and quality filtered with Usearch v11 for sequencing errors (maxee=1) and minimum length. Sequences were then dereplicated and unique sequences were transformed into zero radius operational taxonomic units (ZOTUs) to provide sensitive taxonomic resolution (Usearch v11) (Edgar 2018). ZOTUs, in contrast to OTUs are a more exact sequence variant. Generated ZOTUs were queried against the nucleotide database NCBI (Genbank) and assigned to the species level. Taxonomic assignments were based on an in-house Python script which does further filtering of Blast results (evalue <= 1e-5, %identity >= 97 and qCov >= 100), combines it with ZOTU table results and produces a table containing the taxonomic information available from Blast taxonomy database (accessed April 2020).

It is important to note that sequences recovered are converted to the lowest possible taxon based on similarities and differences to a DNA database (NCBI's Genbank). This database, and the taxonomic framework that underpins it may contain errors. Accordingly, the DNA taxon identifications should be interpreted as the best available assignment based on currently available information and that errors at species level are possible.

Geneious (version 10.2.5) was used to align ZOTUs obtained from the controlled environment samples and the Pilbara water samples, with the ZOTU obtained from two *L. olivaceus barroni* samples from DBCA.

4.0 RESULTS

Python sequence was successfully detected in both the controlled environment samples and the water samples collected in the Pilbara. Two different sequences that had a 99.1% similarity to each other were identified as ZOTU2 and ZOTU3. When compared with NCBI's genbank, ZOTUs 2 and 3 were 94% similar to *Liasis olivaceus* and 98.6% similar to *Aspidites melanocephalus* (both from Rawlings *et al.* 2008). *Liasis olivaceus barroni* is a proposed subspecies (Atlas of Living Australia) and there is no record of this in the NCBI database. The higher similarity of the sequences obtained in this study with *A. melanocephalus* rather than *L. olivaceus* led us to question the validity of the reference sequence of *L. olivaceus* on the NCBI genbank database. To resolve this we contacted the corresponding author on the Rawlings *et al*. (2008) paper who confirmed that the *L. olivaceus* sequence on the NCBI genbank database was incorrect. Subsequently we excluded the genbank sequences from our analysis and used the reference sequence (ZOTU 1) generated by our laboratory from the two *L. olivaceus barroni* samples provided by DBCA.

Sequences obtained from the controlled tank study (ZOTU 2) and the Pilbara water samples (ZOTUs 2 and 3) were compared to the *L. olivaceus barroni* reference sequence (ZOTU 1) generated by our laboratory (Table 4.0). All laboratory extraction and PCR controls were negative.

Table 4.0 Percent identity of sequences obtained from this study with the reference sequence obtained from *L. olivaceus barroni*.

Reference sequence	Sequences from this study	% pairwise identity
L. olivaceus barroni ZOTU 1	ZOTU 2	99.1%
L. olivaceus barroni ZOTU 1	ZOTU 3	100%

4.1 Controlled environment samples

Sequences matching to *L. olivaceus* were detected in tissue and scat samples collected from a captive *L. olivaceus* (ZOTU 2) (Table 4.1). Water samples that had an olive python submerged for 1, 6 and 12 hours tested positive for the presence of *L. olivaceus* (ZOTU 2) (Table 4.2). The control water sample collected prior to placing the olive python in the tank tested positive for the presence of olive python with 4 sequence reads, which is a very low level. This may have occurred as the tub was in the same area as the python enclosure and trace amounts of DNA may have been transferred by handling of equipment.

4.2 Pilbara samples

L. olivaceus DNA was detected at four of the five sites in the Pilbara (Tables 4.3-4.5). Two ZOTUs were detected that match to *L. olivaceus,* indicating genetic variation. ZOTU 2 which was detected in the controlled trial samples, was also present in Pilbara samples. ZOTU 3 was present in more Pilbara samples than ZOTU 2. No other reptiles were detected in the samples.

Sequences matching to ZOTU 2 were detected a low levels in the rinse water that was used for sites WWER-1 and WWER-4; and WWER-7 and WWER-11 (Tables 4.3-4.5). As can be seen from the tables, ZOTU 2 did not occur in all replicates collected at these sites. This indicates that a low level of contamination has occurred in the rinse water, and it is unlikely that this has had an effect on the sample results.

The assay used to detect *L. olivaceus* can also detect other vertebrates which are living in and around the pools. Comparison of these sequences with the genbank database revealed the presence of birds, a frog species and cow. Taxa that had ≥ 97% similarity in the sequence region detected have been reported (Tables 4.3-4.5).

Table 4.1 DNA extracted from scat and tissue samples sloughed from a captive *L. olivaceus.* Successful detection of DNA is indicated by the symbol *

Phylum	Class	Order	Family	*Genus species*	ZOTU	Sloughed tissue	Sloughed tissue center	Scat center
Chordata	Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 2	*	*	*

Table 4.2 Water samples collected from a tank that had a captive *L. olivaceus* submerged for 1, 6 and 12 hours. Successful detection of *L. olivaceus* DNA is indicated by the symbol *. The control sample was collected prior to placing the snake in the tank.

Phylum	Class	Order	Family	*Genus species*	ZOTU	1 hr submerged	6 hr submerged	12 hr submerged replicate 1	12 hr submerged replicate 2	Water Control
Chordata	Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 2	*	*	*	*	* (low level)

Table 4.3 Taxa detected at Pilbara sites WWER-01 and WWER-04.

					SITE WWER-01					SITE WWER-04					RINSE WATER
Class	**Order**	**Family**	***Genus species***	**ZOTU**	**#1**	**#2**	**#3**	**#4**	**#5**	**#1**	**#2**	**#3**	**#4**	**#5**	**Control water Used for WWER-01 and WWER-04**
Amphibia	Anura	Hylidae	*Cyclorana maini*	ZOTU 6					*						
Aves	Anseriformes	Anatidae	*Anser sp..*	ZOTU 12					*						
Aves	Passeriformes	Estrildidae	*Taeniopygia guttata*	ZOTU 8	*	*	*			*	*			*	
Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 2						*		*	*	*	*
Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 3						*	*	*	*	*	
Mammalia	Artiodactyla	Bovidae	*Bos Taurus*	ZOTU 90	*					*				*	

Table 4.4 Taxa detected at Pilbara sites WWER-07 and WWER-11

					SITE WWER-07					SITE WWER-11					RINSE WATER
Class	**Order**	**Family**	***Genus species***	**ZOTU**	**#1**	**#2**	**#3**	**#4**	**#5**	**#1**	**#2**	**#3**	**#4**	**#5**	**Control water Used for WWER-07 and WWER-011**
Amphibia	Anura	Hylidae	*Cyclorana maini*	ZOTU 6	*	*	*	*	*	*	*	*	*	*	
Aves	Anseriformes	Anatidae	*Anser sp..*	ZOTU 12			*								
Aves	Passeriformes	Estrildidae	*Taeniopygia guttata*	ZOTU 8	*	*		*	*		*				
Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 2										*	*
Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 3					*			*			
Mammalia	Artiodactyla	Bovidae	*Bos taurus*	ZOTU 90		*									

Table 4.5 Taxa detected at Site WWER-14

					SITE WWER-14					RINSE WATER
Class	**Order**	**Family**	***Genus species***	**ZOTU**	**#1**	**#2**	**#3**	**#4**	**#5**	**Control water Used for WWER-14**
Amphibia	Anura	Hylidae	*Cyclorana maini*	ZOTU 6	*	*	*	*	*	
Aves	Anseriformes	Anatidae	*Anser sp.*	ZOTU 12						
Aves	Passeriformes	Estrildidae	*Taeniopygia guttata*	ZOTU 8	*	*	*	*	*	
Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 2						
Reptilia	Squamata	Pythonidae	*Liasis olivaceus*	ZOTU 3	*	*	*			
Mammalia	Artiodactyla	Bovidae	*Bos taurus*	ZOTU 90						

SUMMARY

This report documents the successful detection of *Liasis olivaceus* from a controlled environment and from environmental samples collected in the Pilbara. eDNA detection of endangered taxa such as olive python provides a non-invasive method of detection that may be used to provide data for management decisions.

Due to the presence of an erroneous *L. olivaceus* sequence in NCBI genbank, a reference sequence was obtained for this study by subsequently sequencing tissue from two *L. olivaceus barroni* animals.

The detection of ZOTU 2 in the Pilbara study may indicate genetic variation in the Pilbara populations or the presence of both proposed sub-species in the Pilbara. This could be resolved by further testing of other gene regions, and collection of more specimens from the Pilbara to determine the distribution of olive pythons. It seems unlikely that the presence of ZOTU 2 in Pilbara water samples and rinse water occurred as a result of DNA contamination on filtration equipment from the controlled environment study, due to the lack of this sequence occurring in all samples, and also the extended amount of time between the tank study and the Pilbara sample processing.

The DNA extracts derived from this study will be stored within eDNA frontiers premises for a period of 12 months. If samples are required to be stored longer a sample archiving service can be provided.

ARCHIVING OF STUDY DATA

All electronic data relating to the study is stored in an offsite secure server. This includes; all laboratory raw data; personnel records; and the study report. Hard copy documents are archived by study number into a locked area of the test facility located in eDNA frontiers, Curtin University administration area.

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APPENDIX 2

Glossary

Term	Definition
% value in data	Represents the percentage similarity of a DNA sequence recovered from a sample compared to reference sequences in a database (e.g. compared to DNA databases such as GenBank or references generated in-house)
(x) value in data	Represents the frequency the % value was recorded in the dataset
16S rRNA	The 16S rRNA refers to a conserved gene region of mitochondrial DNA, which codes for a subunit of the ribosome. 16S rRNA is found in all eukaryotes making it a good candidate for DNA barcoding
18S rRNA	The 18S rRNA refers to a conserved gene region of nuclear DNA, which codes for a subunit of the ribosome. 18S rRNA is found in all eukaryotes making it a good candidate for DNA barcoding
18S AIS reference database	Reference 18S rRNA sequences of invasive marine species that are available in DNA databases
AIS	Alien Invasive Species
Assay	In the context of eDNA metabarcoding an assay refers to a PCR 'test' that selectively targets a subset of biota from an environmental DNA sample. The use of multiple assay when combined will always detect a wider diversity of taxa than a single assay. eDNA assays should be selected to address the question relevant to the study.
Barcode	Refers to a region of DNA sequenced for many species that is able to (through variation in the DNA sequence) is able to differentiate species. DNA barcodes are the most common targets of eDNA studies that seek to explore taxon assemblages.
COI	The gene region that is being used as the standard barcode for almost all animal groups is a 648 base-pair region of the mitochondrial cytochrome c oxidase 1 gene ("CO1"). COI is proving highly effective in identifying birds, butterflies, fish, flies and many other animal groups. COI is not an effective barcode region in plants because it evolves too slowly, but two gene regions in the chloroplast, matK and rbcL, have been approved as the barcode regions for plants
CO1 AIS reference database	Reference COI sequences of invasive marine species that are available in DNA databases
DNA	Deoxyribonucleic Acid (DNA) is the hereditary material that contains the genetic information of an organism
DNA metabarcoding	Is a genetic technique that simultaneously amplifies and sequences barcode regions (e.g. COI, 18S, 16S) of many different species in parallel

Term	Definition
eDNA	Environmental DNA (eDNA) refers to genetic material that is recovered from an environmental substrate (e.g. water, sediment, air)
Eukaryotes	An organism where cells contain a nucleus surrounded by a membrane and has the DNA bound together by proteins (histones) into chromosomes. The cells of eukaryotes also contain an endoplasmic reticulum and numerous specialised organelles not present in prokaryotes, especially mitochondria, golgi bodies, and lysosomes
Fisheries	Department of Primary Industries and Regional Development, Fisheries Division, Aquatic Biosecurity Section
GenBank	Publicly available repository of genetic information. Contains the barcode information of genes that have previously been sequenced
Genome	A genome is all the genetic material of an organism. It consists of DNA (or RNA in RNA viruses). The genome includes both the genes (the coding regions) and the noncoding DNA. In eukaryotes it refers to the genomes of the nucleus, mitochondria and chloroplasts. In prokaryotes, there is a single genome (as they do not contain mitochondria or chloroplasts)
Illumina MiSeq	Next generation sequencing platform developed by the company Illumina
IMP	Introduced marine pests
Low abundance	Low abundance reads have been defined as those that constitute <0.1% of total reads for a particular sample
Metabarcoding assay	A PCR reaction using a specific set of primers that simultaneously amplifies the same gene target from multiple species. Also see definition of 'assay'.
Mitochondrial DNA (mtDNA)	The mitochondrion (plural mitochondria) is a double membrane-bound organelle found in all eukaryotic organisms. mtDNA markers (e.g. 16S or COI) are common DNA barcodes.
Mitogenomes	Refers to the mitochondrial genome
NGS	Next generation sequencing or second generation sequencing refers to massively parallel sequencing technology, as opposed to first generation sequencing or sanger sequencing where only a single template is sequenced at one time
Nucleotide	A compound consisting of a nucleotide linked to a phosphate group. Nucleotides form the basic structural unit of nucleic acids such as DNA
PCR	Polymerase chain reaction (PCR) is the technique that is used to amplify (akin to photocopying DNA) specific regions of the genome from specific groups of taxa
Primer	A short DNA strand (≈20bp in size) used in PCR to target particular groups of organisms and genes. Two of them are required for PCR (a forward and a reverse)

Term	Definition
Primer binding site	A primer-binding site is the target region of a genome where the primer attaches to start replication. The primer binding site is on one of the two complementary strands of a double-stranded nucleotide polymer, in the strand which is to be copied, or is within a single-stranded nucleotide polymer sequence
Prokaryote	Any of the typically unicellular microorganisms that lack a distinct nucleus and membrane-bound organelles and that are classified as a kingdom (Prokaryotae syn. Monera) or into two domains (Bacteria and Archaea)
RNA	Ribonucleic acid (RNA) is a polymeric molecule implicated in various biological roles in coding, decoding, regulation, and expression of genes
rRNA	ribosomal ribonucleic acid is the RNA component of the ribosome, and is essential for protein synthesis in all living organisms
Sequence	DNA sequencing is the process of determining the precise order of nucleotides within a DNA molecule. It includes any method or technology that is used to determine the order of the four bases—adenine, guanine, cytosine, and thymine—in a strand of DNA
Shotgun sequencing	Refers to randomly sequencing short pieces of DNA (≈150bp in size) after shearing or cutting DNA (e.g. fragmenting a genome)
OTU	Operational Taxonomic Unit is a molecular biology term that describes unique DNA barcode clusters and how they are different from one another. It is usually defined by a % cut-off based on DNA sequence similarity. The value of OTUs is that biodiversity can be compared without the need to assign each sequence into a taxonomic framework and is most appropriate when there are large deficiencies in the underpinning taxonomic framework. OTUs are very similar in function to ZOTUs (see below).
ZOTU	Zero-radius Operational Taxonomic Unit is a molecular biology terms that describes unique DNA barcode clusters and how they are different from one another. It is usually defined by a % cut-off based on DNA sequence similarity. The value of ZOTUs is that biodiversity can be compared without the need to assign each sequence into a taxonomic framework and is most appropriate when there are large deficiencies in the underpinning taxonomic framework. ZOTU are very similar in function to OTUs (see above) but describe more exact sequence variants

Appendix E – Night Parrot Targeted Survey Results

Nigel Jackett
P.O. Box 3221
Broome W.A. 6725
Phone: 0472 529 904
Email: nigel.jackett@gmail.com
ABN 28 786 512 608

17 April 2020

Ashleigh Jenkins
Graduate Zoologist
Biologic Environmental Survey

Ref: 1951

Dear Ashleigh,

Please find below the results of Biologic's survey targeting the Night Parrot in March 2020 for Project 1951.

Survey summary

Biologic Environmental Survey conducted sampling for the Night Parrot (*Pezoporus occidentalis*) in March 2020. Wildlife Acoustic Song Meter 4 bioacoustic recording units were deployed across 12 sites, and recorded a combined total of 61 nights of data (Table 1). The provided dataset comprised 10,013 sound files (in .wav or .w4v formats) totalling 253 GB. Each unit recorded continuously from dusk until dawn (approx. 12 hours).

Table 1. Bioacoustic recordings analysed from the March 2020 survey.

Site name	Recording start date (PM)	Recording end date (AM)	Total recording nights
VWER-04	05/03/2020	11/03/2020	6
VWER-05	05/03/2020	11/03/2020	6
VWER-06	05/03/2020	11/03/2020	6
VWER-07	05/03/2020	11/03/2020	6
VWER-08*	05/03/2020	11/03/2020	6
VWER-09	05/03/2020	11/03/2020	6
VWER-11	11/03/2020	16/03/2020	5
VWER-12	11/03/2020	16/03/2020	5
VWER-14	11/03/2020	16/03/2020	5
VWER-37	11/03/2020	16/03/2020	5
VWER-48*	11/03/2020	12/03/2020	1
VWER-49	11/03/2020	15/03/2020	4
		Total	61

* Trigger setting active on song meter so periods between triggered calls not recorded

Results

The analysis was undertaken using the software Kaleidoscope Pro v5.1.8, targeting the frequency range of 1000 – 4000 Hz for which all known calls of the Night Parrot are distributed within (Jackett *et al.* 2017; Murphy *et al.* 2017; Leseberg *et al.* 2019). Searching for calls over a large frequency range such as this is likely to produce a high number of false-positive results due to many other bird species, and often nocturnal insects, calling at similar frequencies. A total of 84,926 Kaleidoscope detections were manually assessed for Night Parrot vocalisations, and as expected, a high percentage (100% of all calls in this analysis) were false-positives.

No calls attributable to Night Parrots were detected during the analysis.

Thirty-eight non-target bird species were detected during the analysis and are listed in Appendix 1.

Analysis remarks

There was considerable insect noise across most sites, but with peak frequencies much higher than any known calls of the Night Parrot. However, these insects were clearly very close to the song meters and accounted for the majority of false positive detections, as their sheer power meant the frequency bands below 4000 Hz were being impacted upon during each insect call pulse. Wind interference (at site VWER-05) and machinery noise (at site VWER-12) were also detected, but overall, the background sound levels were clear and mostly noise free, particularly in the target frequency band.

Non-target bird species were detected across all nights at all sites. The frequency range and call duration of many of the non-target bird species detected overlaps with the calls of the Night Parrot. It can therefore be expected that the deployed Song Meter 4 units would have recorded any Night Parrot vocalisations had they occurred within a reasonable distance of a unit. Despite non-target species being detected at sites VWER-08 and VWER-48, there is the potential that single or faint calls may not have been recorded depending on how the trigger functions were set on that specific Song Meter (used at both of these sites).

If you have any questions or comments relating to the analysis, don't hesitate to be in touch.

Sincerely,

Nigel Jackett

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Appendix 1 – Species detected during the analysis

Species	Site (VWER-)											
	04	05	06	07	08	09	11	12	14	37	48	49
Crested Pigeon							•					
Diamond Dove	•	•	•	•		•	•					•
Horsfield's Bronze-Cuckoo	•		•									
Pallid Cuckoo		•	•						•			
Spotted Nightjar			•			•			•	•	•	
Australian Owlet-nightjar									•			
Eastern Barn Owl	•											
Southern Boobook	•	•				•						
Red-backed Kingfisher	•											
Rainbow Bee-eater								•				
Brown Falcon	•		•			•						
Galah	•	•				•			•	•		
Cockatiel	•											
Australian Ringneck								•				•
Budgerigar	•			•						•		
Western Bowerbird								•				
Striated Grasswren			•									
White-winged Fairy-wren					•	•	•				•	
Purple-backed Fairy-wren		•										•
Red-browed Pardalote	•	•										
Western Gerygone										•		
Yellow-throated Miner									•			•
Spiny-cheeked Honeyeater	•	•	•	•	•	•	•	•	•	•		•
Singing Honeyeater	•	•	•	•	•	•	•	•	•	•	•	
Black-faced Woodswallow			•					•				
Grey Butcherbird							•					
Pied Butcherbird								•	•			
Black-faced Cuckoo-shrike									•			
Grey Shrike-thrush		•								•		
Rufous Whistler	•			•		•		•	•	•	•	•
Crested Bellbird	•	•	•			•	•		•	•		
Hooded Robin			•			•				•		•
Willie Wagtail	•			•			•	•	•	•		•
Torresian Crow							•		•			
Rufous Songlark	•	•										
Spinifexbird	•	•	•			•			•			
Painted Finch	•											
Zebra Finch	•	•	•	•				•				
Total	19	13	13	7	3	12	9	10	14	11	4	8

Appendix F – Species of Conservation Significance Recorded During the Survey

Species	Common Name	Date	Site	Latitude	Longitude	Method
Mammals						
Dasyurus hallucatus	Northern quoll	14/03/2020	VWER-26	-23.403	119.6603	Scat
Dasyurus hallucatus	Northern quoll	16/03/2020	OPP	-23.4052	119.6055	Scat
Dasyurus hallucatus	Northern quoll	14/03/2020	VWER-26	-23.4031	119.6604	Scat
Macroderma gigas	Ghost bat	2/12/2019	VWER-01	-23.4127	119.5835	Scat
Macroderma gigas	Ghost bat	3/12/2019	VWER-02	-23.3923	119.6663	Scat
Macroderma gigas	Ghost bat	3/12/2019	VWER-03	-23.397	119.6607	Scat
Macroderma gigas	Ghost bat	3/12/2019	VWER-03	-23.397	119.6607	Sighted
Macroderma gigas	Ghost bat	12/03/2020	VWER-10	-23.3827	119.6137	Scat
Macroderma gigas	Ghost bat	12/03/2020	VWER-16	-23.3981	119.6592	Other
Macroderma gigas	Ghost bat	14/03/2020	VWER-26	-23.403	119.6603	Scat
Macroderma gigas	Ghost bat	14/03/2020	VWER-28	-23.4115	119.6474	Scat
Macroderma gigas	Ghost bat	16/03/2020	VWER-03	-23.397	119.6607	Scat
Pseudomys chapmani	Western pebble-mound mouse	13/03/2020	OPP	-23.386	119.6368	Mound (inactive)
Pseudomys chapmani	Western pebble-mound mouse	13/03/2020	OPP	-23.3946	119.6289	Mound (inactive)
Pseudomys chapmani	Western pebble-mound mouse	13/03/2020	OPP	-23.3859	119.6347	Mound (recently inactive)
Pseudomys chapmani	Western pebble-mound mouse	13/03/2020	OPP	-23.3861	119.6347	Mound (inactive)
Pseudomys chapmani	Western pebble-mound mouse	14/03/2020	OPP	-23.4064	119.6211	Mound (inactive)
Pseudomys chapmani	Western pebble-mound mouse	14/03/2020	OPP	-23.4066	119.6202	Mound (inactive)
Pseudomys chapmani	Western pebble-mound mouse	15/03/2020	OPP	-23.4016	119.6131	Mound (inactive)
Birds						
Falco peregrinus	Peregrine falcon	15/03/2020	OPP	-23.4041	119.6155	Sighted
Reptiles						
Liasis olivaceus subsp. *barroni*	Pilbara olive python	15/03/2020	VWER-17	-23.3944	119.6187	Scat
Liasis olivaceus subsp. *barroni*	Pilbara olive python	12/03/2020	VWER-17	-23.3944	119.6172	Sighted
Liasis olivaceus subsp. *barroni*	Pilbara olive python	13/03/2020	VWER-17	-23.3939	119.6181	Scat
Liasis olivaceus subsp. *barroni*	Pilbara olive python	15/03/2020	VWER-10	-23.3821	119.6134	Sighted
Liasis olivaceus subsp. *barroni*	Pilbara olive python	15/03/2020	VWER-40	-23.4047	119.6142	Scat
Liasis olivaceus subsp. *barroni*	Pilbara olive python	16/03/2020	OPP	-23.4051	119.6055	Scat

Appendix G – Habitat Assessments

Site ID	Coord.	Date	Habitat Type	Landform	Aspect	Slope	Soil Type	Soil Avail.	Outcropping Rock Type	Rock Size	Veg. Litter	Dominant Veg. Type	Rocky Cracks/ Crevices	Burrowing Suitability	Hollows count	Water present	Disturbances	Last Fire	Notes
VWER-01	-23.4127, 119.5835	2/12/2019	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	South/ East	Very Steep	Clay Loam	Scarce	Major Outcropping BIF	Gravel (1-4cm)	Few Small Patches	Scattered Eucalypts, Tussock Grassland	Very High	Nil	0	None	Non-Discernible	Old (6+ yr.)	
VWER-02	-23.3923, 119.6663	3/12/2019	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	North/ West	Steep	Clay Loam	Non-Discernible	Moderate Outcropping BIF	Gravel (1-4cm)	Scarce	Scattered Eucalypts, Spinifex Hummock Grassland	High	Low	0	None	Mining Exploration	Old (6+ yr.)	
VWER-03	-23.3970, 119.6607	3/12/2019	Gorge/ Gully	Gully	North	Moder ate	Clay Loam	Few Small Patches	Moderate Outcropping BIF	Gravel (1-4cm)	Scarce	Scattered Eucalypts, Spinifex Hummock Grassland	High	Low	0	None	Non-Discernible	Old (6+ yr.)	
VWER-04	-23.3816, 119.6088	5/03/2020	Undulati ng Low Hills	Undulating Low Hills	North	Low	Clay Loam	Scarce	Negligible	Pebbles (5-10cm)	Scarce	Scattered Eucalypts, Sparsely scattered eucalypts over scattered Grevillea shrubs and open Triodia hummock grassland, with scattered larger mature hummocks, Spinifex Hummock Grassland	Nil	Nil	0	None	Road/ Access Track	Old (6+ yr.)	
VWER-05	-23.3902, 119.5874	5/03/2020	Undulati ng Low Hills	Undulating Low Hills	North	Low	Clay Loam	Scarce	Negligible	Gravel (1-4cm)	Scarce	Acacia Shrubland, Sparsely scattered Individuals or patches of Grevillea and Acacia shrubs over open Triodia grassland, with scattered larger mature hummocks, Spinifex Hummock Grassland	Nil	Nil	0	None	Road/ Access Track	Old (6+ yr.)	
VWER-06	-23.3967, 119.5739	5/03/2020	Undulati ng Low Hills	Undulating Low Hills	North/ West	Low	Clay Loam	Non-Discernible	Negligible	Pebbles (5-10cm)	Scarce	Scattered Grevillea shrubs over open Triodia grassland, with scattered larger mature hummocks, Spinifex Hummock Grassland	Nil	Nil	0	None	Road/ Access Track	Old (6+ yr.)	
VWER-07	-23.4043, 119.5849	5/03/2020	Stony Plain	Stony Plain	Flat	Flat	Clay Loam	Many Small Patches	Negligible	Gravel (1-4cm)	Many Small Patches	Acacia Shrubland, Scattered Eucalypts, Scattered eucalypts over scattered patches of Acacia shrubs over open Triodia grassland of various life stage, with sparsely scattered larger mature hummocks, Spinifex Hummock Grassland	Nil	Nil	0	None	Road/ Access Track	Old (6+ yr.)	
VWER-08	-23.4117, 119.6215	5/03/2020	Stony Plain	Stony Plain	Flat	Flat	Clay Loam	Few Large Patches	Negligible	Gravel (1-4cm)	Few Small Patches	Acacia Shrubland, Mulga Woodland, Scattered Mulga patches and other Acacia shrubs over open Triodia grassland of various life stages, larger mature hummocks sparse, Spinifex Hummock Grassland	Nil	Low	0	None	Road/ Access Track	Moderate (3 to 5 yr.)	Larger Triodia hummocks sparse, probably not great not that great for night parrot

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VWER-09	-23.4152, 119.6326	5/03/2020	Stony Plain	Stony Plain	Flat	Flat	Clay Loam	Few Small Patches	Negligible	Gravel (1-4cm)	Few Small Patches	Acacia Shrubland, Mulga Woodland, Scattered Eucalypts, Sparsely scattered patches of Mulga and mallee eucalypts over patchy Open Acacia shrubland over open Triodia grassland, with scattered patches of larger mature hummocks, Spinifex Hummock Grassland	Nil	Low	0	None	Road/ Access Track	Old (6+ yr.)	
VWER-10	-23.3833, 119.6146	11/03/2020	Gorge/ Gully	Gully	North/ West	Moderate	Clay Loam	Many Large Patches	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Fig trees, sedge, Scattered Eucalypts, Tussock Grassland	Moderate	Nil	5	Prone to Pooling	Non-Discernible	Old (6+ yr.)	
VWER-11	-23.4015, 119.6401	11/03/2020	Gorge/ Gully	Stony Plain	South	Flat	Clay Loam	Evenly Spread	Negligible	Gravel (1-4cm)	Few Small Patches	Acacia Shrubland, Spinifex Hummock Grassland	Nil	Moderate	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-12	-23.3907, 119.6401	11/03/2020	Stony Plain	Stony Plain	East	Flat	Clay Loam	Evenly Spread	Negligible	Pebbles (5-10cm)	Scarce	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland	Nil	Moderate	0	None	Road/ Access Track	Moderate (3 to 5 yr.)	
VWER-13	-23.3913, 119.6381	11/03/2020	Stony Plain	Gully	East	Low	Loam	Many Small Patches	Major Outcropping BIF	Pebbles (5-10cm)	Few Large Patches	Scattered Eucalypts, Spinifex Hummock Grassland	Very High	Low	3	Prone to Flooding	Non-Discernible	Old (6+ yr.)	
VWER-14	-23.4159, 119.6513	11/03/2020	Gorge/ Gully	Sandy/ Stony Plain	South	Flat	Clay Loam	Evenly Spread	Limited Outcropping BIF	Gravel (1-4cm)	Few Small Patches	Scattered Eucalypts, Spinifex Hummock Grassland	Nil	Moderate	1	None	Road/ Access Track	Old (6+ yr.)	
VWER-15	-23.4131, 119.5688	12/03/2020	Gorge/ Gully	Gully	South	Moderate	Silty Clay Loam	Scarce	Major Outcropping BIF	Large Rocks (21-60cm)	Many Small Patches	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Nil	0	Prone to Pooling	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-16	-23.3981, 119.6593	12/03/2020	Gorge/ Gully	Gully	South/ West	Moderate	Clay Loam	Many Large Patches	Major Outcropping BIF	Boulders (>61cm)	Few Large Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Low	0	None	Non-Discernible	Old (6+ yr.)	
VWER-17	-23.3941, 119.6171	12/03/2020	Gorge/ Gully	Gorge	North/ West	Cliff	Loam	Scarce	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	Very High	Nil	0	Prone to Pooling	Non-Discernible	Old (6+ yr.)	
VWER-18	-23.4004, 119.6270	12/03/2020	Gorge/ Gully	Gully	South	Steep	Clay Loam	Few Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Nil	5	None	Mining Exploration	Old (6+ yr.)	
VWER-19	-23.4102, 119.5578	11/03/2020	Gorge/ Gully	Gully	East	Steep	Silty Clay Loam	Scarce	Major Outcropping BIF	Small Rocks (11-20cm)	Scarce	Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Low	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-20	-23.3991, 119.6382	12/03/2020	Gorge/ Gully	Gully	West	Moderate	Clay Loam	Few Large Patches	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Spinifex Hummock Grassland	Moderate	Low	0	None	Mining Exploration	Old (6+ yr.)	
VWER-21	-23.4208, 119.5549	13/03/2020	Gorge/ Gully	Gully	South	Steep	Clay Loam	Scarce	Major Outcropping BIF	Boulders (>61cm)	Many Small Patches	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Nil	0	None	Mining Exploration	Old (6+ yr.)	

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VWER-22	-23.3993, 119.6309	13/03/2020	Gorge/ Gully	Gully	East	Steep	Clay Loam	Many Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Nil	10	Prone to Pooling	Mining Exploration	Old (6+ yr.)	
VWER-23	-23.4197, 119.5568	13/03/2020	Gorge/ Gully	Gorge	South	Steep	Silty Clay Loam	Non-Discernible	Major Outcropping BIF	Boulders (>61cm)	Many Small Patches	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland	High	Nil	1	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-24	-23.3855, 119.6307	13/03/2020	Gorge/ Gully	Gully	East	Moderate	Clay Loam	Many Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Many Large Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Low	4	None	Mining Exploration	Old (6+ yr.)	
VWER-25	-23.4091, 119.5824	13/03/2020	Gorge/ Gully	Gorge	North/ East	Steep	Clay Loam	Scarce	Major Outcropping BIF	Boulders (>61cm)	Few Small Patches	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	Moderate	Nil	2	None	Mining Exploration	Old (6+ yr.)	
VWER-26	-23.4037, 119.6605	14/03/2020	Gorge/ Gully	Gully	South/ East	Low	Clay Loam	Scarce	Moderate Outcropping BIF	Gravel (1-4cm)	Scarce	Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Low	2	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-27	-23.3989, 119.6078	14/03/2020	Gorge/ Gully	Gorge	North	Steep	Clay Loam	Non-Discernible	Extensive Outcropping BIF	Boulders (>61cm)	Scarce	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Nil	0	Prone to Pooling	Non-Discernible	Old (6+ yr.)	
VWER-28	-23.4117, 119.6467	14/03/2020	Gorge/ Gully	Gully	South	Low	Clay Loam	Scarce	Minor Outcropping BIF	Gravel (1-4cm)	Few Small Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Low	2	None	Mining Exploration	Old (6+ yr.)	
VWER-29	-23.3987, 119.6058	14/03/2020	Gorge/ Gully	Gorge	North	Steep	Clay Loam	Non-Discernible	Extensive Outcropping BIF	Large Rocks (21-60cm)	Many Small Patches	Mulga Woodland, Scattered Eucalypts, Tussock Grassland	High	Nil	1	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-30	-23.4007, 119.6402	14/03/2020	Gorge/ Gully	Stony Plain	Flat	Flat	Clay Loam	Evenly Spread	Negligible	Gravel (1-4cm)	Few Small Patches	Cleared	Nil	Low	0	Permanent	Mining Exploration	Old (6+ yr.)	
VWER-31	-23.4103, 119.5716	13/03/2020	Gorge/ Gully	Gorge	West	Very Steep	Silty Clay Loam	Scarce	Major Outcropping BIF	Large Rocks (21-60cm)	Many Small Patches	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland	Very High	Nil	1	Prone to Pooling	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-32	-23.4033, 119.6242	14/03/2020	Gorge/ Gully	Gully	South	Very Steep	Clay Loam	Many Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Few Small Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	Moderate	Nil	3	None	Non-Discernible	Old (6+ yr.)	
VWER-33	-23.3926, 119.6169	14/03/2020	Gorge/ Gully	Hillcrest/ Upper Hillslope	South/ West	Low	Clay Loam	Non-Discernible	Limited Outcropping BIF	Large Rocks (21-60cm)	Non-Discernible	Scattered Eucalypts, Spinifex Hummock Grassland	Low	Nil	0	None	Road/ Access Track	Old (6+ yr.)	
VWER-34	-23.4037, 119.6212	14/03/2020	Hillcrest/ Hillslope	Gully	South	Very Steep	Clay Loam	Many Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Scarce	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Nil	3	None	Non-Discernible	Old (6+ yr.)	
VWER-35	-23.3972, 119.6123	14/03/2020	Gorge/ Gully	Gorge	North	Moderate	Clay Loam	Non-Discernible	Extensive Outcropping BIF	Large Rocks (21-60cm)	Scarce	Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Nil	1	Prone to Pooling	Non-Discernible	Old (6+ yr.)	

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VWER-36	-23.3944, 119.6543	14/03/2020	Gorge/ Gully	Gully	South	Low	Clay Loam	Many Large Patches	Major Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland	High	Low	2	None	Mining Exploration	Old (6+ yr.)	
VWER-37	-23.4213, 119.5640	11/03/2020	Gorge/ Gully	Undulating Low Hills	South	Low	Silty Clay Loam	Scarce	Limited Outcropping BIF	Pebbles (5-10cm)	Scarce	Eucalypt Woodland, Mulga Woodland, Spinifex Hummock Grassland	Low	Low	1	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-38	-23.4032, 119.6176	14/03/2020	Minor Drainag e Line	Gully	South	Very Steep	Clay Loam	Few Small Patches	Major Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Eucalypt Woodland, Spinifex Hummock Grassland, Tussock Grassland	Very High	Low	10	Prone to Pooling	Non-Discernible	Old (6+ yr.)	
VWER-39	-23.3875, 119.6221	15/03/2020	Gorge/ Gully	Gorge	East	Moder ate	Clay Loam	Scarce	Moderate Outcropping BIF	Large Rocks (21-60cm)	Many Small Patches	Scattered Eucalypts, Spinifex Hummock Grassland	Low	Nil	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-40	-23.4038, 119.6151	15/03/2020	Gorge/ Gully	Gully	South	Steep	Clay Loam	Few Small Patches	Extensive Outcropping BIF	Large Rocks (21-60cm)	Many Small Patches	Acacia Shrubland, Eucalypt Woodland, Spinifex Hummock Grassland	Very High	Low	5	Prone to Pooling	Non-Discernible	Old (6+ yr.)	
VWER-41	-23.3862, 119.6211	15/03/2020	Gorge/ Gully	Gully	East	Moder ate	Clay Loam	Non-Discernible	Moderate Outcropping BIF	Small Rocks (11-20cm)	Many Small Patches	Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Nil	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-42	-23.3972, 119.6141	15/03/2020	Gorge/ Gully	Gully	North	Steep	Clay Loam	Scarce	Major Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Spinifex Hummock Grassland	Moderate	Low	0	Prone to Pooling	Non-Discernible	Old (6+ yr.)	
VWER-43	-23.4046, 119.6117	15/03/2020	Gorge/ Gully	Gully	West	Steep	Clay Loam	Many Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Acacia Shrubland, Scattered Eucalypts, Spinifex Hummock Grassland, Tussock Grassland	High	Nil	5	None	Non-Discernible	Old (6+ yr.)	
VWER-44	-23.3855, 119.6140	15/03/2020	Breakaw ay/ Cliff	Cliff	South/ East	Cliff	Clay Loam	Scarce	Extensive Outcropping BIF	Boulders (>61cm)	Many Small Patches	Eucalypt Woodland, Mulga Woodland, Spinifex Hummock Grassland	Very High	Nil	1	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-45	-23.4047, 119.6053	15/03/2020	Gorge/ Gully	Gully	South	Steep	Clay Loam	Few Small Patches	Extensive Outcropping BIF	Boulders (>61cm)	Few Small Patches	Eucalypt Woodland, Spinifex Hummock Grassland	Very High	Low	6	Prone to Pooling	Mining Exploration	Old (6+ yr.)	
VWER-46	-23.4023, 119.5953	15/03/2020	Gorge/ Gully	Gorge	South/ East	Very Steep	Clay Loam	Non-Discernible	Extensive Outcropping BIF	Large Rocks (21-60cm)	Many Small Patches	Eucalypt Woodland, Mulga Woodland, Spinifex Hummock Grassland	High	Nil	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-47	-23.3923, 119.6316	16/03/2020	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	North/ West	Flat	Clay Loam	Few Small Patches	Moderate Outcropping BIF	Gravel (1-4cm)	Few Small Patches	Scattered Eucalypts, Spinifex Hummock Grassland	Moderate	Low	10	None	Road/ Access Track	Old (6+ yr.)	
VWER-48	-23.4059, 119.5561	11/03/2020	Gorge/ Gully	Footslope	West	Flat	Silty Clay Loam	Scarce	Negligible	Gravel (1-4cm)	Scarce	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland	Nil	Low	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-49	-23.4079, 119.5963	11/03/2020	Minor Drainag e Line	Drainage Area/ Floodplain	Flat	Flat	Silty Clay Loam	Few Small Patches	Negligible	Gravel (1-4cm)	Few Small Patches	Mulga Woodland, Scattered Eucalypts, Spinifex Hummock Grassland	Nil	Low	0	None	Mining Exploration	Moderate (3 to 5 yr.)	
VWER-50	-23.4127, 119.5835	3/12/2019	Gorge/ Gully	Gully	North	Moder ate	Clay Loam	Few Small Patches	Moderate Outcropping BIF	Gravel (1-4cm)	Scarce	Scattered Eucalypts, Spinifex Hummock Grassland	High	Low	0	None	Non-Discernible	Old (6+ yr.)	